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A LONG TERM ENERGY POLICY MODEL FOR CANADA

by

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ABSTRACT

The construction of a dynamic, long term model of the Canadian energy sector is discussed, with examples of policy analysis done with the model. A linear process model of energy supply, conversion, distribution and end-use is linked to a model of the demands for services provided by energy in combination with other inputs. Nonlinear programming is used to find the supply-demand equilibrium by maximizing the discounted sum of consumers' plus producers' surplus over all periods -- three five-year periods followed by three ten-year periods, from 1975 to 2020. Long-run marginal cost curves for coal, oil and natural gas are approximated by limiting the total amounts available at different cost levels. Upper limits on exports represent current policies and bring about a two price system (domestic and international) in the model. Two regions are distinguished throughout the model: the west, west of the Ontario-Manitoba border, is the main producer of coal, oil and gas; the east, with the larger energy demands, may import coal, oil and gas from the west, or coal and oil from other countries, if necessary. The model may be used to analyze issues of energy pricing, the timing of the introduction of frontier resources and new technologies, the competitiveness and impacts of some new technologies, the impacts of various levels of energy exports, and the impacts of various potential policy constraints.

A base case is developed, with the best estimates of all parameters. In addition, low demand and high demand cases are developed to test the sensitivity of conclusions to base case assumptions about economic and population growth.

Some important conclusions are as follows. Frontier natural gas will not be needed until after the year 2000. Coal liquefaction will probably not

be competitive, but coal gasification may play an important role after the year 2000. Nuclear power will be important in the east. However, a "no-new-nuclear" policy after 1985 would have negligible cost, but would force a switch in the east from electricity to oil with the tar sands playing an important role after the turn of the century. District heating by cogeneration with nuclear electricity in the east may increase nuclear safety by reducing reliance on nuclear power through the partial displacement of electric resistance heating. The electric automobile will probably not be competitive unless there are technical breakthroughs which lower the initial cost difference between the conventional and electric automobiles, or the road tax burden is less for electric than for conventional cars.

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Chapter 1. Introduction

Just a few short years ago, it would have been necessary to introduce a dissertation on the analysis of energy policy with an argument that it is a worthwhile topic of investigation. Today, however, it is impossible to read a newspaper without reading several articles on aspects of energy policy questions. Whether the news features a debate on oil pricing, a pipeline proposal, a report on environmental effects in Ontario from increased use of coal in the U.S.A., or the promotion of solar energy and the denigration of nuclear power, it is clear to anyone that energy policy is an important area of investigation. It is perhaps not so clear to everyone why the construction and use of mathematical models of the energy system should form a necessary part of energy policy analysis, nor why another energy model, the one developed here, should be added to the already long list.

The complex relationships among the demands for and supplies of the different energy commodities suggest that a careful and systematic analysis must be carried out before a decision is made. "Back of the envelope" calculations cannot begin to come to grips with questions of interfuel substitution and changing market shares, especially over the longer term. One would expect that carefully constructed mathematical models can do better. However, as Marcuse (1980) points out

> "... energy models ... cannot be relied upon for prediction ... models of socioeconomic phenomena unlike those of physical phenomena cannot possibly include all of the pertinent variables. Even if they could, the relationships among the variables are not and perhaps cannot be known."

Marcuse argues that an important role of the model in decision support is in answering "what if" questions. That is, the analyst can compare the values of key variables in the model solution under different scenarios. If certain policies or technologies are preferred in a reasonable range of scenarios, they are said to be "robust", and some useful information can be given to the decision makers. Furthermore, Marcuse observes that insight is gained in the very process of modelling, by forcing the analyst to be systematic and to seek the reasons for counter-intuitive model results. As well, the need for data for the model often forces the analyst to collect previously unavailable data, which turns out to be useful information in itself.

Discussed here is the construction of a model of the energy sector of the Canadian economy. The model takes into account the interaction of energy supplies and demands, but ignores effects the energy sector has on the rest of the economy. It is a long term model, covering the period 1975 to 2020, (three five-year periods, followed by three ten-year periods) a sufficiently long time for the exhaustion of the conventional reserves of crude oil and natural gas, and for the transition to alternate fuels. A linear process model of energy supply, conversion, distribution and end-use is linked to a model of the demands for services provided by energy in combination with other inputs such as capital. Nonlinear programming is used to find the supply-demand equilibrium by maximizing the discounted sum of consumers' plus producers' surplus. Two regions - east and west, with the dividing line at the Ontario-Manitoba border -- are distinguished throughout the model, since many important questions centre on the difficulties of transporting the large hydrocarbon supplies of the west to the large markets of the east. The west exports hydrocarbons to other countries and to the east. The east imports coal and oil. Electricity is exported from both regions. Upper limits are placed on all exports to other countries, to represent national decision-makers' present risk-averse behaviour. (To examine a policy of unrestricted exports, the model would require some alterations from its present formulation).

Linear approximations to long-run marginal cost curves for exhaustible hydrocarbon resources (coal, oil, and gas) are included in the model. Crude oil from the tar sands is considered separately. Other primary resources include hydroelectricity, nuclear electricity, solar heat and biomass. All costs of production, conversion, transportation and distribution are unit costs which include capital components (with a stipulated rate of return). The model represents a network of energy flows from primary production, through secondary conversions (e.g. coal to electricity), to end-use conversions into final demands (e.g. space heating).

Linkages among the periods are found in constraints which require established new capacities of many production and conversion processes to last for stipulated lifetimes. Oil and gas production capacities decline in the latter parts of their lifetimes. Constraints limiting the total amount of production of exhaustible resources also link different periods.

The model calculates equilibrium quantities and many prices throughout the network of energy sector flows. Because of the export limits, domestic resource prices are typically below the international prices -- that is, the export limits imply the two-price system presently in effect in Canada. (To examine the world pricing alternative, the model would have to be altered in the manner required for examination of unrestricted exports.) Prices for exhaustible resources rise, over time, to the costs of the "backstop" sources (i.e. sources which are, for all practical purposes, in unlimited supply, at a possibly high cost).

The model fills a gap in Canadian energy modelling. It is one of only three Canadian energy models (all recently developed) which calculates both equilibrium quantities and prices in an integrated supply-demand framework. The process modelling of interfuel substitution, including some functional end-use processes, make this model the only one of the three which may be used for the evaluation of both new secondary and new end-use energy technologies. The computational simplicity and relatively small size of the model make it possible for a single analyst to update the data and structure. It may be used to analyze issues of energy pricing (assuming continuation of the two price system), the timing of the introduction of frontier resources and new energy technologies, the competitiveness and impacts of some new energy technologies, the impacts of various levels of energy exports, and the impacts of various potential policy constraints. For example, it is shown in this thesis that frontier natural gas is not needed until after the year 2000, according to the model. This is a robust conclusion under a reasonable range of assumptions about energy demands. Model results suggest that the "appropriate competitive relationship" of gas and oil prices (to use the phrase of the Department of Energy, Mines and Resources, 1976a) may be quite different in the west than in the east: gas should be priced lower than oil in the west, until 1990, and somewhat higher afterwards; but the eastern gas price should be about equal to that of oil until 1990, and then considerably higher than the oil price. It is found that the electric automobile will not be competitive unless there is a breakthrough lowering the difference in initial cost between electric and conventional automobiles, or unless the government subsidizes the electric auto by lessening the road tax on electric auto users. Analysis of a moratorium on new nuclear power plants after 1985 suggests that the economic effects would be negligible, that total eastern electricity production and use would be much lower, and that oil from the tar sands would be the main alternative to nuclear electricity in the east after the turn of the century.

Chapter 2 reviews some related energy sector models and indicates the niche filled by this model.

A detailed listing of model variables, parameters and equations appears in Appendix B. An overview of the structure is contained in Chapter 3. Appendix A contains the explanation of the derivation of the demand functions. The method used to find the equilibrium quantities and prices (the maximization of consumers' plus producers' surplus) is given in Chapter 4, together with a discussion of the size of the nonlinear program and the typical computing time required to find the solution. Listings of data and program files for the base case, and an explanation of the technicalities of the computing procedure are presented in Appendix F.

Collection of the data was a major part of the effort, as it is with most large energy modelling projects. The details of sources and calculations for all parameters for the base case (the most likely values) are in Appendix C, except for elasticities of demand, which are discussed in Appendix A. An overview of important (and sometimes controversial) data assumptions for the base case is presented in Chapter 5.

The base case results are analyzed in Chapter 6. The sensitivity of the results to alternative assumptions about energy demands is investigated in Chapter 7, focusing on the high and low demand cases. Observations on key energy policy issues are drawn from comparisons of the high, base and low cases. Detailed listings of the calculated values of all variables of these three cases are found in Appendices D and E.

Some energy policy questions are analyzed in Chapter 8 with the aid of the model. The impacts, including costs, of a moratorium on new nuclear power development are examined, followed by an estimate of the impacts and economic benefits of allowing district heating by cogeneration with nuclear generated electricity. The possibility that the real costs of producing crude oil may have recently escalated above the estimates used is examined next. Finally, the effects of the availability of coal gasification and electric automobiles at competitive costs are examined. (Under the base case cost assumptions, these two technologies do not enter the solution).

Conclusions and suggestions for further research are found in Chapter 9.

Chapter 2. A Review of the Literature on Energy Modelling

Since the early 1970s, and especially since the dramatic increase in the international price of oil in 1973, hundreds of energy models have been developed in North America and Europe with the aim of aiding the analysis of energy policies. This review is a partial survey, covering those models whose elements were used in the development of the model discussed here, or may be used in future research stemming from the present modelling work. Several important Canadian models are also outlined. More thorough surveys may be found in Fuller and Ziemba (1980), and in Manne et al. (1979). Articles on many energy models in the United States and Canada may be found in the collections edited by Ziemba, Schwartz and Koenigsberg (1980), and by Ziemba and Schwartz (1980). The models discussed in this review treat the entire energy sector of a country (or larger region) as a system, to represent the crucially important behaviour of interfuel substitution. The current state of national energy modelling in Canada is discussed, with an indication of the niche filled by the model developed here. Some comments on directions for future research follow, with reference to some models which are reviewed. (A more complete discussion of future research may be found in Chapter 9).

Nordhaus (1973) introduced an important methodology and several concepts which are central to much of the later analysis. The extraction, transportation and processing of energy to meet final demands is represented in a linear programming (LP) framework. He considers five regions in the non-Communist world: the United States, Western Europe, Japan, the Persian Gulf and North Africa, and the rest of the world. There are five demand categories for energy products: electricity, industrial nonelectric energy uses, residential nonelectric uses, substitutable transportation (i.e. electricity could conceivably supply the necessary energy), and nonsubstitutable transportation (i.e. air traffic and long-distance automobile traffic, neither of which can be run on electricity). Demands are specified exogenously for each category, on the grounds that price elasticities are quite low, and that the chief response to price changes is interfuel substitution, which is represented in the model. The model determines the allocation of energy resources, over several time periods (five ten-year periods, followed by two twenty-five-year periods and two fifty-year periods) which minimizes the discounted costs of meeting the specified final demands.

Nordhaus' primary use of the model is to discuss the introduction dates of new technologies and primary resources, and to estimate the efficient price paths for the fuels. An important concept introduced by Nordhaus is the notion of the "backstop" technology. Since the planning problem is really over an indefinite length of time, it is necessary, in principle, to include at least one infinitely plentiful primary resource and technologies which can transform it into all final energy demands. Such "backstop" technologies may be much more expensive than today's technologies, but they must be included in order to ensure feasibility of the infinite-time-horizon problem.

Nordhaus' discussion of resource prices is instructive for understanding the behaviour of other models, such as the model developed here. Exhaustible resource prices, taken from the appropriate dual variables' values at the optimal solution, have two components. The first is the exogenous cost of production. The second component of the price is the "royalty" or economic rent due to the scarcity of the resource. The price of a resource gradually rises toward the cost of the backstop technology, as the less costly but exhaustible sources are used up. As the price rises to the backstop cost, the royalty component shrinks to zero. When the backstop technology is relied upon, there is no economic rent, because the price equals the cost of production. In earlier periods, prior to reliance on the backstop technology, the cost of the backstop is a ceiling on the price of the resource.

A modelling procedure developed by Hoffman (1973) forms the basis of the Brookhaven Energy Systems Optimization Model (BESOM). The procedure begins with the "Reference Energy System", which is a network representation of the energy flows from primary energy commodities through conversion, transportation, distribution and utilization activities. A linear programming model is developed from the Reference Energy System to minimize the cost of meeting specified end use energy demands. BESOM optimizes over a single year and one region (usually the U.S.A.). End use demands are defined by function (e.g. space heating) rather than by broad statistical categories (e.g. commercial energy demand). There is extensive detail in the energy supply, conversion, transportation, distribution and utilization technologies. Environmental emissions are also calculated. BESOM can be used either in the optimization mode with various objectives, or in a simulation procedure, as outlined by Kydes (1980), for the assessment of energy technologies, or to study the impacts of various possible energy policies.

The Hudson and Jorgenson (H-J) (1974) model ties together a macroeconomic growth model, an interindustry model with energy sector detail and a model of consumer demand. There are four non-energy sectors and five energy sectors in the interindustry model, whose input-output coefficients are determined endogenously and are price responsive. Translog price possibility frontiers relate the prices of inputs to the prices of outputs, and provide flexibility in the representation of substitution responses among inputs.

The H-J model finds the market equilibrium one period at a time. Its econometric estimation of behavioural responses contrasts sharply with the process-oriented models with technological detail, like BESOM. Another important distinction is the H-J model's explicit representation of the interactions between the energy sector and the whole economy. The H-J model has been used extensively to examine alternative U.S. tax policies for stimulating energy conservation and reducing dependence on energy imports.

The H-J and BESOM models have been combined, using a procedure described in Hoffman and Jorgenson (1977). (The integration of dynamic versions of both models is discussed in Hudson and Jorgenson, 1978.) The combined model is a single period model, like BESOM, having the advantages of both the H-J and BESOM models. The integration of the models is based on an interindustry accounts system which is an expansion of the H-J system. The solution procedure involves an iterative method. The combined model can provide assessments of the impacts of research, development and demonstration policies on the energy sector (typical of BESOM analyses), as well as impacts of these policies on the whole economy (typical of H-J analyses). The model can be used to evaluate the impacts of energy tax policies on the economy (typical of H-J Analyses) and in particular on the detailed energy sector, including impacts on the introduction of new technology, via the BESOM component.

The PILOT modelling project at Stanford University has developed the Welfare Equilibrium Model (WEM) of energy - economic interactions in the U.S.A. (Parikh, 1980). WEM is an intertemporal linear programming model, with many linear approximations to nonlinear relations, maximizing a household welfare function that characterizes a standard-of-living measure. An input-output model of the economy is linked to a detailed energy submodel which explicitly includes resource depletion and many energy technologies. The usual unresponsiveness of input-output coefficients is modified in WEM by the use of multilevel hierarchy of pairwise substitutions, represented by linear approximations to nonlinear homothetic functions. WEM is a "clairvoyant" model, solving for all time periods simultaneously as if all decision makers in the economy have perfect foresight for all future prices, in contrast to the H-J model, which is "myopic", solving for one period at a time, as if all decision makers make their decisions based strictly on present economic conditions.

WEM has been used to explore the long term effects on the U.S. economy of rising energy import prices. It has also been used to aid the planning staff of the Electric Power Research Institute with preparation of their research and development plan involving new energy technologies (Parikh et al., 1978). Long range energy projections have been developed for the U.S. Department of Energy with the aid of WEM. Generally, it can be used for detailed sectoral assessments of the impacts on the economy of various energy supply, price and tax scenarios.

The Energy Technology Assessment (ETA) model (Manne, 1976) is a nonlinear programming model which maximizes consumers' plus producers' surplus in the U.S. energy sector. The constraints are linear, as in a conventional LP process analysis. ETA has a seventy-five-year planning horizon (fifteen five-year intervals), from 1970 to 2045, but results are presented only to 2030, to avoid "horizon" effects. See Grinold (1980) for an analysis of "horizon" effects in the ETA model. Like WEM, ETA is a clairvoyant model. The exogenous GNP trend is the principal driving force for expansion of energy demands over time. In addition, ETA demand is price-responsive, incorporating own- and cross-price elasticities of demand between electric and non-electric energy. Unitary elasticity of substitution between electric and non-electric energy is assumed. Prices for electric and non-electric energy are equal to their marginal costs of supply, at optimal production and distribution levels. Energy supply possibilities have their own cost parameters, and future technologies have their own introduction dates (i.e. when they are available, although they may not be part of the optimal mix). In ETA, many scenarios are possible, according to input data on costs, introduction dates, and availability of new technologies. The benefits of different technologies can be evaluated by running ETA with and without the availability of the technology in question; the difference in the optimal value of the objective function is a measure of the benefits of the technology.

Manne (1977) describes a modification of the ETA energy sector model, called ETA-MACRO, which involves the replacement of the ETA objective function with an aggregated macroeconomic growth model. Electric and non-electric energy are supplied by the energy sector to the rest of the economy (represented by the macro growth model). Aggregate economic output is allocated between interindustry payments for energy costs and final demands of current consumption and investment. It is assumed that gross output depends upon four inputs: capital, labor, electric energy and non-electric energy. The objective function for the optimization runs is the discounted sum of the logarithms of future consumption.

The macro model is driven by three exogenous parameters: the discount rate in the objective function (the main determinant of the savings-investment accumulation process), the labor force growth index, and the elasticity of substitution between energy and non-energy (the principal factor governing the economy's ability to cope with higher energy prices)

ETA-MACRO is used to examine the two-way linkage between energy and the rest of the economy. A base case is developed involving the best estimates of all parameters. The model is small enough (350 rows, 600 columns in the matrix of linear constraints, and 80 variables entering nonlinearly into the objective function) that numerous alternative cases can be run quickly, at low cost. Manne (1977) finds that a "no-nuclear" policy would have negligible macroeconomic effects, unless the elasticity of substitution is quite low and there are serious restrictions on non-nuclear energy resources.

After the dramatic rise in oil prices in 1973, the U.S. federal government required not just energy trend forecasts, but a description of the interaction of the supply and demand of many energy products, over time, with a variety of geographical characteristics. Since there was little agreement in defining desirable feasible futures, a descriptive rather than a normative modelling approach was needed to calculate the logical implications of a consistent set of assumptions or policies. The Project Independence Evaluation System (PIES) is one such forecasting tool (Eynon et al. 1975, Hogan 1975, 1977 and Greenberg 1980a). (PIES has recently been renamed as the Medium Term Energy Forecasting System). PIES is used for policy analysis for five to fifteen year planning horizons. It is a regional model, and forecasts prices and quantities of energy goods produced, consumed, or converted, facility construction requirements and operational modes, transportation activities and associated resource requirements. PIES is composed of a demand model, a collection of supply models, and an integrating model. There is a separate model at each supply region, for each product (coal, oil, natural gas, shale oil), to characterize the price-quantity relationship for that product. The products are moved through a transportation, conversion, and distribution system to the demand regions. A separate model, incorporating cross-price elasticities of energy demand, characterizes the price-quantity relationship determining the demand for energy products. If the demand vector is known, the selection of supply alternatives is made by a linear programming, minimum total cost calculation. The dual variables are the supply prices, for the given demand vector. In this way, implicit supply curves are generated.

The system is brought into equilibrium by the integrating mechanism when supply equals demand, and the supply prices equal the prices calculated by the demand model for the equilibrium demand. The integrating mechanism involves iterations of a linear programming approximation to a fixed point algorithm.

Eynon et al. (1975) give the following examples of exogenous inputs which have been introduced into the PIES system for policy analysis: price changes in imports; import tariffs; import quotas; domestic fuel taxes, accelerated new material supply; conservation measures; demand management; oil to coal conversion in electric utilities; various coal and nuclear construction limits; and electricity load management. Greenberg (1980a) discusses the political background to use of the model for the U.S. National Energy Plan in 1977.

The SRI-Gulf model was originally developed by the Stanford Research Institute (SRI) in 1973 to analyze a synthetic fuels strategy for Gulf Oil Corporation. Versions of the model have been used for other purposes, such as a study of the economic forces influencing the development of western U.S. energy resources such as coal and oil shale (SRI, 1976). The model is regional, dynamic, and contains a great deal of detail on energy technology and market behavior (including market imperfections).

In construction of the model, described by Cazalet (1977, 1978), perfect competition is not assumed, the market adjustment process is described, and process technologies are explicitly represented. The decision problem to be analyzed is decomposed into different sub-models, which are connected by a network.

At the bottom of the network are processes describing long run resource supply curves and depletion of reserves in the various supply regions. Later stages in the network involve transportation and conversion processes. When a need can be filled from several different sources, allocation processes describe the sharing of the market among competing fuels. At the top of the network are processes describing the regional end-use demands for energy (not for fuels, but for residential/commercail space heat, industrial steam, etc.), as functions of end use energy prices, demographic factors, economic factors, weather, etc. The model also includes simplified models of the U.S. economy and population growth, and processes describing the price changes of materials used in the construction of energy facilities due to energy industry demands. Each of these processes in the network consists of physical relations describing flows, efficiencies, etc., and behavioral relations describing the decision making behavior which sets prices and quantities.

An iterative algorithm computes tentative prices of process outputs for all time periods, starting from the resource supply prices and moving up through the network, using the behavioural relations, with quantities estimated at the last iteration. At the second step of an iteration, the quantities of inputs to processes are computed by working downward through the network, using the physical relations. The algorithm terminates when all prices and quantities are unchanged on successive iterations.

The method used in the SRI-Gulf model can account for market imperfections and human behaviour,such as price controls, rationing, learning curves for new technology, and the determination of economic rents on primary resources from estimates of future prices. Applications and extensions of the modelling approach are described in Cazalet (1979).

Debanné (1975, 1980) has developed a series of network based energy sector models. The version described in Debanné (1975) deals with a network of oil, gas, nuclear, hydro, coal, geothermal and solar energy flows in ten U.S. and nine Canadian regions. The model minimizes the total cost of meeting exogenous energy demands, in interaction with submodels of investment in capacity expansion and of exploration and reserves accumulation. With the model, one can examine, from a continental point of view, the economic advantages of alternative pipeline projects, and the effect on fossil fuel market shares of various new energy technologies. Debanné (1980) discusses methods for incorporating price-responsive demand and supply functions in the network minimization framework.

The National Energy Board (NEB) and the federal Department of Energy, Mines and Resources (EMR) use two similar versions of a model for making energy demand projections in Canada. The EMR version is discussed in detail in a publication by EMR (1977a). Sahi and Erdmann (1980) discuss an important development in the EMR model -- an interfuel substitution component. CANDIDE, a large econometric model of the Canadian economy, discussed in McCracken (1973), supplies consistent, projected values for a majority of the independent variables of the EMR model. These are disaggregated, by assumed ratios, over the five statistical regions of Canada -- Atlantic, Quebec, Ontario, the Prairies, B.C. and Yukon. End-use energy requirements for residential, commercial and industrial sectors are projected using double-log equations involving lagged demand, weather variables, and economic and demographic projections, some of which come from CANDIDE. Elasticities of energy demand with respect to relative fuel prices, real disposable income, volume of retail trade, and real domestic product and other variables are incorporated in the projections, allowing for periods of adjustment to the relative price changes by means of the lagged demand terms. Energy prices are supplied exogenously by the model user.

Input energy required for projected end-use (output) energy is estimated in the EMR model, using energy conversion efficiency data. The model user can insert hypothetical future improvements in energy use efficiencies. The market shares of the different fuels in the input energy requirements are calculated by means of semi-log market share equations depending on relative fuel prices, described in Sahi and Erdmann (1980).

The econometric model discussed in Helliwell et al. (1976), Helliwell (1979) and in Helliwell et al. (1980) will eventually be a tool for assessing a great number of current and future energy sources and policy options, but presently, the model emphasizes questions concerning frontier and non-frontier natural gas, non-frontier crude oil, and synthetic oil from the Athabaska oil sands.

The Helliwell model pays close attention to energy trade and transportation, and to domestic oil and natural gas prices. World crude oil prices are determined outside Canada and are exogenous to the model. Domestic oil and natural gas prices are determined by a policy rule. After allowing for transport costs to Statistics Canada's five major consuming regions, the resulting prices are used in a consistent set of estimated demand equations for all end-use sectors aggregated together in each region to forecast demand for oil, gas, coal and electricity. The demand equations, which explicitly account for regional peculiarities such as unavailability of natural gas in the Atlantic provinces, are composed of fuel cost share equations and equations determining the aggregate expenditure on total energy in each region. To account for delays in the adjustments (to changing prices) of total energy consumption and in fuel substitutions due to energy use being associated with capital stocks, the fuel prices used in the cost share equations are weighted averages of the current price and previous three years' prices. Apart from oil and gas prices, other exogenous variables are the gross national expenditure (GNE), the GNE price index, the price of electricity, the growth of hydro-electricity supply, and the growth of natural gas distribution pipelines.

Production sectors for non-frontier and frontier natural gas, non-frontier conventional crude oil, and oil sands, and oil imports meet the calculated demands. Costs of discovery, development and production, production income taxes and royalties, and economic rents are computed. The model hooks up needed reserves, and additions of new reserves are forecast exogenously (an attempt is being made to make the exploration process endogenous). There is considerable detail in tax and royalty arrangements.

There are two types of links between the energy model and the aggregate economy. Quarterly versions of the annual models of arctic and oil sands development, linked with RDX2, a quarterly econometric model of the Canadian economy, allow assessments of the macroeconomic impact of large energy projects. Helliwell et al. (1976) achieve consistency between the entire energy model and RDX2 by using output from the energy model as input for a new solution of RDX2, and vice versa, until a solution which satisfies both models is achieved. An example of the second type of link would be an energy trade surplus flowing into RDX2, where it influences the exchange rate (and other things), which, when fed back to the energy model, affects the Canadian dollar price of world oil and hence all Canadian energy prices.

Daniel and Goldberg (1980) report on work towards integrating the EMR demand model with a model of Canadian energy supply, using the linear programming procedure developed for solving the PIES model. When this work is complete, a major theoretical deficiency in the EMR demand model will have been resolved, namely the absence of simultaneous, integrated projections of both energy demand <u>and</u> supply. The supply side of the Daniel and Goldberg model is to be modified from work by McConaghy and Quon (1980) on an energy supply model for Alberta.

The model developed here is similar in spirit to the Daniel and Goldberg model, namely to integrate the EMR demand work with a model of energy supply, conversion and distribution in Canada. However, here, interfuel substitution is handled by a supply side linear process submodel rather than via the EMR econometric interfuel substitution component. In the model developed here, interfuel substitution is handled in the manner developed by Hoffman for BESOM. Another feature of BESOM which has been used, as far as the existing data will allow, is the specification of energy demands by functional end uses. In the domestic, farm and commercial sector, heating (space and water) is distinguished from other energy demands, and the road transportation demands may be met by either gasoline or electric automobiles. However, in contrast to the static model BESOM, which is solved one period at a time (i.e. the solutions are "myopic", and represent the behaviour of decision makers whose expectations are that future prices will be the same as present prices), the model described here is solved for all time periods at once (i.e. the solutions are "clairvoyant", as if all decision makers' expectations of future prices turn out to be exactly correct). In this respect, this model is similar to Manne's ETA model. Other points of similarity with the ETA model are:

- both are small enough for a single analyst to manage (updating the data base, modifying the structure, making and interpreting runs);
- both are small enough that the computing expense is small, allowing for the development of many scenarios;
- both find the market equilibrium by maximizing consumers' plus producers' surplus; and

- both are formulated as nonlinear programming problems with nonlinear objectives but linear constraints, using the MINOS code (described in Murtagh and Saunders, 1977) to find the solution.

Some major points of dissimilarity between ETA and the model described here are:

- this model carries the process analysis through to the end uses, in the cases of space heating and automobile use, while in ETA the demand is for secondary energy, which is categorized into electric and nonelectric energy; and
- there are two regions, west and east in the model discussed here, but ETA is a one-region model.

An examination of energy-economy interactions is one possible area of future research stemming from the work discussed here. The work could proceed by linking the present model to an existing macroeconomic model, as in the combination of the H-J and BESOM models. Alternatively, the approach of the PILOT project with the WEM model -- a single optimizing model containing an economic model and energy sector detail -- might be adopted. In the early development of the model discussed here, an attempt was made to represent energy-economy interactions by the method of ETA-MACRO. Although this approach is appealing since it keeps the model small and manageable, it had to be abandoned to keep the process detail in the end use sectors because there was no apparent way to make each end use sector's share of total output energy endogenous.

Another possible direction for future work is in increasing the number of regions distinguished in the model. Computational feasibility of such a larger model may require decomposition methods, perhaps along the lines of the solution method used by the SRI-Gulf model.

A complete discussion of future research possibilities may be found in Chapter 9.

The model discussed here fills a gap in the energy modelling efforts in Canada. This model, the Daniel-Goldberg model and a recent version of the Debanné (1980) model are, to the author's knowledge, the only energy models for Canada which calculate both prices and quantities, given price-responsive representations of supply and demand. Other models calculate demands if the prices are given (e.g. the EMR model), supplies if the demands are specified (e.g. McConaghy and Quon), or both supplies and demands if the prices are given (e.g. Helliwell). The model developed here differs from the Daniel-Goldberg model mainly in its handling of interfuel substitution by the supply side linear process submodel, which has advantages over an econometric approach for long range projections. Another difference is in the computational methods -- this model is solved by a single optimization, while the Daniel-Goldberg model is solved by the complex iterative method originated for the PIES work. This model is distinguished from both the Daniel-Goldberg and Debanné models in its explicit process modelling of some end-use demands, by function. The Debanné model also uses a complex iterative solution procedure. The advantages, then, of the model described here, compared to other Canadian models, are the integrated supply-demand equilibrium approach, the process modelling of interfuel substitution, including some functional end-use specifications, and computational simplicity. This model will hopefully be useful in making a contribution to the debate in the areas of Canadian energy policy for which it seems well-suited, namely energy pricing, the timing of the introduction of frontier energy resources and new energy technologies, the competitiveness and impacts of some new energy technologies, the impacts of various levels of energy exports, and the impacts of various potential policy constraints (e.g. a nuclear moratorium). Examples of several such analyses are presented in Chapters 6, 7 and 8.

Chapter 3. An Overview of the Structure of the Model

The model is composed of a linear process submodel of energy supply, distribution and use, coupled with a model of the demands for the services provided by the energy. The complete specification of all variables and relations may be found in Appendix B. The model equilibrates energy supplies and demands by maximizing consumers' plus producers' surplus (the procedure is described in chapter 4). There are two regions -- west and east, with the dividing line at the Ontario-Manitoba border. This division represents the most important regional aspect of Canadian energy policy questions -- fossil fuel supplies are largest in the west, while the main markets are in the east. Figure 1 illustrates the general structure of the model. The west exports energy to other countries and to the east. The east is an energy importer, taking supplies of fossil fuels from the west and from other countries, but a relatively small amount of electricity is exported from the east to the U.S.A. In each region, the energy commodities undergo various conversion processes and are distributed to the four end-use sectors within the linear process model:

1. the domestic, farm and commercial sector,
2. the industrial sector,
3. the road transportation sector, and
4. the "other" transportation sector.

In the end-use sectors are the final conversions to output energy (which may be viewed as an index of the useful services provided by energy in combination with other inputs such as capital - e.g. space heat, transportation, etc.), still within the linear process model of supply. For each end-use sector of each region, output energy demand is specified as a

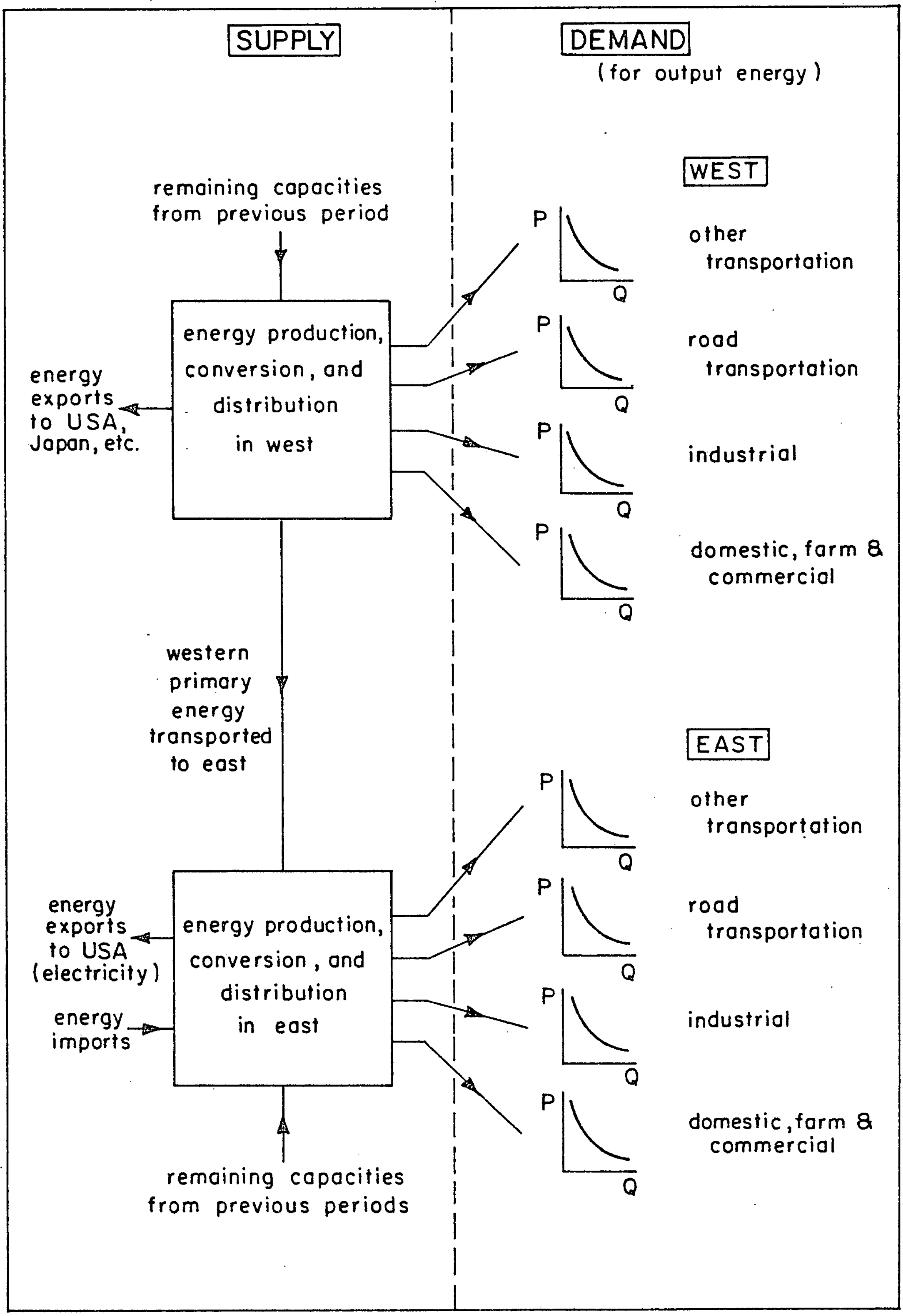

FIGURE 1 SCHEMATIC DIAGRAM OF MODEL IN EACH PERIOD

function of several exogenous economic and demographic variables, and of the endogenous price of the output energy. Output, rather than secondary energy is used in the demand functions because the demand for secondary energy is a derived demand. The demands are for the services such as heating, transportation, etc., which may be met by various combinations of inputs such as secondary energy and capital. The use of output energy in the demand functions allows a process representation of present and possible future devices for supplying the services represented by output energy. In this way, the secondary energy fuel shares may be determined endogenously, with explicit consideration of future technologies which will use secondary energy. The two data which represent an end-use conversion process are the conversion factor (the ratio of output energy to secondary fuel input) and the non-fuel conversion cost (representing the other inputs). It should be noted that in reality the conversion factors and non-fuel costs are price-responsive, but in the model, they are fixed exogenously. However, this theoretical deficiency is likely minor in the case of space heating, since interfuel substitution (which is represented in the model) will probably dominate the effect of fuel price on the conversion coefficients and costs. For oil used in the two transportation sectors, the conversion coefficents are varied over time, exogenously, to indicate expected increases in fuel efficiencies. This theoretical deficiency may have a significant effect in the industrial sector.

There are six time periods - three of length five years, followed by three of length ten years, for a total span of 45 years, from 1975 to 2020. A seventh "period" represents the time from 2020 to infinity, in a procedure to mitigate end effects, described later in this chapter.

The later periods are longer primarily for computational efficiency, but the decreased accuracy is not very important since there is much larger uncertainty in these later periods. The production levels in a period are influenced by levels in earlier periods, as described later.

In each time period, the linear process submodel is represented as a network of flows of energy commodities. Figures 2 and 3 illustrate, in complete detail, the networks for the west and the east, respectively. Primary energy in its various forms (i.e. crude oil, natural gas, coal, hydroelectricity, nuclear electricity, biomass energy products, and solar space heat) is converted into secondary energy (oil products, gas, coal and coke, electricity, space heat from cogeneration, and solar space heat), which is converted to output energy in the four end use sectors.

The aggregation chosen for the model limits the user's ability to examine certain questions easily with the model. For example, since coal is treated as a single commodity, separate consideration of different grades of coal is impossible. Similarly, there is no separate treatment of the different refined oil products. The upgrading of heavy oil and its separate treatment for the purposes of export may not easily be considered in the model. The modeller must make decisions on the degree of aggregation, to make the model a manageable size. The proper examination of certain questions may require a restructuring of the model. In some cases, an element may be left out of the model because the decisions associated with it are separable from the other energy policy questions. For example, nuclear power enters the model as a primary energy source, without reference to uranium, since it appears that uranium resources in Canada are so huge that their exhaustion is not a limiting factor over the time span of the model (see Energy, Mines and Resources, 1976c, 1978d). Furthermore the possibilities of the thorium near-breeder reactor and the fusion reactor replacing uranium-based plants make consideration of

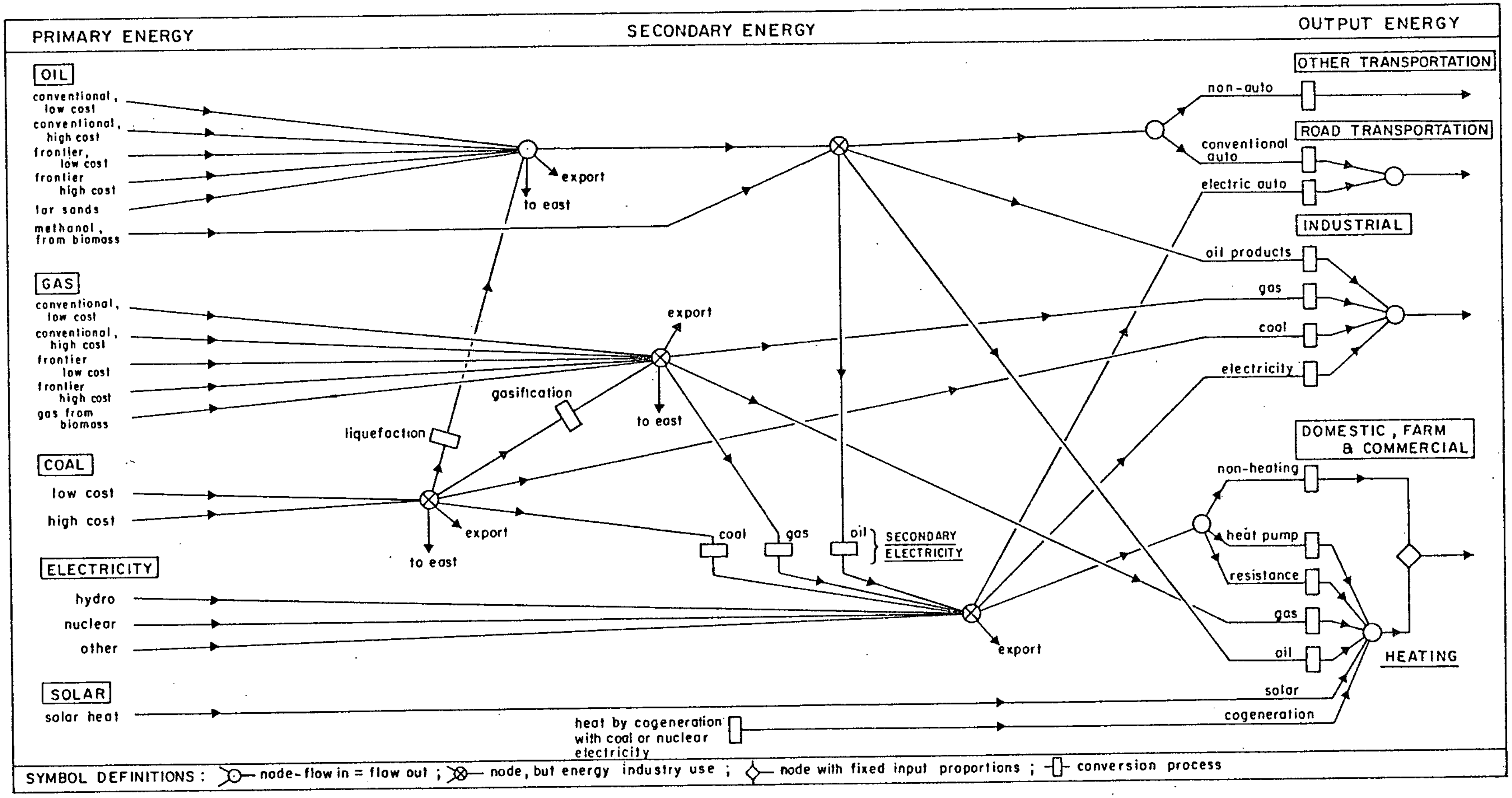

FIGURE 2 ENERGY FLOWS IN WESTERN CANADA

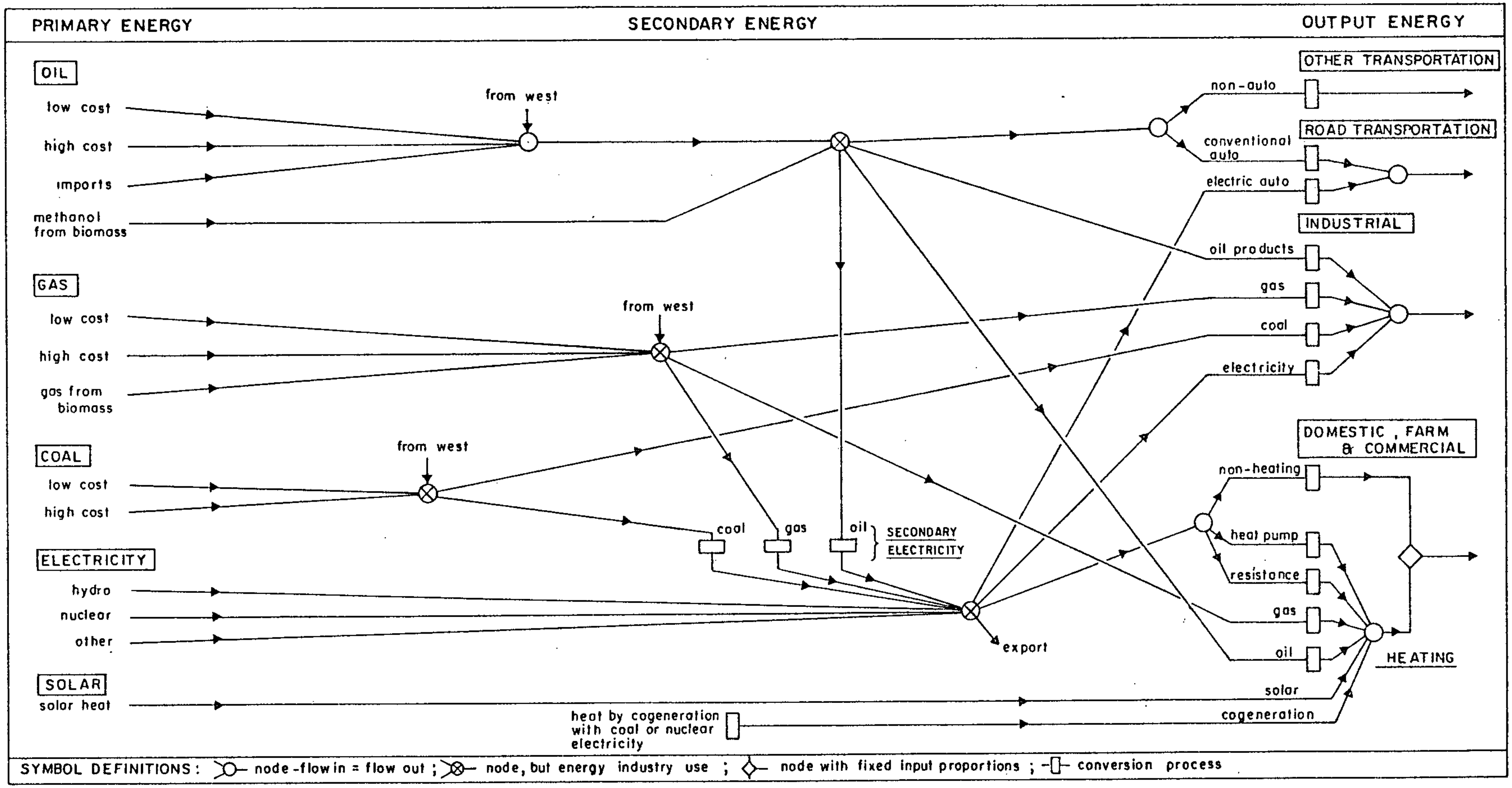

FIGURE 3 ENERGY FLOWS IN EASTERN CANADA

a single "nuclear" backstop electricity source quite reasonable.

For most depletable primary energy resources there are simple approximations to long run marginal cost curves, represented by two cost levels (low and high), with limits on the total resources available at each cost level. For crude oil from the tar sands, there is only one cost level. These cost levels are intended to cover the capital costs (with a stipulated rate of return) and the operating costs of finding and extracting the resource. Economic rents (e.g. royalties) can be calculated after the solution of the model as the differences between the equilibrium prices (derived from the dual variables) and costs of production. Non-depletable primary resources (hydro, nuclear, solar and biomass), are each available at unit costs covering operating and capital expenses, with a rate of return.

Apart from the costs of primary energy production, the other components of the total cost of meeting a given set of output energy demands are the costs of secondary conversion (coal gasification and liquefaction, and the conversion of oil, gas and coal to electricity), of non-fuel heating in the domestic, farm and commercial sector, of transporting oil, gas and coal from west to east, of distribution of secondary energy to the end use sectors, and the extra cost of electric automobiles over conventional ones. These unit costs also incorporate both operating and capital expenses, at a stipulated rate of return. A refining cost is included in the distribution cost of each oil flow to the end-use sectors. Revenues from exports of oil, gas, coal and electricity are included in the total energy cost calculation as negative amounts, since they are benefits.

Many constraints in the model are physical balance constraints which account for all flows in the network, using exogenous factors to account for energy losses due to inefficiencies of conversion and the energy industries' uses of energy (e.g. transmission losses in electricity distribution, refinery use of still gas, energy losses in conversion of coal to electricity, etc.).

Linkages between different time periods are found in the capacity expansion and retirement constraints, in the oil and gas production decline constraints, in the constraints limiting the total availability of depletable resources, and in the objective function (the maximization of the discounted sum of consumers' plus producers' surpluses, which is discussed more fully in chapter 4). The capacity expansion and retirement constraint for nuclear electricity production, for example, specifies that new capacity (productions and capacities are taken to be identical in the model) established in one period must carry on at the same level for a total of 30 years. Many primary and secondary processes also have 30 year lifetimes, but most heating processes (except cogeneration) have 15 year lifetimes, and automobiles are taken to have 10 year lifetimes. Through the oil and gas production decline constraints, typical production time-profiles are represented by insisting that new capacities established in one period last at non-zero levels for a total of 25 and 30 years for oil and gas, respectively, but at declining levels in later periods.

The demand functions are derived from work done at the Department of Energy, Mines and Resources, described in Sahi and Erdmann (1980), except for the road transportation sector. In the latter case, the demand function is derived from work by Dewees, Hyndman and Waverman (1975) on

Canadian demand for gasoline. The complete derivations and descriptions of the demand functions are presented in Appendix A.

From a theoretical point of view, the aggregation of output energy should be in categories distinguished by end-use functions which are performed with the aid of secondary energy inputs. For example, it would be preferable to distinguish, say, high, medium and low temperature requirements in the industrial sector, and a separate category for mechanical drive requirements, rather than the aggregate "industrial output energy" presently in the model. This would be preferable because each functional end use category could in principle be supplied by several possible fuel inputs, and if end-use conversion efficiencies and costs were known, a total cost minimization calculation would select the fuels for each functional end use. In this way, the market shares of each fuel input to the industrial sector could be determined endogenously. However, this approach cannot be fully adopted yet. In the industrial sector, demand functions would need to be estimated for each functional end use, but there are no such estimations for Canada, likely because there is not a good data base on the existing levels of the functional end uses of energy (and their fuels) in Canada, particularly in industry. The approach adopted in this model, for the industrial sector's fuel shares, has been to put upper and lower limits on the shares of the input fuels in industrial output energy. In the domestic, farm and commercial sector, the functional end use approach has been adopted in a limited way, with space/water heating distinguished as a demand which can be supplied by six possible processes (see Figures 2 and 3). However, other non-heating demand is a fixed proportion of the total sectoral output demand, and is supplied only by electricity. In the road transportation sector, output energy demand (i.e. road transportation services) can be met by either conventional, oil-fueled vehicles, or by electric vehicles. (It has been suggested that automobiles could be converted to running on natural gas. This possibility is not included in the model since the present natural gas surplus is only temporary. It is therefore unlikely that great changes will be made in the service stations and automobile engine design for a short-lived innovation.) Oil is the only fuel which can supply the other transportation sector in the model. It is assumed that the use of coal on railways and in ships will be negligible, and that there are no technical alternatives to oil fuels in aviation.

In order to represent factors involving geography, climate, the introduction dates and rates of new technologies, etc., there are upper limits on some shares - the shares of hydro in electricity generation in each region, the share of electric automobiles in road transportation services, and the shares of solar heat, the heat pump and district heating by co-generation in the supply of heating in the domestic, farm and commercial sector. In other cases of new technologies or new primary supply sources, upper bounds have been used to model the introduction dates and rates, with a zero-bound prior to the earliest date of introduction.

There is a constraint which places an upper limit on the fraction of eastern crude oil demand which can be met from western Canadian sources. This constraint represents the physical extent of the pipeline which carries western oil to eastern markets. If the upper limit on the fraction is less than one in any period, then the eastern region is forced to rely on imported oil or eastern offshore supplies, if the latter are available in sufficient quantities.

The access of western coal and gas to eastern markets is modelled by upper bounds on the flows of these commodities from west to east. In the case of coal, the potential capacity limitation is taken to be in the coal-handling facilities at Thunder Bay. The bounds on the flow of gas from west to east are intended to represent the lack of a pipeline east of Montreal (or, if the modeller wishes, the elimination of the upper bound represents the existence of a pipeline to Quebec and the Maritimes).

Coal, oil and gas may be exported from the west, and electricity may be exported from either region. Since the assumed export prices are usually mugh higher than domestic prices, and since export revenues are benefits in the model, upper limits are imposed on all exports, consistent with reasonable projections. Without such upper limits, the model tends to set exports at absurdly high levels. (In an early stage of model development, the model was mistakenly run with no export limits, and with the highest cost source of "oil", methanol from biomass, available in unlimited quantities at a cost lower than the export price. The problem was, of course, unbounded, since even after the rapid exhaustion of conventional oil and tar sands, the objective function could always be improved by producing and exporting more methanol from biomass). One reason for the need for export limits is that the model is deterministic, viewing all resources and future conditions as known with certainty. If this were true, it would make sense to export cheap supplies as quickly as possible to reap the large benefits of export revenues very early. In such a situation, domestic energy prices would rise to the export prices and the "backstop" energy supplies would more quickly become the chief domestic energy sources.

However, in reality, resources and all future conditions (e.g. the availability of the backstop supplies) are uncertain, which has led policy makers to place restrictions on exports. Therefore, upper limits on exports in the model are realistic representations of decision-makers' risk-averse, somewhat nationalistic, behaviour. However, an examination of the opposite policy -- unrestricted exports -- would require alterations to the model. If it is assumed that Canada is a price-taker, then energy exports would increase to the point where the marginal cost of production equals the export price, under an unrestricted export policy. To represent this behaviour, a model would need increasing marginal costs of labour, capital, and possibly other inputs to the production of the commodities for export. The present formulation of the model has simply a single unit cost of production for each resource, which is acceptable if exports are restricted. In summary, the present formulation of the model is as a restricted-export model, which represents the present risk-averse behaviour of national policy-makers. However, this formulation has important implications for model behaviour: domestic energy prices will <u>not</u> rise to world prices, but will rise at the most to the backstop costs; the introduction of new, more costly technologies may be much later than in an unrestricted-export model; and of course, resources will be depleted much less quickly than in an unrestricted-export model. In short, the limitation of exports, with the implied two-price system (domestic and international), is a key assumption.

Except for coal, all energy flows are in natural units in the model. Coal is in units of 10^{15} BTU rather than in tons because the single commodity, coal, in the model represents all of the grades of coal, of different thermal contents. The units used in the model are listed in Table 1. Monetary values are expressed in units of 10^{10} dollars to avoid scaling difficulties in the solution of the model.

Table 1: Units Used in the Model

Coal	10^{15} BTU
Oil	10^{9} bbl
Gas	10^{12} cubic feet (Tcf)
Electricity	10^{12} kwh
Solar Heat	10^{15} BTU
Heat by Cogeneration	10^{15} BTU
output energy	10^{15} BTU
monetary values	10^{10} Canadian dollars (1975$)

In the reporting procedure after the model has been solved, coal quantities are expressed in short tons, using the conversion factor, 1 short ton = 21 x 10^{6}BTU, which is midway between the factors for bituminous and sub-bituminous coal. As well, decimal points are shifted in some prices to report them in their most familiar units.

The model is a multi-stage nonlinear programming problem, with decisions in one period affecting decisions in future periods through the various constraints relating quantities in different time periods. To solve the problem, only a finite number of periods may be considered, introducing possible end effects, or distortions in the final periods. For example, if there is no provision in the model for times beyond the end of the last period, the production capacities of some depletable resources may be increased too rapidly in the last few periods, exhausting the resources by the last period and ignoring the usual constraints that ordinarily would make new capacity last a certain length of time, beyond the last period. Grinold (1980) describes various methods for mitigating end effects. The most promising is the dual equilibrium method. This procedure has been adopted in the linear process model of energy supply, and extended to the demand model. The essential assumption is that undiscounted prices are constant after the last period (i.e. all dual variables are constant, if they are converted to undiscounted, actual values in each period; and undiscounted output energy prices are constant). This is certainly justified if prices reach the backstop costs by the last period. Using this basic assumption, extra variables and constraints are derived, along with a special weight for the nonlinear expression in the objective function involving the extra variables. See Appendix B for details.

Chapter 4. The Solution Method

The equilibrium prices and energy quantities are calculated to maximize consumers' plus producers' surplus. In the linear process model of energy supply and distribution, the total cost in each period of supplying and distributing a given mix of energy quantities is calculated. The sum of the areas under the eight demand curves (four end-use sectors, two regions) may be interpreted as consumers' benefits of energy use in each time period. The difference between consumers' benefits and total cost for a given mix of energy supplies is the consumers' plus producers' surplus in a time period. Maximizing the consumers' plus producers' surplus is equivalent to finding the eight output energy demands for which the price paid by the consumer is equal to the marginal cost - i.e. finding the intersection points of the demand and supply curves. This is done in a single maximization calculation for all time periods by maximizing the discounted sum of the consumers' plus producers' surpluses in each time period.

If

$E_{i,t}$ = output energy in an end-use sector in period t ($i = 1,2, \ldots,8$),

$P_{i,t}$ = real price output energy in the end-use sector i, in period t, and

ei = price elasticity of demand in the end-use sector i (ei > 0),

then the demand curves are:

$$E_{i,t} = A_{i,t} \cdot P_{i,t}^{-ei}, i = 1,2,\ldots,8,$$

where $A_{i,t}$ = the product of the factors independent of $P_{i,t}$.

The consumers' benefits from using $E_{i,t}$ are

$$\int_0^{E_{i,t}} P_{i,t}\, dE_{i,t} = A_{i,t}^{1/ei} \cdot \int_0^{E_{i,t}} E_{i,t}^{-1/ei}\, dE_{i,t}$$

$$= ei/(ei-1) \cdot A_{i,t}^{1/ei} \cdot E_{i,t}^{1-1/ei} + \text{constant.}$$

If the lower limit of integration is zero as above, then the constant term is finite only if $1-1/ei > 0$ (i.e. $ei > 1$). However, since the constant term is independent of $E_{i,t}$, the lower limit of integration may be strictly positive (making the constant term finite without restricting ei) and the constant term may be dropped from the objective function.

Finally, if

EC_t = total cost of the energy supply mix in period t,

and d = the real social discount rate,

then to maximize consumers' plus producers' surplus over time gives the objective function:

$$\text{maximize} \quad \sum_t 1/(1+d)^t \cdot \left(\sum_{i=1}^{8} ei/(ei-1) \cdot A_{i,t}^{1/ei} \cdot E_{i,t}^{1-1/ei} - EC_t \right).$$

The whole optimization is a nonlinear programming problem, with the above nonlinear objective function and the linear constraints of the linear process model of energy supply and distribution.

It should be noted that it is assumed that there are no cross price elasticities among demands for output energy. Some such assumption is necessary to make the matrix of partial derivatives of demands with respect to prices symmetric. This ensures that the demand functions are integrable (see, e.g., Intriligator, 1971, p. 165) so that a utility function (the objective function) can be constructed. Without such an assumption ensuring the existence of an appropriate objective function, nonlinear programming could not be used to solve the model as it is here. It does seem reasonable, however, to assume that demands for output energy in the four sectors and two regions are independent to a great extent, that is, that the cross price elasticities are zero.

Solutions to the model have been obtained using the MINOS nonlinear programming algorithm, described in Murtagh and Saunders (1977). This algorithm is well-suited to solving this model, since it is designed for large-scale problems with linear constraints and nonlinear objective functions. MINOS is a reduced gradient algorithm employing sparse LU factorization. A stable quasi-Newton method for optimizing the objective function within a given subspace is used as long as storage requirements are not excessive. Otherwise, MINOS uses a conjugate-gradient method, which requires little storage but which converges slowly.

The model has 746 rows, 960 columns, 3423 non-zero matrix elements, and 56 variables entering nonlinearly into the objective function. Solution of the model requires about 700 K bytes of storage. Usually the model is solved by starting from a basis for a similar problem, in order to save computing time. In order to gain an appreciation of how efficient the model would be as a frequently-used tool in energy policy analysis, the model was solved with high-case data (see Chapter 7), from a "cold start", without specifying an initial basis near the optimal solution. (However, the INITIAL facility in MINOS was used, with which the optimal solution to a related LP problem is first found, with the nonlinear variables fixed at reasonable guesses, followed by the solution of the NLP problem starting from the basis of the LP optimal solution). The solution of this problem required 2742 iterations, and 301 CPU seconds on the IBM 3031 at the

University of Waterloo. The CPU time includes both the MINOS calculations of the optimal solution, and calculations to produce more readable printed output and plot files to be sent to the CALCOMP plotter (there are 27 plots produced).

Chapter 5. An Overview of the Assumptions for the Base Case

The data for the "base case" are the best estimates of all the model parameters, and the most likely projections of all exogenous variables and limits. The details of all derivations and sources may be found in appendix C, "Data for the Base Case". The key assumptions and approaches to estimating parameters are discussed here.

There are many unit costs which are derived from data on capital and operating costs. In all such cases, a real social rate of return on capital of 8% per annum was used to amortize the capital costs over assumed fixed lifetimes of the processes' equipment. The choice of 8% was based on work by Jenkins (1977), who estimated real social rates of return on all physical capital in Canada for the period 1965-1974. Jenkins adjusted reported rates of return by revising depreciation estimates to correspond to actual service lives, and by removing the spurious effects of inflation on capital stock valuation (he estimates the current replacement value of the capital stock) and on income (he makes an inventory valuation adjustment). The return on capital includes all taxes attributable to the capital investment, in order to derive a social rate of return. The real social rate of return averaged over all industries(including housing and agriculture), weighting each industry's rate by the fraction of total 1970 capital stock found in that industry, and averaged over 1965-1974, was approximately 8%.

The real social discount rate, used in the objective function, is taken to be 10%, based on a result of the study by Jenkins (1977). Jenkins calculated the social opportunity cost of government expenditures. He assumed that if government funds for expenditures are borrowed, then these funds are not available for the private sector to make the usual rate of return. Furthermore, Jenkins assumes that even if the funds were raised through taxes, they could alternatively be used to lessen government debt, making more funds available to the private sector. In either case, the private sector's usual rate of return enters into the calculation of the social opportunity cost of government expenditures. Other factors are the after-tax (Canadian taxes) rate of return earned by foreign investors in Canadian assets, the decrease in consumption due to increases in personal savings when interest rates rise because of government borrowing, a "foregone foreign exchange premium", and the difference between the social opportunity cost of labour and the wage rate which would be paid if the investment funds were available to the private sector. Jenkins finds that "the social opportunity cost of government funds is at least 10 percent per year on the total amount invested in public projects." In the energy sector model discussed here, one of the key intertemporal elements is the calculation of the prices of exhaustible resources. Since these prices include large royalty components, and since the royalties, or economic rents, accrue largely to governments, it is sensible to use the social opportunity cost of government funds, 10 percent per year, as the discount rate. The National Energy Board (1979) has also used a 10% real social discount rate in a cost-benefit analysis of new natural gas exports.

All costs and prices in the input data and in the output are expressed in real terms, in 1975 dollars. The Consumer Price Index has been used for all conversions to 1975 dollars, including conversions in energy production sectors.

The "low cost" levels, in the approximations to the long-run supply curves for coal, crude oil and natural gas production from sources important before 1975, are taken to be the average prices, at the point of extraction (after natural gas plant processing, in the case of gas), just prior to the rapid rise in prices in the early 1970s. This procedure avoids the inclusion of "windfall profits" and vastly increased royalties which are characteristic of the mid and late 1970s. These estimates of production costs are on the high side, since royalties are included in the prices which are used, although the royalties are at the relatively low levels of the early 1970s. These low costs for existing sources are $0.20 per million BTUs for western coal, $0.80 per million BTUs for eastern coal, $4 per barrel for western conventional oil, and $0.30 per thousand cubic feet for western natural gas.

The "high cost" levels for existing production, and the cost of levels for oil and gas production not yet important in the early 1970s, are based on estimates by other researchers, as explained in appendix C. In particular, synthetic crude oil from the tar sands is assumed to be available at a cost of $12 per barrel, using estimates of capital and operating costs by Energy, Mines and Resources (1977c), and a real rate of return of 8% per annum, over 30 years.

The non-fuel costs of fossil-fuel electricity generation are based on figures presented by Hedlin, Menzies and Associates (1976), using an 8% real rate of return, over 30 years. The generation cost of hydroelectricity is assumed to be 7.7 mills per kilowatt-hour, based on the capital cost of a recent, large project in Manitoba (see Protti, 1978), using an 8% rate of return over 30 years, and assuming that non-fuel operating costs are the same as for coal-fired electricity. This is in line with costs of projected new hydro sites for several provincial utilities (also in Protti, 1978). Nuclear electricity is assumed to have a generation cost of 10 mills per kilowatt-hour, using capital and non-fuel operating costs in Hedlin, Menzies and Associates (1976), and fuelling costs in Kee and Woodhead (1977). The capital and non-fuel operating cost estimates are higher than for existing reactors, since they are based on Bruce units 5-8 which will be operational in 1983. The older Pickering reactor recorded a generation cost of less than 8 mills per kilowatt-hour in 1976, according to Dalrymple and Anderson (1978).

Except for district heating by cogeneration, the non-fuel costs of heating in the DFC sector are based on estimates presented by the Stanford Research Institute (1976) for "high load" (cold) regions of the U.S.A., using an 8% rate of return, over 15 years. The non-fuel cost of heating by cogeneration is based on work by Berthin (1980), using an 8% rate of return, over 30 years. The cogeneration cost is mainly the distribution cost -- i.e. the cost of the network of pipes to the customers.

The margins for distribution, refining (in the case of oil), and taxes, for coal, oil, gas and electricity, have been estimated by subtracting production costs from prices paid in 1970 or 1971 (before the sharp increase in energy prices) by customers in the end use sectors. These margins are assumed to be constant in all time periods.

The extra cost of the electric automobile is based on the estimate by Wayne (1979) of a $1500 price difference between the electric and conventional automobiles, in Canadian, 1975 dollars. It is further assumed that cars last 10 years and travel 10,000 miles per year, on the average.

The costs of transporting energy commodities from the west to the east are based on various sources. They are $1.03 per million BTUs for coal, $0.50 per barrel for oil (from Edmonton to Port Credit), and $0.44 per thousand cubic feet for gas.

The price elasticities of demand for output energy in each end use sector are based mainly on work by Energy, Mines and Resources, and in the case of road transportation, on Dewees, Hyndman and Waverman (1975). The elasticities are 0.81 for the DFC sector (this would be 0.39 if the output energy price did not include the non-fuel costs of heating), 0.48 for the industrial sector, and 0.36 for both transportation sectors (see appendix A for details). The demand functions have been calibrated using price and quantity data from 1970 and 1971, and 1970 values of the indices for population and for the exogenous economic parameters.

The projections of the indices of the exogenous variables (eastern and western population, eastern and western real domestic product, income per capita, and industrial capital-output ratio) up to 2000 are based on the base case values of the most recent National Energy Board projections, except for the capital-output ratio projection which is based on the projection by Energy, Mines and Resources (1977a), until 1990. The growth rate of the capital output ratio is assumed to decrease to zero by the period after 2010. Population after 2000 is assumed to grow at the rate of the mean of the Statistics Canada (cat. no. 91-520) projections. Other economic variables after 2000 are tied to population growth, assuming approximately a 2% per annum rate of increase of output per worker, due to technological change.

Conversion efficiencies for coal gasification and liquefaction, and for heating in the DFC sectors are based on estimates by the Stanford Research Institute (1976). End use conversion efficiencies in industry, road transportation and other transportation are based on estimates presented by Energy, Mines and Resources (1977a), with improvements in the transportation sectors in later periods. Conversion efficiencies for electricity from fossil fuels have been calculated from data for 1971-1975 compiled by Statistics Canada (cat. no. 57-207), with improvements assumed in later time periods. The parameters representing energy industry use of the energy commodities are also based on Statistics Canada data for 1971-1975, with improvements assumed in the case of electricity.

The remaining reserves of oil and natural gas are based on the 40% probability levels of the resource estimates by Energy, Mines and Resources (1977b) (because the distributions are skewed, the 40% level is closer to the mean value of the estimates than the 50% level). It is assumed that there are 200 x 10^9 barrels of recoverable synthetic crude oil from the tar sands. Coal reserves are assumed to be very large in the west -- 1,587 x 10^{15} BTUs at the low cost level -- but very limited in the east -- 22 x 10^{15} BTUs at the low cost level.

The prices of coal imports and exports are assumed to increase at the real rate of 2.5% per year until 2000, from their levels in 1975. The real prices of natural gas and crude oil exports are assumed to increase at the rate of 4% per year until 2000. The oil import price is assumed to be lower than the export (international) price, in the first three periods, because of the import subsidy. The subsidy is reduced gradually to zero by the fourth period, 1991-2000.

The upper limits on oil and gas exports have been set at the currently approved export levels. Western coal exports are allowed to reach a maximum which increases at the rate of 5% per year. The maximum levels of electricity exports increase at the rate of 1% per year in the two regions.

Production from the tar sands is fixed at the "base case" level of the National Energy Board (1978) for the first four periods. This is necessary because the cost of syncrude from the tar sands is higher than most other sources of oil, which would ordinarily cause the tar sands to be left out of the model's solution until well after the turn of the century. In reality, though, tar sands production is an attractive, immediate alternative, since it is certain and accessible, while frontier sources are not. Fixing production at the most likely level is therefore a realistic approach.

To ensure a reasonable transition to the use of eastern offshore oil and gas, there are bounds on several variables in the first few periods. Production of oil from southeast offshore sources is assumed to be available in large quantities for the first time in the 1986-1990 period, at a maximum level of 50 million barrels per year, with a buildup in the previous period. There are no upper limits in later periods. Oil production from northeast offshore sources is allowed in the model for the first time in the period 1991-2000, at a maximum rate of 50 million barrels per year, with a buildup in the previous period, and no limits in later periods. Southeast offshore gas is available in the model starting in 1988, at a maximum of 0.8×10^{12} cubic feet per year, and no upper limit after 1990.

Reasonable transition behaviour of energy flows from west to east are brought about by a constraint on oil and upper bounds on coal and gas in the first few periods. Western oil is allowed full accessibility to eastern markets for the first time in the period 1986-1990. Upper limits on the transportation of western gas to the east, in the first three periods, are intended to represent the possible installation of a Quebec and Maritimes pipeline in 1985, and a five-year buildup to the full potential of gas in the energy markets east of Montreal. The transportation of coal from west to east is bounded above in the first three periods, to represent likely limits on the coal-handling facilities at Thunder Bay.

The maximum production rate allowed from eastern coal reserves is increased at the rate of 15% per year for the first three periods. Without such limits, the model tends to expand production unrealistically quickly, because the cost of eastern coal is so low, compared to the alternative coal sources available to the eastern region.

Chapter 6. Discussion of the Base Case Output.

Throughout this chapter and the two following chapters, there are many figures which present plotted output of the model. Since the plotted points (which are connected by straight lines) are the average values for the periods in which they occur, the points have been plotted at the midpoints of the periods. Thus, the last plotted point in each graph is for the year 2015, representing the average annual value in the period 2011-2020.

6.1. Oil

Production from conventional areas in the west (Figure 4, 'western'), including Lloydminster heavy oils, continues at an almost steady level until 1990, then declines rapidly. Northern frontier oil, both western Arctic and offshore Labrador, is not used until after 2000, even though there are no exogenous assumptions which directly force such a late entry. Southeastern offshore oil becomes important after 1985, when exogenous upper limits in the model first allow high production levels. This source is depleted by 2020. Oil production from the tar sands is fixed at the National Energy Board (1978) base case level until 2000. After 2000, tar sands production drops slightly since there is no new capacity added during 2001-2010, but old capacity is retired. It then increases, to become the predominant oil source (49% of total supply) in the last period (2011-2020). Imports cease after 1985, when it is assumed that the entire eastern oil market first becomes fully accessible to western oil. There is no oil produced from coal and none from biomass. The total of oil production plus imports drops from the first period to the second, and then levels off.

Crude oil prices (Figure 5) in the east are $0.50 per barrel higher than in the west, after 1985, when there are no more imports. The $0.50 difference is the transportation cost from west to east. Apart from this

Table 2. Oil Production, Base Case.

```
              BASE CASE;          ;

OIL PRODUCTION:
IN UNITS OF   10**9 BBL PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980    1985    1990    2000    2010    2020


IMPORTS;            0.2786  0.1109  0.0000  0.0000  0.0000  0.0000
FROM BIOMASS;       0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
FROM COAL;          0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
EASTERN;            0.0008  0.0100  0.0500  0.1772  0.2058  0.0740
TAR SANDS;          0.0362  0.0744  0.1534  0.2756  0.2516  0.3442
WEST ARCTIC;        0.0000  0.0000  0.0000  0.0000  0.0635  0.2554
WESTERN;            0.5567  0.4956  0.5010  0.2512  0.1319  0.0332
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 4. Thus, the differences between the plotted lines are the entries in Table 2.)

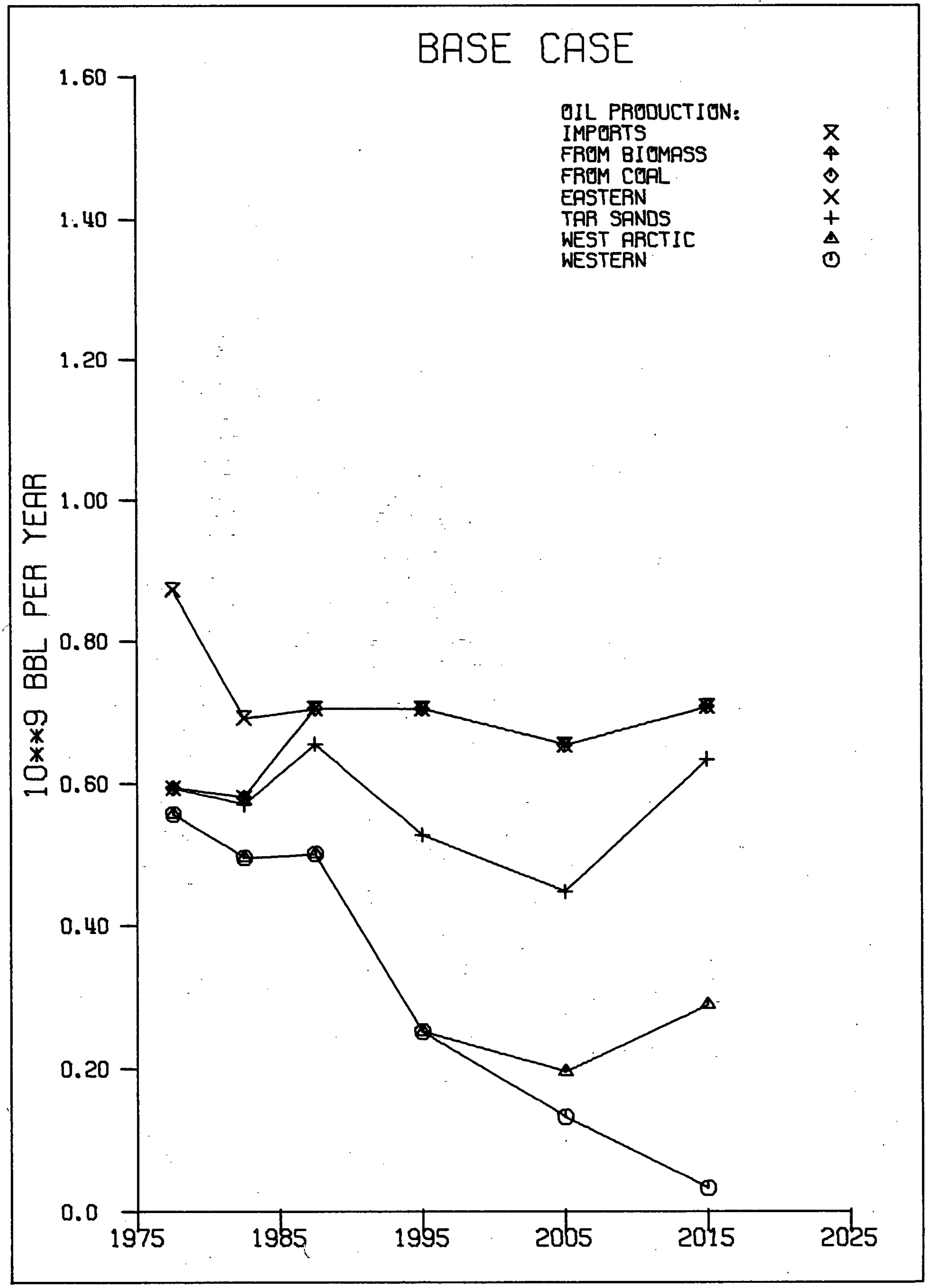

Figure 4. Oil Production, Base Case.

Table 3. Crude Oil Prices, Base Case.

```
             BASE CASE;              ;

CRUDE OIL PRICES:
IN UNITS OF   1975$ PER BBL

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                       1980    1985    1990    2000    2010    2020


EXPORTS;            14.6000 17.8000 21.6000 32.0000 32.0000 32.0000
IMPORTS;            10.8000 14.8000 19.3000 32.0000 32.0000 32.0000
EAST;                8.0200 10.1021  9.1277  8.9758 11.0672 12.5000
WEST;                5.1524  8.1992  8.6276  8.4755 10.5673 11.9998
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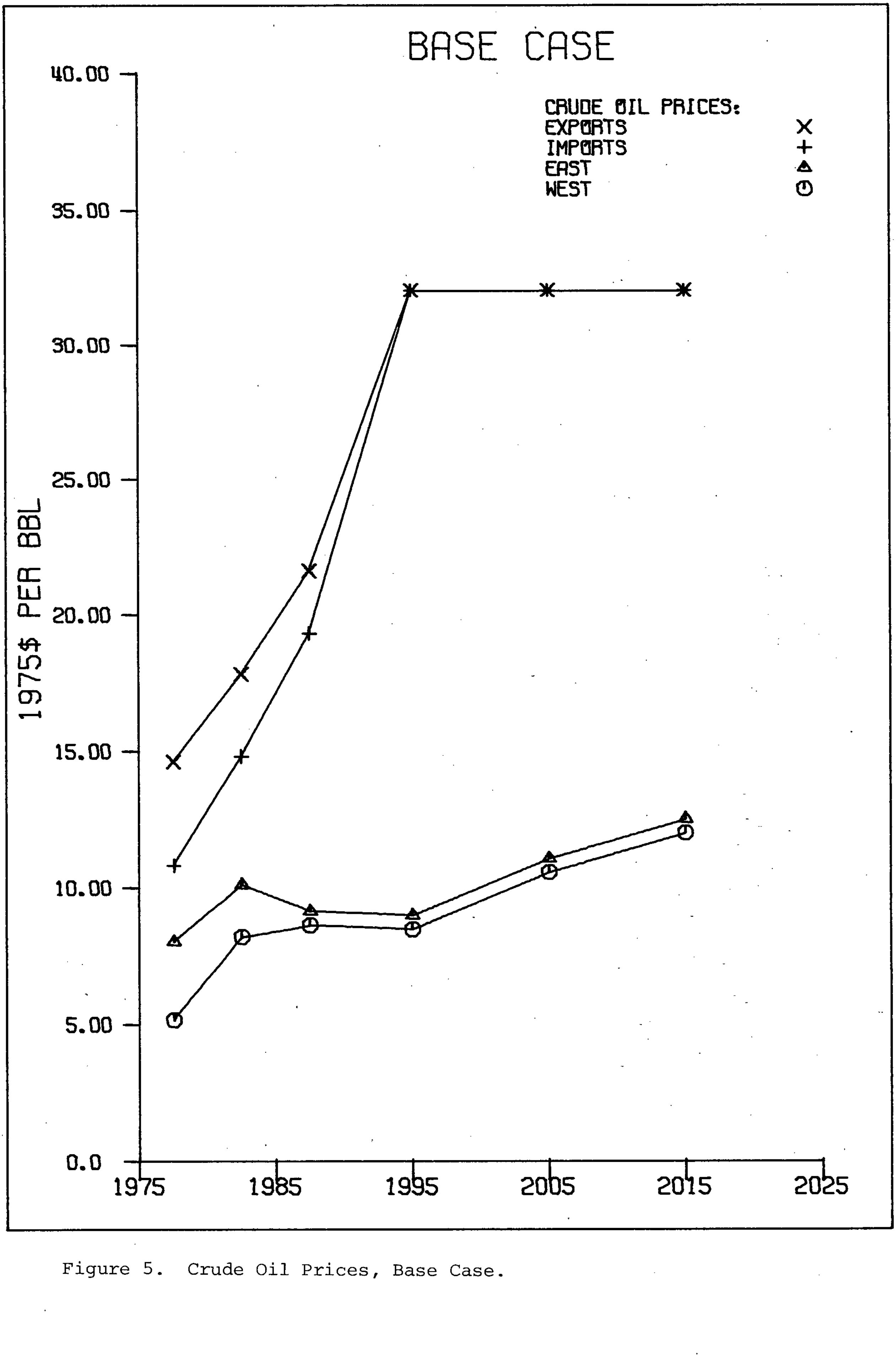

Figure 5. Crude Oil Prices, Base Case.

difference, prices (in 1975 $) in both regions move gradually upward to the cost of synthetic crude oil from the tar sands ($12 per barrel) as the less costly oil is depleted. This $12 ceiling is to be expected, since the tar sands production is effectively a "backstop" source of oil over the timespan considered in the model. (An examination of the value of the tar sands reserves limit constraint shows that the tar sands are far from depletion, even including the production for the extra "end effects" period which is an approximation of the remainder of the infinite problem beyond 2020. See Appendix B, section 10 for details of the approximation.) However, prices are below the $12 ceiling until after 2010, even though tar sands production is used, because this oil source is forced into the solution exogenously in the first four periods. The model brings new tar sands capacity into the solution without exogenously forcing it only in the sixth period, when the oil price therefore reaches the tar sands cost. The difference between the cost of oil from the tar sands ($12/bbl) and the western oil price in the solution of the model may be interpreted as an upper limit on the subsidy to be paid to tar sands producers for the "insurance" of production from the certain tar sands resource, in the face of uncertainties about the existence and costs of the other oil resources. The oil prices should therefore be viewed as lower limits (under the restricted trade, two-price assumption), except for the last period. A detailed, stochastic model of the oil sector may be needed to examine more carefully the problem of the subsidy for tar sands "insurance".

In the first two periods, the eastern oil price is more than $0.50 above the western price because the east is forced to rely to some extent on costly imported oil. The eastern price is the average of the western price (plus the transportation cost) and the price of imported oil, weighted by the two corresponding quantities.

The exogenous prices of oil imports and exports are included in Figure 5 for comparison with the endogenous domestic prices. The export price is assumed to increase at the rate of 4 percent per year until the year 2000, and the import subsidy is assumed to shrink to zero after the period ending in 1990.

The reader familiar with the dictum that price must be equal to marginal cost may be puzzled by the fact that in the first two periods the eastern price is not as high as the price of imported oil, which is the highest cost source of supply in those periods. The reason is related to the form of the constraint limiting the accessibility of western oil to the eastern region:

$$\text{NOMEM:} \quad \text{WOE} \leq \text{opipe} \cdot \text{EOG},$$

where opipe = 0.54 and 0.77 in the first and second periods, respectively. In words, the constraint says that the amount of western oil flowing east (WOE) must be less than or equal to a fraction (opipe) of eastern oil demand (EOG). In the third and later periods, opipe = 1.0, giving western oil full access to eastern markets. Because of exogenous limits on eastern production in the first two periods, the constraint is binding then, because western oil is much cheaper than imported oil. However, the marginal cost of oil to the east is not the price of imported oil in the model. A fraction (opipe) of the last barrel of oil demanded comes from the west, and the remaining fraction (1-opipe) comes from imports. Therefore, the cost of the "last barrel" demanded is the average of the prices of the two sources, weighted by their fractional contributions to the "last barrel."

If the constraint limiting the flow of oil from west to east had been a binding, absolute upper limit rather than a "relative" upper limit, then the marginal cost of eastern oil would have been the price of imported oil, since the "last barrel" of oil would have come entirely from imports. Of the two types of upper limit - relative or absolute - which is the more realistic? An absolute upper limit would correctly represent a sharply defined physical limit on pipeline capacity, but it may be argued that no such limit exists. The velocity of the fluid in the pipe, and therefore the flow rate, can usually be increased, perhaps with additional pumping capacity, up to a point. After that point, capacity can be increased quickly (compared to the five-year length of the first two periods), by looping. Quick increases in capacity may also be achieved by oil "swap" agreements with the United States, whereby oil is shipped from western Canada to the United States and an equal amount is shipped from the eastern United States to eastern Canada. However, if there are in fact constraints on western oil production in addition to those in the model, then real behaviour may be more like a model with an absolute upper limit on oil shipments from west to east. (The only limitations on western oil production in this version of the model are the reserves limits, and the oil production decline constraints by which new capacity is forced to continue for ten years, then decline at 10% per year for 15 years, and then cease.) The present formulation, with the "relative" upper limit, may therefore be viewed at least as a very plausible representation. The gradual transition to full access to eastern markets for western oil could be made first by supplying all Montreal refiners' needs from the Sarnia to Montreal pipeline and secondly by either constructing an extension of the pipeline to the east coast or constructing facilities at Montreal for loading oil onto tankers which would unload at points east of Montreal. The solution of the model, with the "relative" limit on oil shipments from west to east, in effect indicates a subsidization of the portion of the east not served by western oil, during the first two periods. Since the import price in the model is subsidized exogenously in the first two periods (to represent behaviour if the subsidy cost is not borne by the energy sector, which appears to be the case), the results indicate an extension of the present policy of subsidization out of concern by national policy makers for economic conditions in the Atlantic region and part of Quebec, which must rely on imported oil. In the model, the further subsidy comes from an extra charge for oil in the portion of the east served by western oil, making the calculated eastern price an average price. The other major oil subsidy indicated by the model -- that on tar sands production -- is not included in any sort of average. As discussed above, it may be calculated after solution of the model as the difference between the cost of oil from the tar sands, and the western price calculated by the model.

The difference in price, above the transportation cost, between east and west in the first two periods is unrealistic (although not large - \$2.37/bbl and \$1.40/bbl in the first two periods), given the federal government's determination to pursue a policy of a single, national price. Since it would be difficult to put a constraint into this model, representing a single, national price, it is probably best to assume that the calculated eastern price for crude oil, adjusted for the west-to-east transportation cost, should be interpreted as the national oil price, since eastern oil demand is much larger than western demand. Under this interpretation, the calculated national oil price is shown below in Table 4. Also included in Table 4 is the national oil price in nominal dollars, adjusted by the increase in the Consumer Price Index from 1975 to 1978 (26%, according to the Economic Council of Canada, 1979), at 8% per annum to the mid-year of the next period, 1983, and at 6% per annum to the mid years of the remaining periods. For reference, the ceiling price of \$12/bbl -- the cost of oil from the tar sands -- is converted to nominal dollars in the third line of Table 4.

Table 4. National Oil Price, Real and Nominal Dollars, Base Case.

Period Ending	1980	1985	1990	2000	2010	2020
Price (1975 $/bbl)	7.52	9.60	8.63	8.48	10.57	12.00
Nominal Price	9.48	17.77	21.38	32.52	72.60	147.61
Nominal Tar Sands Cost	15.12	22.22	29.73	46.03	82.42	147.61

How does the first period's price compare with the actual price levels? According to Helliwell (1979), the actual wellhead prices in 1978, the representative year of the first period, were $11.75/bbl after January 1, and $12.75 after July 1. The nominal price calculated by the model, $9.48/bbl, is lower than the actual price. This may indicate that the oil production costs perceived by the oil industry have been higher than has been assumed in this study. The possibility that oil costs are higher than those assumed for the base case is examined in Chapter 8. Such uncertainties in key data indicate the need for continually updating a model such as this one.

An earlier discussion indicated that the assumption of oil export limits implies a two-price system for oil -- the domestic price is lower than the international price, and it has a ceiling equal to the domestic backstop cost (as long as the oil export limits are not so great that the tar sands are exhausted in the model). A related observation may be made: if the price paid to oil producers is raised much higher than the domestic equilibrium price (allowing for royalties to the owners, provincial governments), there would be very strong pressure to raise export limits, as producers would bring in higher cost supplies too quickly to be absorbed in the domestic market. This has happened recently in the Canadian natural gas industry. The price paid to producers (the "netback", not including royalties) was increased dramatically after 1974, leading to vast new additions to reserves and tremendous industry pressure to export more natural gas. The same phenomenon could be observed in the case of oil if the domestic price is raised much above the domestic equilibrium price and if the producing companies receive some of this extra economic rent.

It is now clear why there is no oil produced from coal, and none from biomass. With the price of coal in the model output, the distribution margin applied to coal for oil production, the assumed factor for conversion of coal to oil, and the assumed conversion cost, the cost of oil from coal is $17.23/bbl in all periods (1975 $). Therefore, as long as the tar sands can produce, with no binding upper limits, at $12.00/bbl, coal from oil will be uneconomic. It should be noted that one key assumption in this matter is that the same distribution margin for coal to western industry applies to coal for liquefaction. This margin amounts to $7.46 of the $17.23/bbl. It is conceivable that this distribution margin could be lower, since coal liquefaction plants could be located close to the mine. Even with no distribution margin, coal liquefaction would not be economic until after 2000, given the prices in the base case solution. Oil products from biomass, assumed to cost $25/bbl, are also uneconomic as long as oil is available from the tar sands or from coal liquefaction. Of course, if it turns out that there are unavoidable environmental or other limits on tar sands production, or if the oil price is set above the optimal price, we could see oil from biomass or coal.

An examination of the detailed output of the base case reveals that the rate of transport of western oil to the east decreases as eastern offshore oil

Table 5. Oil Use, Base Case.

BASE CASE; ;

OIL USE:
IN UNITS OF 10**9 BBL PER YEAR

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
EXPORTS;	0.1194	0.0304	0.0146	0.0067	0.0000	0.0000
OTHER TRANSPORT;	0.0623	0.0692	0.0815	0.1029	0.1283	0.1646
ROAD TRANSPORT;	0.2128	0.2046	0.2115	0.2351	0.2672	0.3311
INDUSTRY;	0.1508	0.1214	0.1753	0.2984	0.2093	0.1591
DFC;	0.2545	0.2007	0.1565	0.0000	0.0000	0.0000
ELECTRICITY;	0.0172	0.0160	0.0142	0.0095	0.0000	0.0000

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 6. Thus, the differences between the plotted lines are the entries in Table 5.)

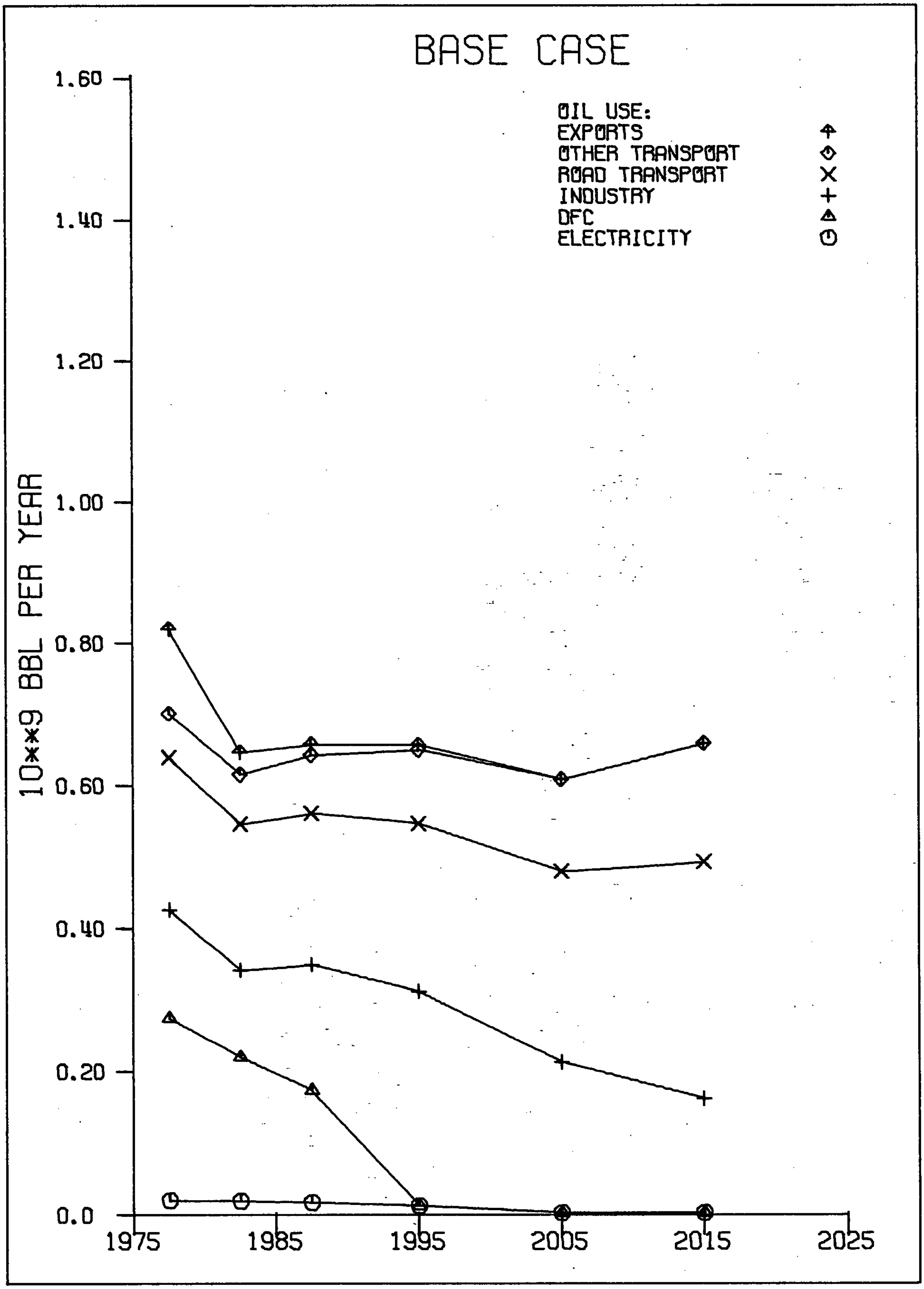

Figure 6. Oil Use, Base Case.

is exploited, beginning mainly after 1990, but it rises again after 2010 when the main oil source for the east is from the west (mainly from the tar sands, but also from the western arctic).

Oil is used in the DFC sector for heating (Figure 6) in the early periods, but is phased out rapidly to zero in the west after 1985, and in the east after 1990. Oil ceases to be used for electricity in the west and east after 2000. The use of oil in industry peaks in the period ending in the year 2000. (For a complete discussion of fuel use in industry, see section 6.6 below, in this chapter.) Oil remains the sole fuel used in road transportation (the electric automobile is not in the optimal solution). Because of assumptions about early, rapid improvements in the efficiency of automobiles, the use of oil in road transportation stays nearly constant until after 2000, then begins to rise, since efficiency improvements are not assumed to be as rapid then. The use of oil in "other" transportation increases gradually, and exports of crude oil and oil products are at the exogenously assumed upper limits. Total oil use drops by a large amount between the first and second periods, for several reasons -- the oil export limit is lower, the eastern oil price rises to a temporary peak in the east in the second period (it falls in the third), and oil is phased rapidly out of use in several areas, as discussed above.

6.2. Natural Gas

Natural gas production (Figure 7) is almost entirely from the conventional western areas until after 1985, when significant quantities of southeast offshore gas are allowed to enter the model solution. Western conventional gas production peaks in the period 1981-1985. This is roughly in agreement with the National Energy Board (1979), which projects a peak in 1985. Overall production, including eastern production peaks in the period 1986-1990. Eastern production by itself peaks in the period 1991-2000.

Natural gas from northeast offshore sources is not needed until after 2000, and gas from the northwest arctic is not used until after 2010. This conclusion clearly contradicts the conclusions reached by the National Energy Board (NEB) and the Department of Energy, Mines and Resources in the mid-1970s, reported in Helliwell (1979, Table 7). The "date of estimated need for frontier gas" made by the NEB in 1969, according to Helliwell (1979, Table 7) was after 2000, as this present model predicts. As Helliwell (1979) discusses, the reasons for the mid-1970s pessimism about conventional natural gas supplies, at least in the case of the NEB, included the NEB's acceptance of the arguments by the Mackenzie Valley pipeline groups, the major producing companies, and some Canadian nationalist groups and individuals. According to Helliwell (1979), the pipeliners were trying to justify their northern gas pipeline applications, the producers were attempting to show the need for higher prices and lower taxes, using the argument that the expensive northern gas must soon be tapped, and the nationalists argued that the need for expensive northern gas proved that oil and gas exports should be reduced immediately.

There is a tiny amount of gas produced from biomass after 2000 in the east, at the upper limits allowed in the base case. There is no gas produced from coal.

The use of natural gas (Figure 8) for electricity declines to zero after the turn of the century. However, the use of gas in both the DFC and industrial sectors grows until 2000. Gas use in western industry falls to its lower limit (in share terms) in the next period, producing a dip in the total of industrial gas use in both regions. (See section 6.6 below for a discussion

Table 6. Gas Production, Base Case.

BASE CASE; ;

GAS PRODUCTION:
IN UNITS OF TCF PER YEAR

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
FROM BIOMASS;	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004
FROM COAL;	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EASTERN;	0.0002	0.0002	0.4800	0.7703	0.7054	0.6165
WEST ARCTIC;	0.0000	0.0000	0.0000	0.0000	0.0000	0.3428
WESTERN;	2.9561	4.0261	3.7211	3.0271	1.2000	0.2212

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 7. Thus, the differences between the plotted lines are the entries in Table 6.)

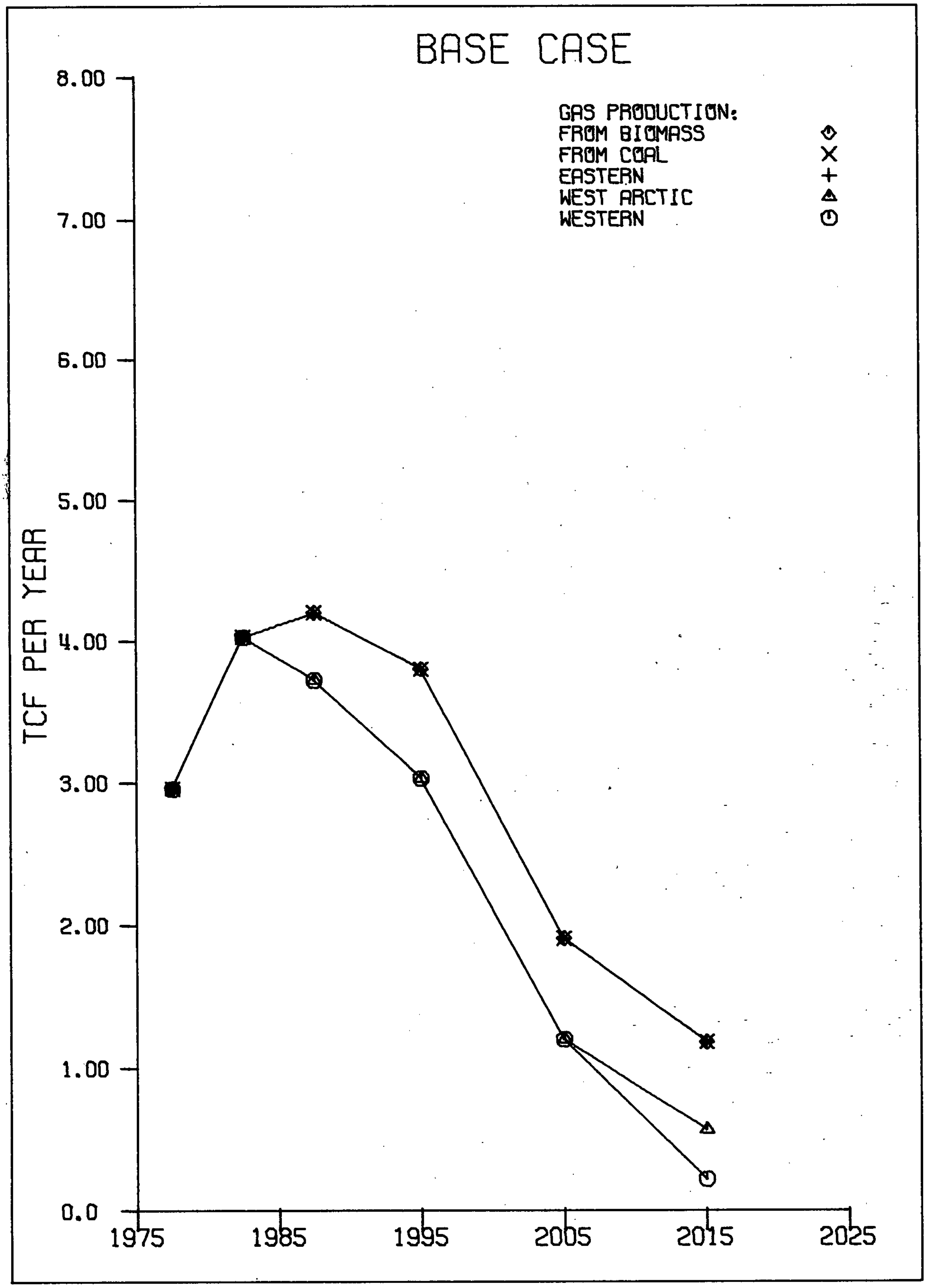

Figure 7. Gas Production, Base Case.

Table 7. Gas Use, Base Case.

```
             BASE CASE;          ;

GAS USE:
IN UNITS OF   TCF PER YEAR

         AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980    1985    1990    2000    2010    2020


EXPORTS;             1.0800  1.6800  0.7400  0.0300  0.0000  0.0000
INDUSTRY;            0.5497  0.6120  0.7909  0.7988  0.5928  0.7733
DFC;                 0.7996  1.0851  2.0334  2.4460  1.1395  0.3158
ELECTRICITY;         0.1474  0.1382  0.1232  0.0805  0.0000  0.0000
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(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 8. Thus, the differences between the plotted lines are the entries in Table 7.)

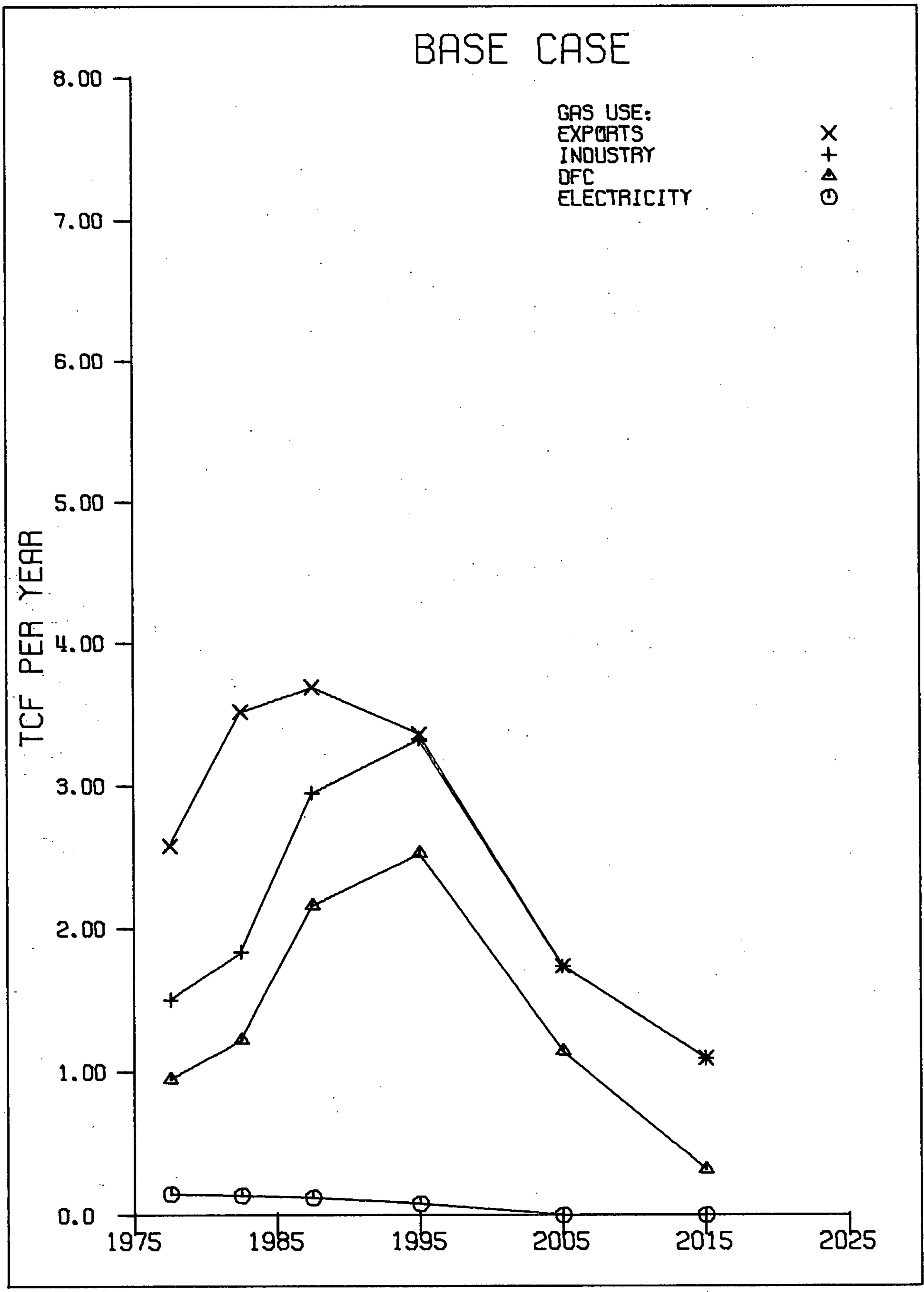

Figure 8. Gas Use, Base Case.

Table 8. Gas Prices, Base Case.

```
              BASE CASE;          :

GAS PRICES:
IN UNITS OF   1975$ PER MCF

         AVERAGE VALUES FOR THE PERIOD ENDING IN

                         1980    1985    1990    2000    2010    2020


EAST,AT TORONTO;       2.1488  2.5052  1.9103  2.1086  3.0005  3.0005
WEST, WELLHEAD;        0.9194  0.9653  1.0227  1.4741  2.2610  2.5003
Corrected, Toronto;    1.48      1.53    1.60    2.11    3.00    3.00
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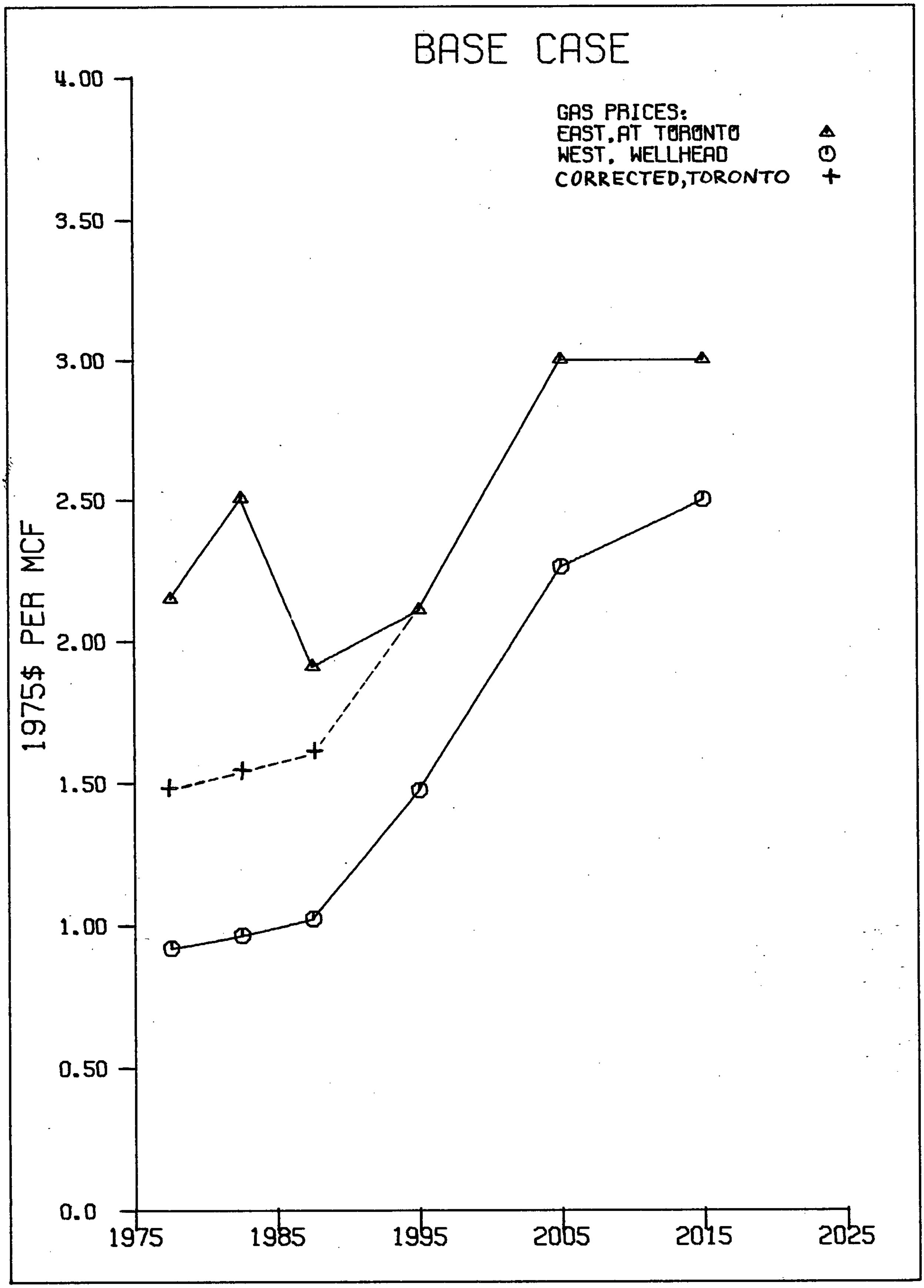

Figure 9. Gas Prices, Base Case.

of fuel shares in industry.) Exports continue to be very large in the first two periods, but decline to zero by the turn of the century. Exports are at the exogenous upper limits, which represent existing approved exports, as reported by the NEB (1979).

Wellhead prices for gas in the west (Figure 9) rise quite smoothly from \$.92/mcf in the first period to \$2.50/mcf after 2010. The latter price is the cost of "low cost" gas from the western arctic, which comes into use after 2010 for the first time. Toronto city-gate prices are more volatile than western prices, with quite high prices in the first two periods, followed by a drop, then a rise to \$3.00/mcf after 2000, when northeastern offshore gas (costing \$3.00/mcf) first comes into use. A large component of the eastern price in the first three periods is due to the binding upper limit on WGE, gas transported from west to east, in these periods. This limit, which is increased at the rate of 3.5% per year in the first two periods (from its level in 1971-1975) and by a larger amount in the third period, is intended to represent the initial inaccessibility of gas to points east of Montreal, followed by an extension of the pipeline to Quebec and the Maritimes during the third period, from 1986-1990. There is no upper limit on WGE after the third period. This method of representing the inaccessibility of gas to part of the east has the drawbacks that the model behaves as if consumers in all of the eastern region have access to gas distribution lines and as if equipment that uses gas is spread evenly over the entire region. The imposed supply shortage forces the price up and drives some gas "users" to alternate fuels. Of course, there will be no gas distribution lines in the region in question for several years, at least, and there will be no gas-using equipment there until then. A more theoretically pleasing procedure to represent the situation would involve the distinction of a third region which has no gas-using equipment in the end-use sectors and secondary electricity, and which shrinks in some way to represent the extension of the gas pipeline and gradual market penetration of gas. However, such a procedure would introdue great complexities. A simpler procedure is the present model formulation, together with the recognition that the component of the eastern price which is due to the upper limit on WGE is artificial and should be removed. This price component reflects an artificial, unsatisfied demand for gas in the model from points east of Montreal. The corrected Toronto city-gate gas price is given in Table 8, according to this approximation to the more theoretically exact type of model discussed above.

The corrected price for gas at Toronto in the first period (whose representative year is 1978) agrees well with the Toronto city-gate prices in 1978 reported by Helliwell (1979). If the corrected price is inflated by the increase in the Consumer Price Index between 1975 and 1978 (26%), reported by the Economic Council of Canada (1979), the price in 1978, in 1978$, is $1.87/mcf. The actual Toronto city-gate prices in 1978, reported by Helliwell (1979) were $1.68/mcf during January, $1.85/mcf beginning on February 1, and $2.00/mcf beginning on August 1.

The Department of Energy, Mines and Resources (1976a) has stated a policy of moving domestic natural gas prices to an "appropriate competitive relationship with oil". What is this relationship, according to the base case results of this model? The following table shows the prices of natural gas in the west and east (corrected as above), as percentages of the prices of crude oil, where prices are initially expressed in dollars per million BTUs, using the conversion factors: 1 mcf gas = 1.04 MMBTU, and 1 bbl oil = 5.8 MMBTU. The crude oil prices were taken to be the national wellhead prices calculated in section 6.1 of this chapter, for the west, and the same prices for the east, adjusted upward by the cost of transporting oil from west to east ($.50/bbl).

Table 9. Gas Prices as Percentages of Oil Prices

Period Ending	1980	1985	1990	2000	2010	2020
East	103%	84%	98%	131%	151%	134%
West	68%	56%	66%	97%	119%	116%

Apparently the "appropriate competitive relationship" should be different in the two regions. According to this analysis, gas in the east should be priced about equivalently with oil until 1990 but significantly higher than oil after 1990. However, in the west, gas should be priced considerably below the equivalent oil price until 1990 (perhaps 2/3 of the oil price, roughly), but the price should move to somewhat higher than the oil price after the year 2000. The higher price ratio in the east may be largely explained by the fact that the west-to-east transport cost is a much greater fraction of the eastern gas price than of the eastern oil price (the transport costs are $.44/mcf and $.50/bbl). Thus, the conclusion that the "appropriate competitive relationship" should be different in the two regions is simple to understand, but it may not have been obvious without the "prompting" of the model results.

It is now apparent why there is no gas from coal in the base case solution. Using the price of coal in the solution, the assumed distribution margin for coal used in gasification, and the assumed conversion efficiency and cost, the cost of gas from coal would be $3.00/mcf. Since the price of gas in the west (the only region in which gasification is allowed) only reaches $2.50/mcf over the time span of the model, coal gasification is uneconomic.

Coal gasification could therefore be introduced some time after 2020, when the western arctic gas costing $2.50/mcf nears depletion. Note that $1.41/mcf of the $3.00/mcf cost is due to the assumed margin for the distribution of coal to industry, which is also applied to coal for gasification. However, even if this margin were zero (for a mine-mouth plant, say), coal gasification would not be economic until after 2000, given the western gas prices from the base case solution. In the long run, though, coal gasification could play the role of a backstop technology for gas, because of the huge size of the coal reserves.

6.3. Coal

Coal production (Figure 10) rises quite significantly over the time span of the model. Eastern coal imports decline to zero after 1985, when a combination of eastern coal production and shipments from the west becomes sufficient to meet eastern demand. There is a strong and growing demand in the east for western coal, through all time periods. Eastern "low-cost" coal is depleted by 2020, but western "low-cost" coal is far from depletion.

Eastern use of coal (Figure 11) for electricity drops to zero after 2000, but in the west, coal used for electricity production grows gradually until 2010, and sharply after that. The combined effect on total use of coal for electricity in both regions is a temporary drop in the period ending in 2010, followed by an increase. After 2000, there is cogeneration of heat for space heating from coal-fired electricity production in the west. The sharp increase, after 2010, in coal used for electricity in the west is related to the substitution of cogeneration for gas heating in the DFC sector (Figure 23)., There is no coal used for liquefaction or gasifaction. In later periods, after 1990, industry is the biggest coal user, in both regions. Exports increase at the rate of 5% per year, which is the exogenous

Table 10. Coal Production, Base Case.

```
              BASE CASE;            ;

COAL PRODUCTION:
IN UNITS OF   10**8 TONS PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                    1980     1985     1990     2000     2010     2020


IMPORTS;           0.1581   0.1473   0.0000   0.0000   0.0000   0.0000
EASTERN;           0.0482   0.0964   0.1928   0.3453   0.3267   0.2070
WESTERN;           0.2646   0.3748   0.5026   0.9075   1.3324   2.3532
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 10. Thus, the differences between the plotted lines are the entries in Table 10.)

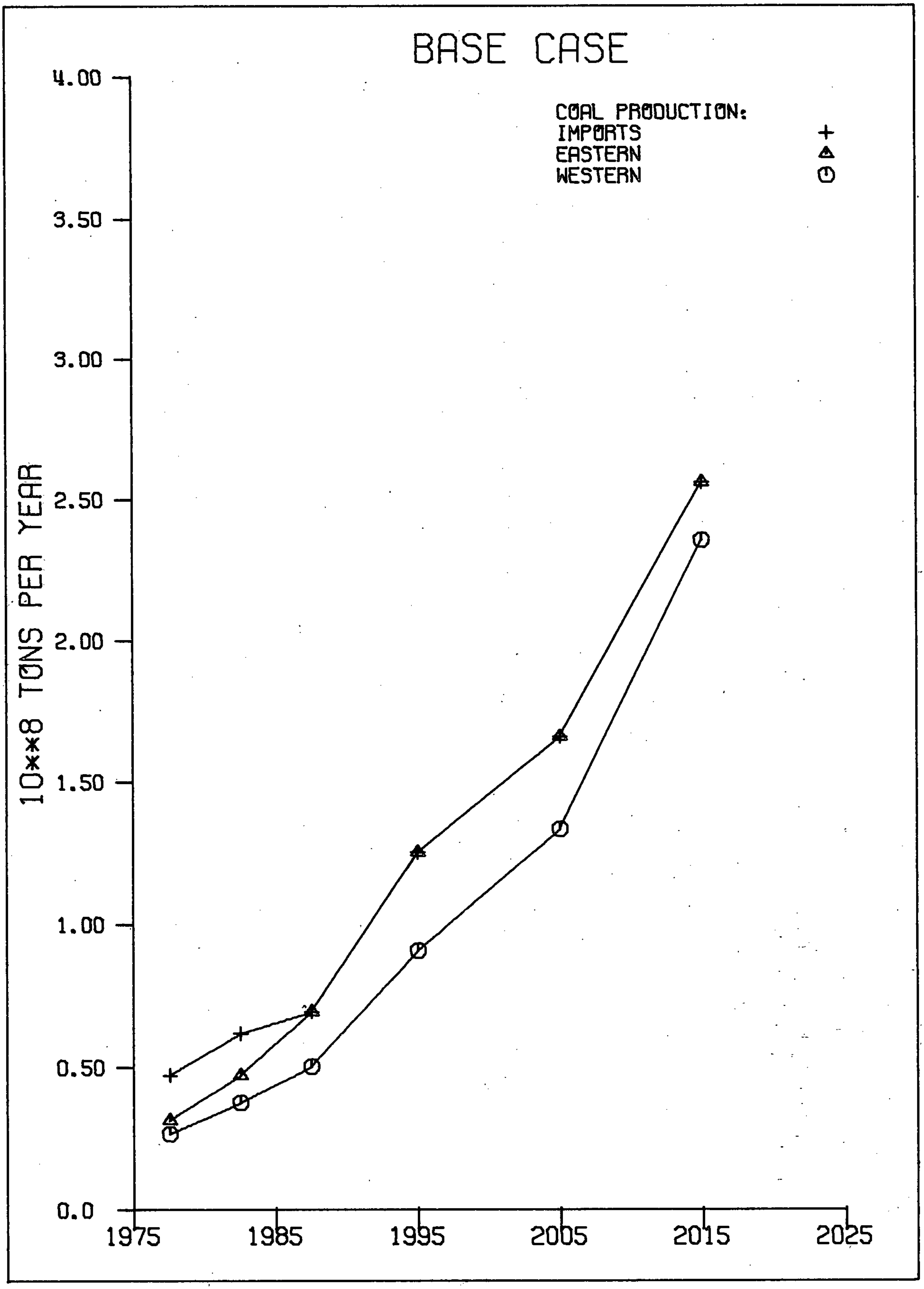

Figure 10. Coal Production, Base Case.

Table 11. Coal Use, Base Case.

```
             BASE CASE;              ;

COAL USE:
IN UNITS OF    10**8 TONS PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                        1980     1985     1990     2000     2010     2020


EXPORTS;               0.1619   0.2095   0.2667   0.4381   0.7048   1.1524
SYNFUELS;              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
INDUSTRY;              0.1325   0.2321   0.2545   0.6514   0.8273   1.0793
ELECTRICITY;           0.1763   0.1765   0.1739   0.1626   0.1260   0.3270
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 11. Thus, the differences between the plotted lines are the entries in Table 11.)

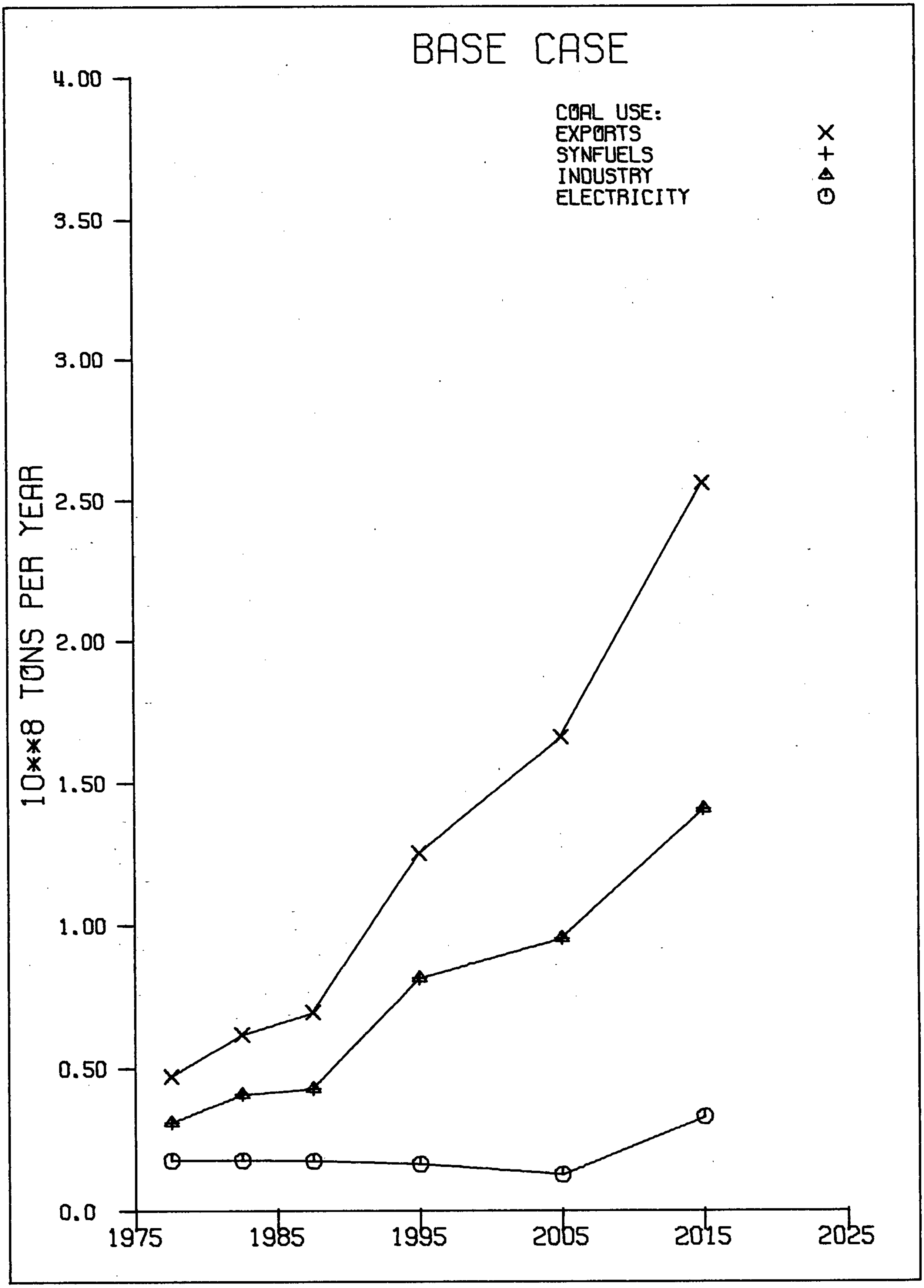

Figure 11. Coal Use, Base Case.

Table 12. Coal Prices, Base Case.

```
               BASE CASE;          ;

COAL PRICES:
IN UNITS OF   1975$ PER TON

         AVERAGE VALUES FOR THE PERIOD ENDING IN

                        1980    1985    1990    2000    2010    2020


EAST,AT TORONTO; 32.5514 36.7489 35.6156 25.8355 25.8355 25.8355
WEST, AT MINE;    4.1983  4.1983  4.1983  4.1983  4.1983  4.1983
```

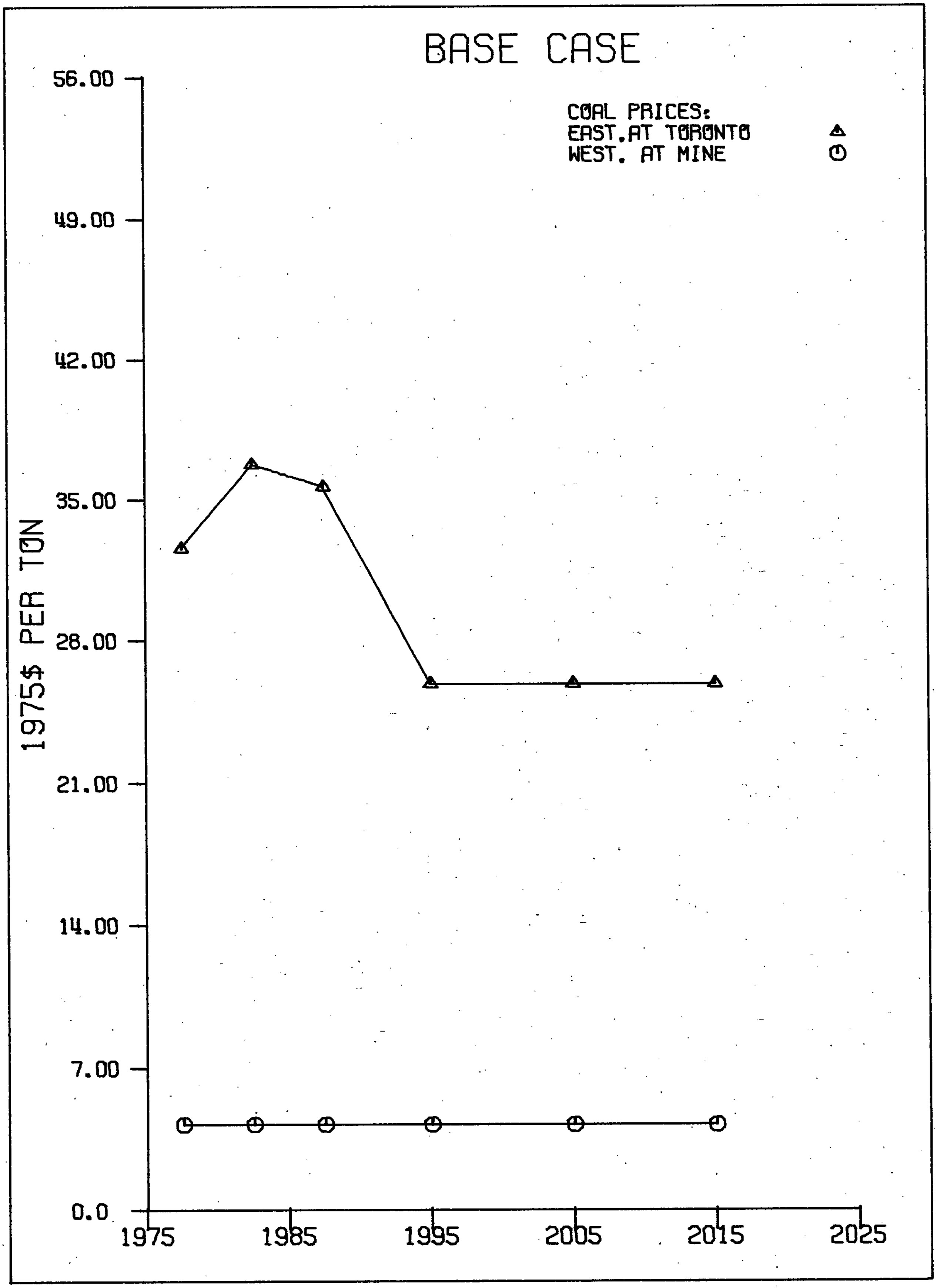

Figure 12. Coal Prices, Base Case.

upper limit.

Coal prices (Figure 12) in the west are at the "low-cost" in all time periods, because the "low-cost" coal is not depleted, even including production in the extra period which mitigates end effects. After 1990, eastern coal prices are equal to the "low-cost" of western coal, plus the cost of transporting coal from west to east. Before 1990, there is a bulge in eastern coal prices due to the (binding) upper limit placed on WCE, the quantity of coal shipped from west to east, in the first three periods. These upper limits are intended to represent the capacity of the coal-handling facilities at Thunder Bay on Lake Superior.

6.4. Electricity

Production of electricity (Figures 13,14) from oil and gas is phased out by the turn of the century in both regions. The bulk of electricity in the west is produced from hydro power, with the remainder (except for electricity from oil and gas in the first four periods) produced from coal. The production of hydroelectricity never reaches its exogenous maximum before 2020 in the west, but the eastern maximum is reached after 1990, forcing an increasingly heavy reliance on nuclear power after the turn of the century. This may be interpreted to mean that after the turn of the century, Quebec and Newfoundland, with their James Bay and Labrador sites fully developed, will be forced to adopt a nuclear future, as Ontario has done. The rapid rise in generation in the west during the period after 2010 -- at the rate of 9.8% per year -- corresponds to a substitution of electricity for oil in western industry. The large increase in the east after 2000 -- at the rate of 8% per year in the period 2001-2010 -- corresponds to a switch from oil to electricity in eastern industry, and to a switch from gas heat to electric resistance in the eastern DFC sector. (See section 6.6 below for

Table 13. Western Electricity Production, Base Case.

BASE CASE; ;

ELECTRICITY, WEST:
IN UNITS OF 10**12 KWH PER YEAR

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
FROM BIOMASS;	0.0008	0.0008	0.0008	0.0004	0.0000	0.0000
NUCLEAR;	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
OIL AND GAS;	0.0086	0.0085	0.0075	0.0051	0.0000	0.0000
COAL;	0.0126	0.0147	0.0170	0.0235	0.0295	0.0764
HYDRO;	0.0506	0.0522	0.0548	0.0677	0.0877	0.2224

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 13 . Thus, the differences between the plotted lines are the entries in Table 13.)

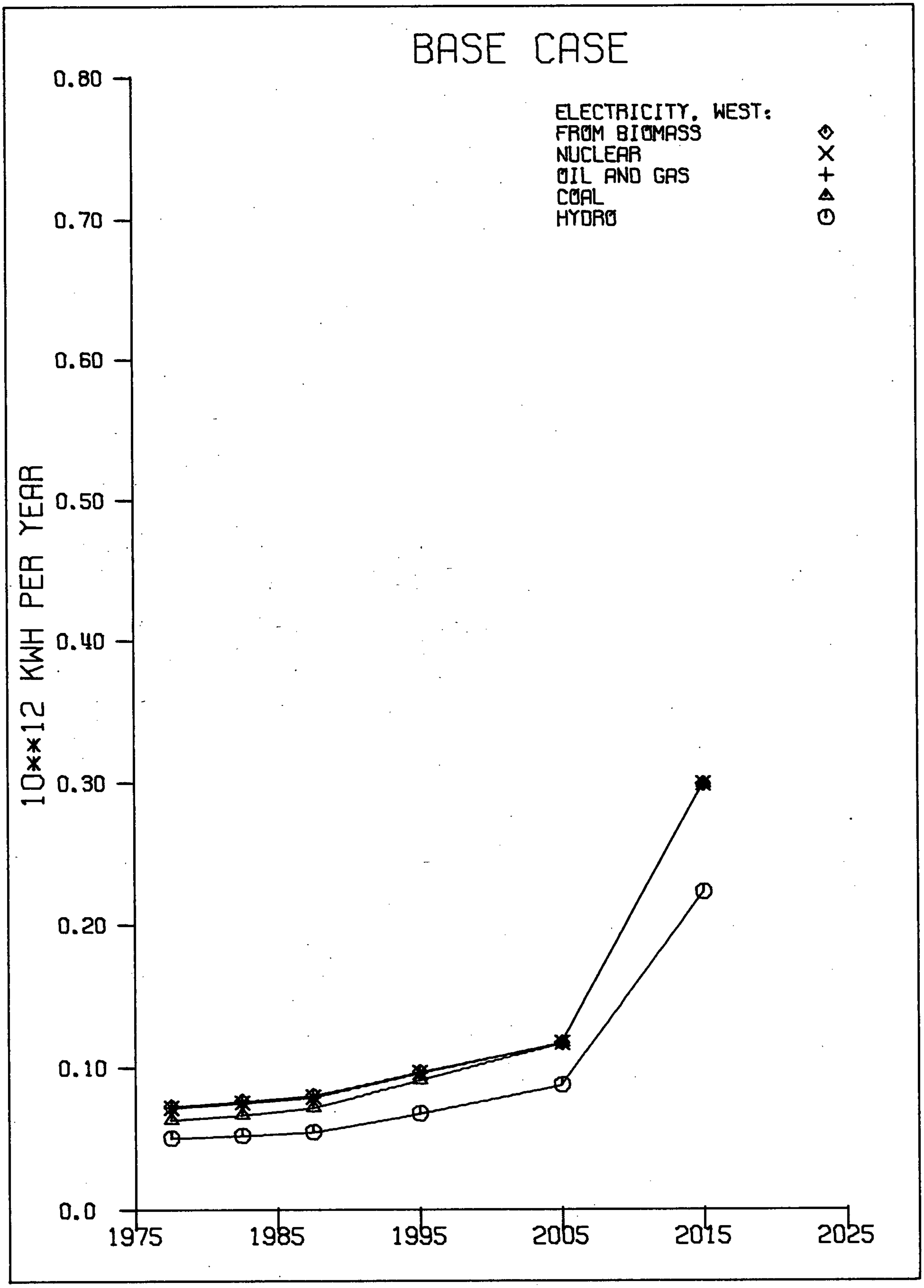

Figure 13. Western Electricity Production, Base Case.

Table 14. Eastern Electricity Production, Base Case.

```
             BASE CASE;          ;

ELECTRICITY, EAST:
IN UNITS OF   10**12 KWH PERYEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                    1980    1985    1990    2000    2010    2020

FROM BIOMASS;     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
NUCLEAR;          0.0201  0.0509  0.0726  0.1216  0.8277  1.0650
OIL AND GAS;      0.0124  0.0128  0.0117  0.0076  0.0000  0.0000
COAL;             0.0228  0.0223  0.0205  0.0145  0.0000  0.0000
HYDRO;            0.1666  0.2620  0.3220  0.4420  0.4420  0.4420
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 14. Thus, the differences between the plotted lines are the entries in Table 14.)

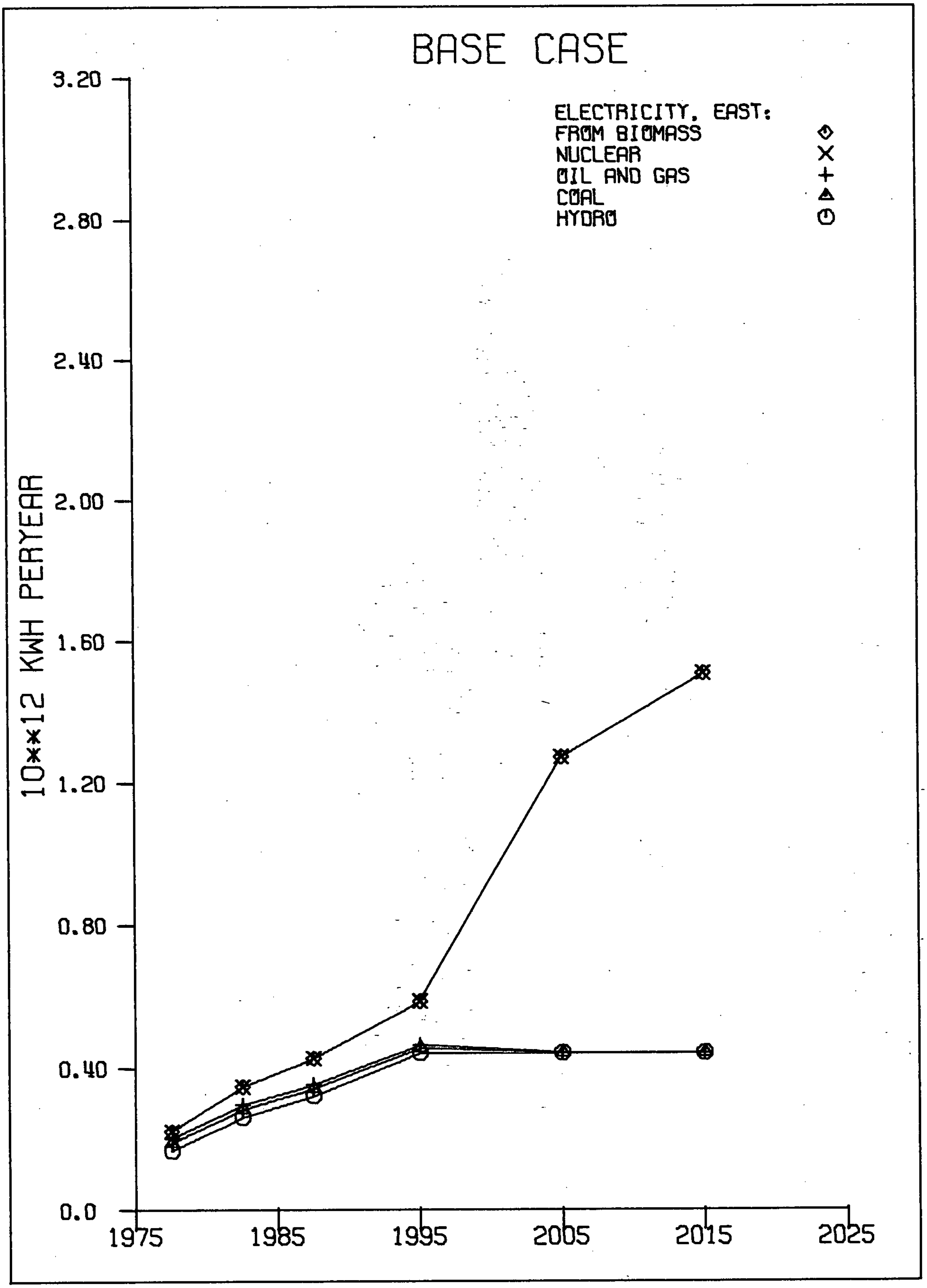

Figure 14. Eastern Electricity Production, Base Case.

Table 15. Electricity Use, Base Case.

```
          BASE CASE;              ;

ELECTRICITY USE:
IN UNITS OF   10**12 KWH PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                    1980     1985     1990     2000     2010     2020


EXPORTS;           0.0099   0.0104   0.0110   0.0120   0.0133   0.0147
ELECTRIC AUTO;     0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
INDUSTRY;          0.1164   0.1927   0.2849   0.2537   0.6327   0.9632
DFC;               0.1411   0.1828   0.1662   0.3563   0.6267   0.6778
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 15. Thus, the differences between the plotted lines are the entries in Table 15.)

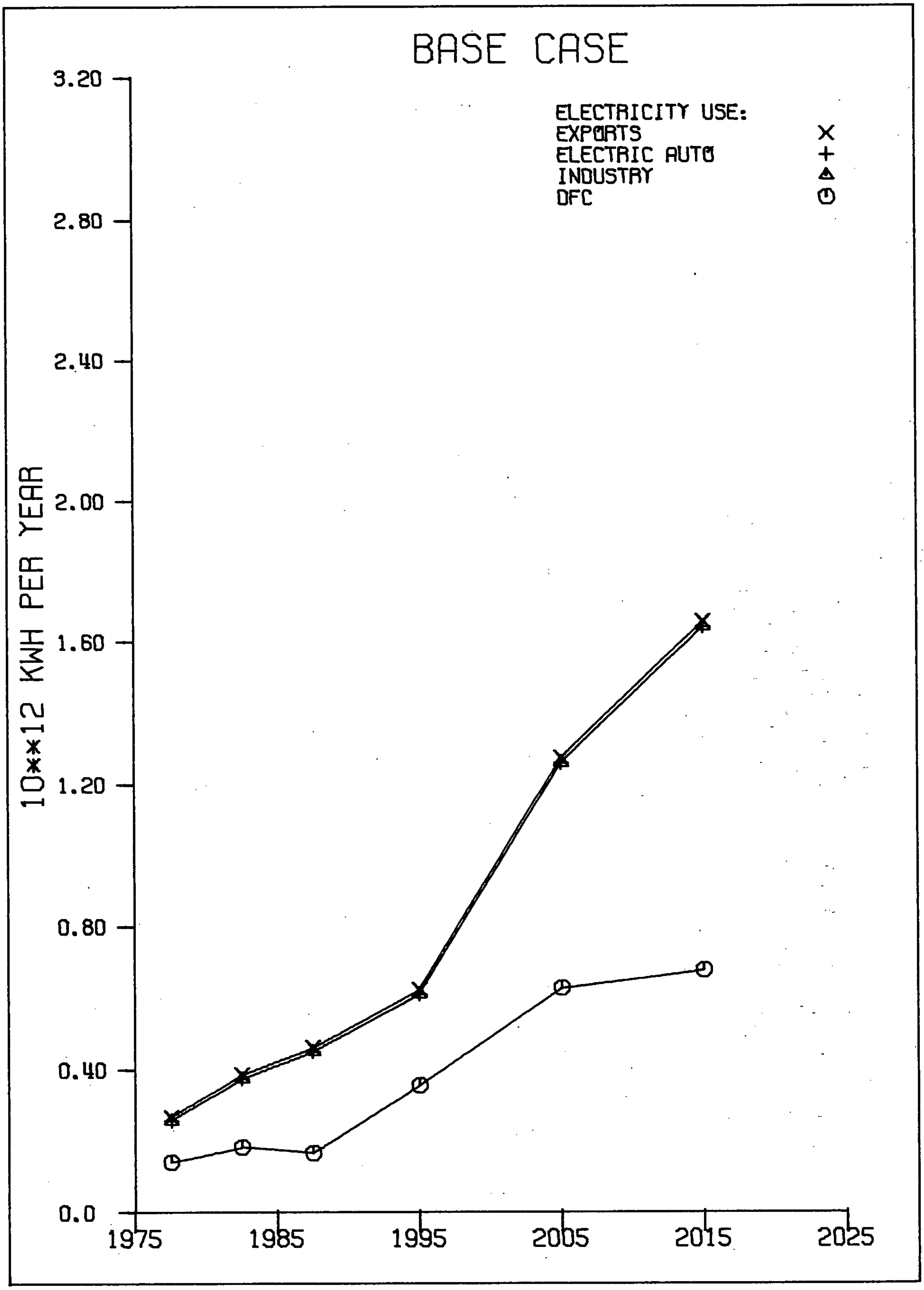

Figure 15. Electricity Use, Base Case.

Table 16. Western Electricity Prices, Base Case.

```
             BASE CASE;          ;

WEST ELECTRIC PRICES
IN UNITS OF   1975 CENTS PER KWH

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980    1985    1990    2000    2010    2020


DFC;                2.4623  2.4575  2.4560  2.4680  2.4255  2.4072
ROAD TRANSPORT;     1.9423  1.9375  1.9360  1.9480  1.9055  1.8872
INDUSTRY;           1.0923  1.0875  1.0860  1.0980  1.0555  1.0372
```

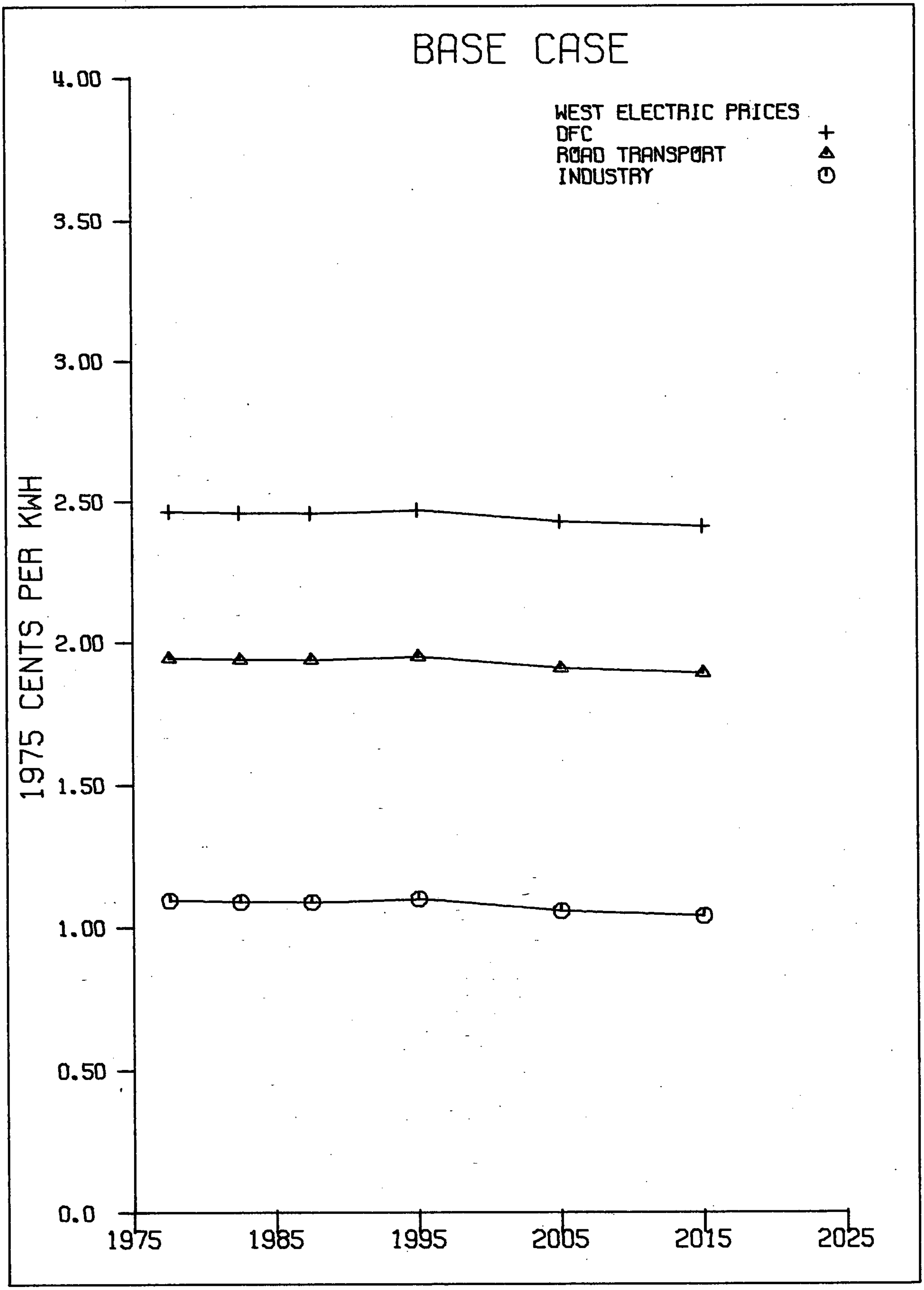

Figure 16. Western Electricity Prices, Base Case.

Table 17. Eastern Electricity Prices, Base Case.

```
              BASE CASE;             ;

EAST ELECTRIC PRICES
IN UNITS OF   1975 CENTS PER KWH

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980     1985     1990     2000     2010     2020


DFC;                 2.4514   2.5024   2.4724   2.4588   2.6318   2.6318
ROAD TRANSPORT;      1.9314   1.9824   1.9524   1.9388   2.1118   2.1118
INDUSTRY;            0.8014   0.8524   0.8224   0.8088   0.9818   0.9818
```

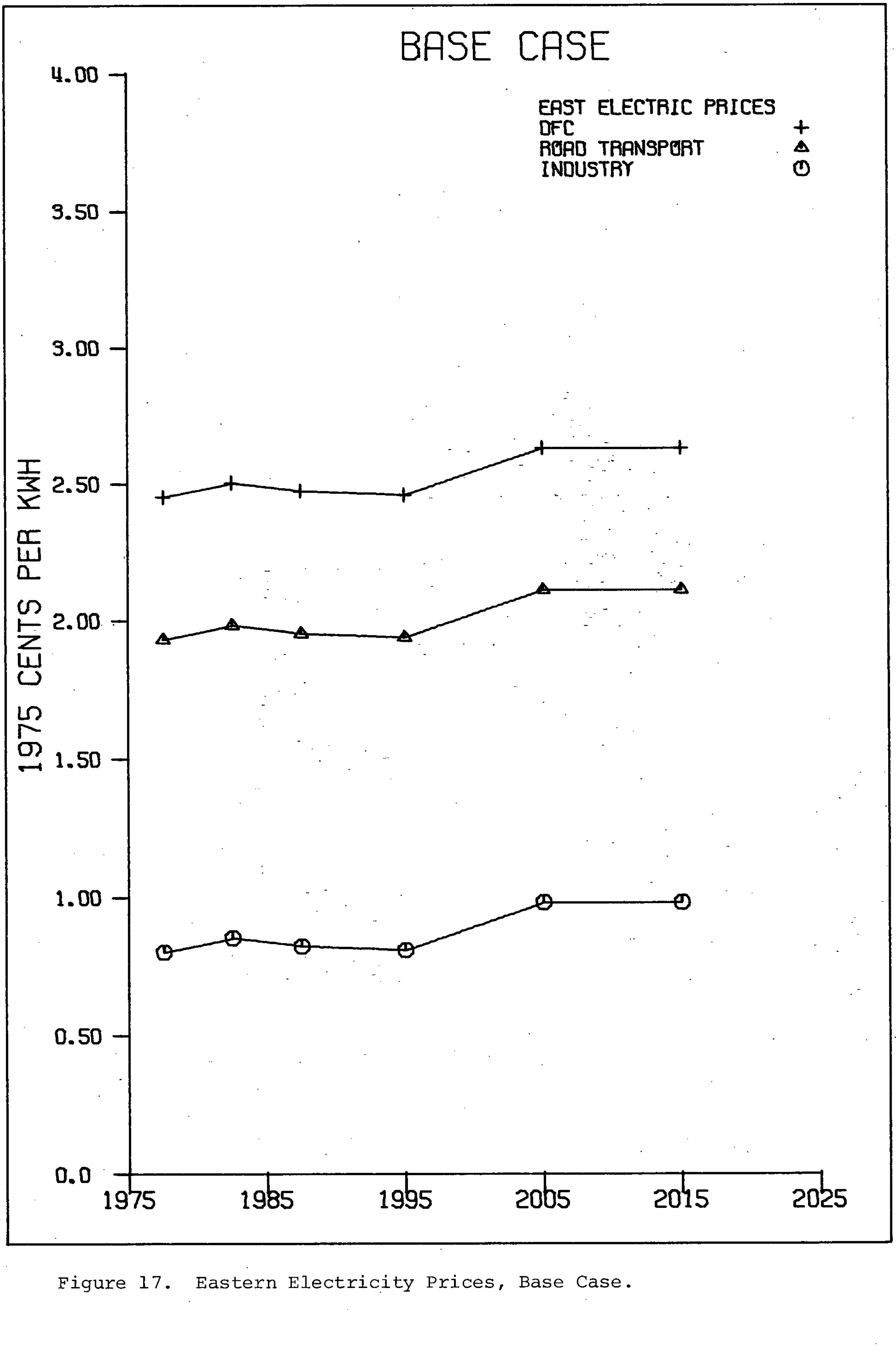

Figure 17. Eastern Electricity Prices, Base Case.

a discussion of industrial fuel use in the model.)

The use of electricity (Figure 15), except for exports, grows at an average rate of 5.2% per year between 1978 and 1995 (the representative years of the first and fourth periods, respectively), and at 5.1% per year between 1995 and 2015. Electricity exports from the two regions are at the exogenously specified levels, increasing at the rate of 1% per year. There is a quickly growing demand for electricity in industry. The growth in electricity demand from the DFC sector is quite strong after 2000, when there is a switch from gas heat to electric resistance and solar in the east. The growth in DFC demand slackens somewhat after 2010, when solar heating becomes quite important in the east. It might be noted that self-generation of electricity by industry is not explicitly allowed in the structure of the model. However, the margins allowed in the model for the distribution of electricity to the industrial sectors are very small (1.8 mills/kwh in the west, and -1.0 mills/kwh in the east) compared to the generation costs and to the margins for distribution to the other sectors. Therefore, to minimize the size of the model, the possibilities of industrial self-generation of, say,hydroelectricity or electricity from wood waste, were included in the appropriate electricity variables as if such electricity originated from the utilities.

Electricity prices (Figures 16,17) are stable in both regions. The cost of nuclear power (1 cent per kwh) becomes the determining element of eastern electricity prices after 2000, when hydroelectric production is at its maximum.

6.5. Transportation

In the road transportation sector (Figure 18), the use of output energy

Table 18. Transportation, Base Case.

```
               BASE CASE;            ;

TRANSPORTATION:
IN UNITS OF   10**15 BTU PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980     1985     1990     2000     2010     2020


OTHER TRANSPORT;   0.0908   0.1046   0.1272   0.1708   0.2196   0.2813
ROAD,ELECTRIC;     0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
ROAD, GASOLINE;    0.2879   0.3399   0.4165   0.5425   0.7069   0.9880
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 18. Thus, the differences between the plotted lines are the entries in Table 18.)

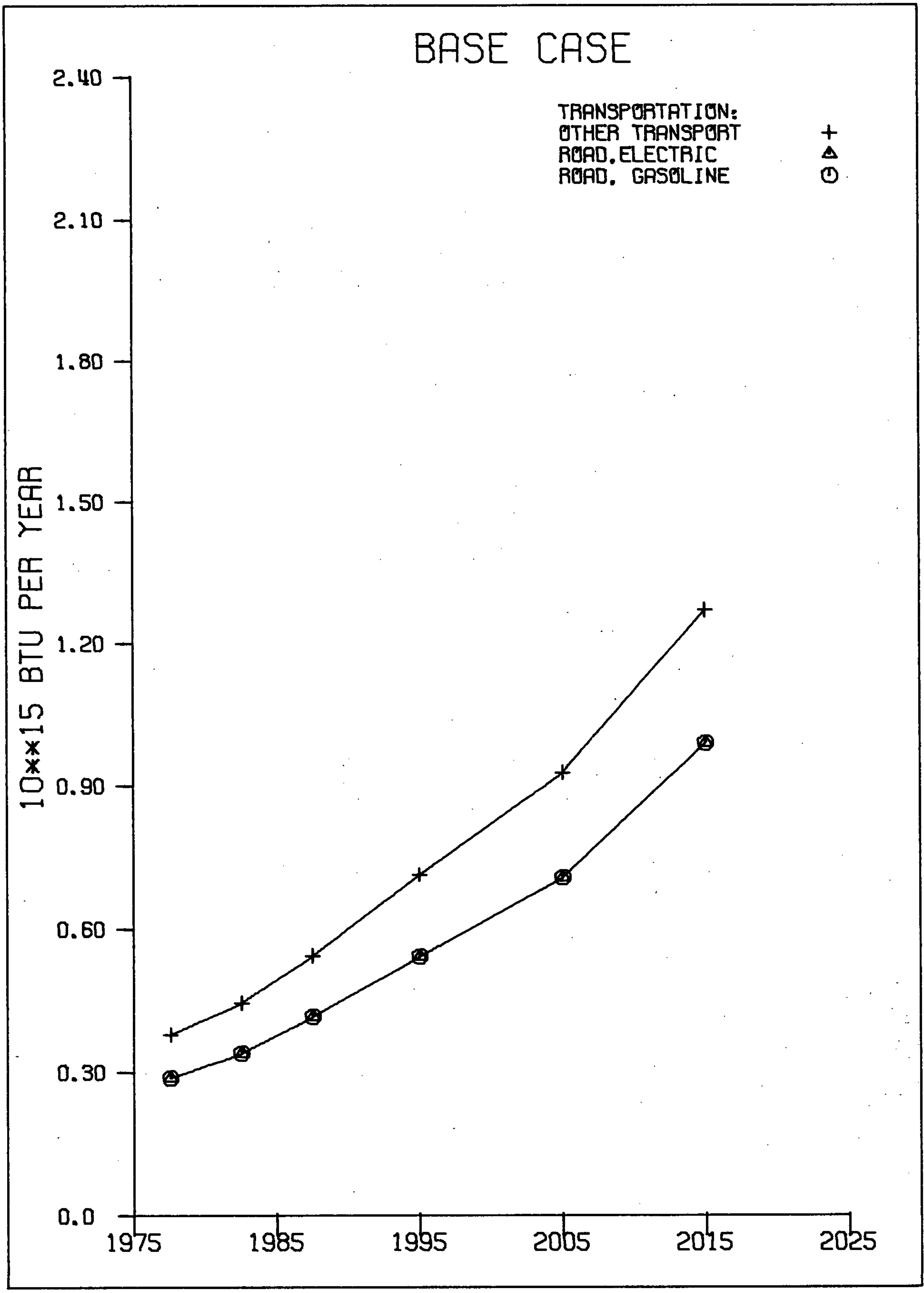

Figure 18. Transportation, Base Case.

Table 19. Western Output Energy Prices, Base Case.

```
             BASE CASE;              ;

OUTPUT PRICES, WEST:
IN UNITS OF   INDEX (1970=1)

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                        1980      1985      1990      2000      2010      2020


OTHER TRANSPORT;      1.0991    1.3262    1.3195    1.2281    1.3519    1.4613
ROAD TRANSPORT;       0.8134    0.7503    0.6433    0.5458    0.5140    0.5399
INDUSTRY;             1.2587    1.3703    1.3654    1.4491    1.6918    1.7706
DFC;                  1.0307    1.0418    1.0576    1.1730    1.3776    1.4077
```

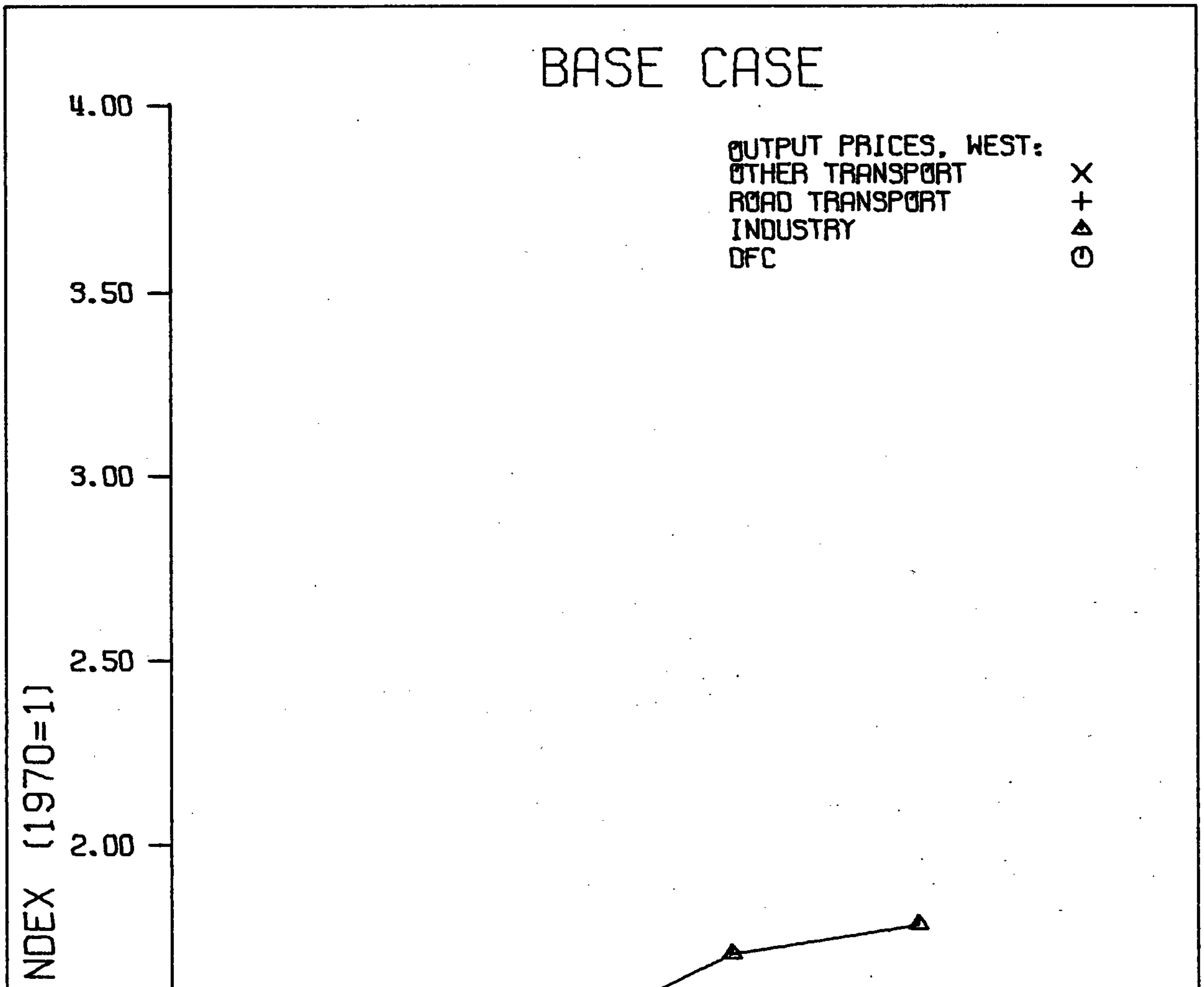

Figure 19. Western Output Energy Prices, Base Case.

Table 20. Eastern Output Energy Prices, Base Case.

```
              BASE CASE;            ;

OUTPUT PRICES, EAST:
IN UNITS OF   INDEX (1970=1)

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                    1980     1985     1990     2000     2010     2020


OTHER TRANSPORT;  1.3245   1.4658   1.3348   1.2421   1.3700   1.4825
ROAD TRANSPORT;   0.9152   0.8028   0.6544   0.5554   0.5207   0.5456
INDUSTRY;         1.5848   1.8146   1.6484   1.5390   1.8249   1.8502
DFC;              1.2706   1.3602   1.1936   1.2779   1.3743   1.3710
```

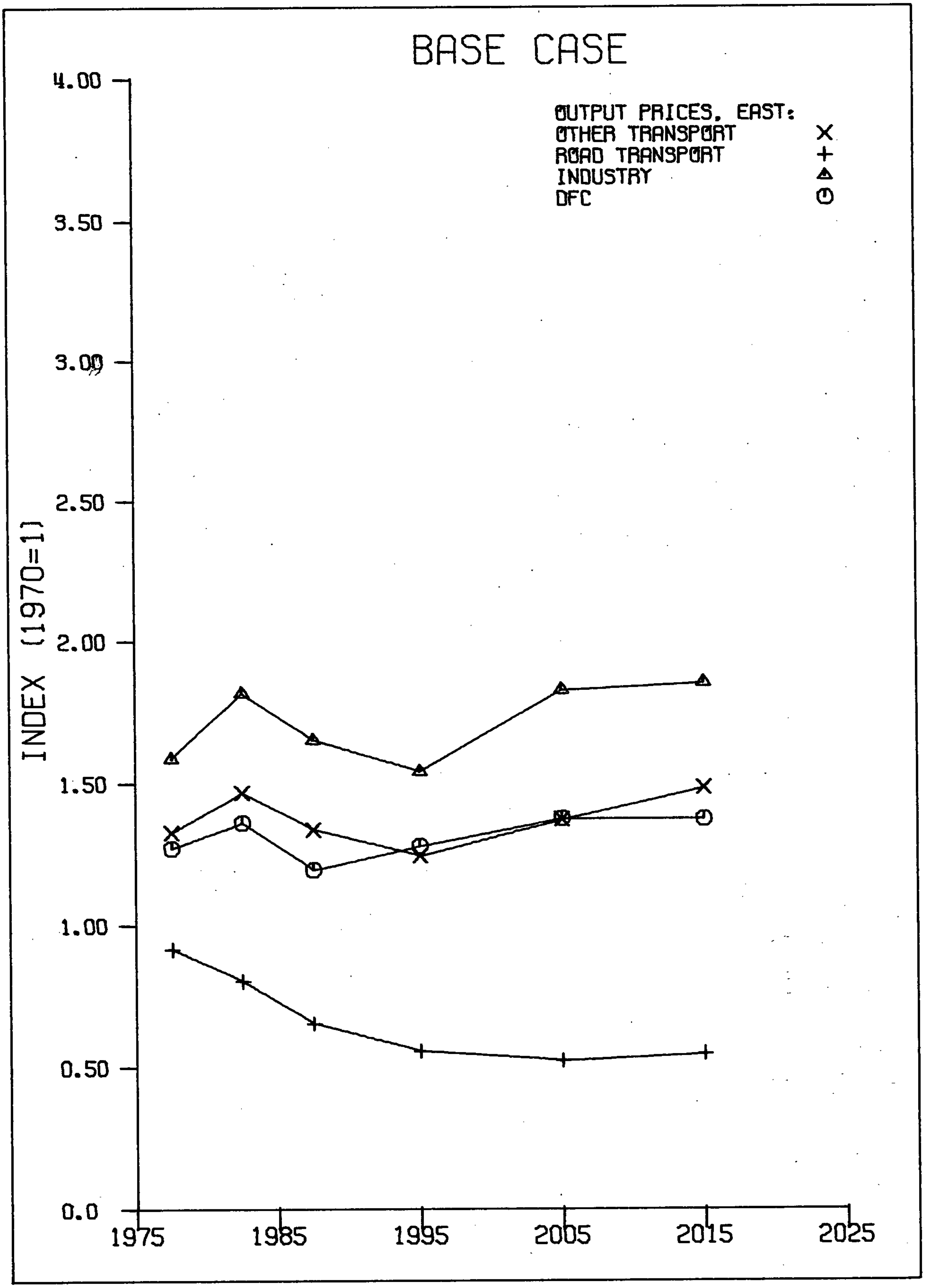

Figure 20. Eastern Output Energy Prices, Base Case.

(which may be interpreted as a measure of road transportation services performed) grows 3.8% per year between 1978 and 1995, and 3.0% per year between 1995 and 2015. This strong growth even in the face of rising oil prices can be explained by a look at the prices of energy in the road transportation sectors (Figures 19,20). Apparently the assumed rate of increase of automobile efficiency is more than enough to offset the effect of rising oil prices on the price of output energy (except for the last period). Although motorists will be paying more and more per gallon for fuel, they will be spending less and less per mile for fuel, according to the base case solution. Thus, even though population growth slows, the declining cost of road transportation encourages rapid growth in the total amount of driving which people do.

The electric automobile is not introduced in either region. The following chart shows the prices of output energy, in model units, in road transportation, using the conventional and the electric automobile. (The price for conventional is from the gradient of the objective function, with the discounting removed, while the electric price is derived from the electricity generation price, plus the distribution margin, converted to an output price, and added to the differential cost of the electric car.)

Table 21. Road Transportation Prices, Base Case.

Period Ending	1980	1985	1990	2000	2010	2020
West, conventional	1.8302	1.6882	1.4474	1.2282	1.157	1.2149
West, electric	n.a.	n.a.	2.1307	2.1357	2.1179	2.1103
East, conventional	2.1557	1.8908	1.5413	1.3083	1.2265	1.2850
East, electric	n.a.	n.a.	2.1376	2.1319	2.2043	2.2043

Two major elements in the price of road transportation by electric car are the road tax assumed to be placed on electricity for electric autos (equal to 0.4313 in the units of the above chart), and the extra initial cost of the electric automobile versus a conventional one (equal to 1.32 in the above units). According to the base case results, then, a substantial narrowing of the difference in the prices ($1,500 for subcompacts is assumed here) of the electric and conventional autos will be necessary, perhaps in combination with a lessening of the road tax for the electric alternative, if the electric auto is to be competitive. It is worth noting, too that the increasing efficiency of the conventional auto makes the electric auto (assumed to have a constant efficiency) less competitive.

In the "other" transportation sector (Figure 18) output energy grows at the rate of 3.8% per year between 1978 and 1995, and at 2.5% per year between 1995 and 2015. The slower growth in other transportation compared to road transportation is likely due to an assumed slower growth in efficiency, which offsets rising oil prices less than in road transportation. This is apparent from a glance at the price indices for other transportation (in Figures 19, 20).

6.6. Industry

The use of oil and gas in industry (Figure 21) peaks in the period 1991-2000. After 1990, coal becomes a very important source for industry, and after 2000, electricity plays the largest role of all the four fuels. Total output energy used in industry grows at the rate of 5.0% per year from 1978 to 1995, and at 2.6% per year from 1995 to 2015.

Output energy prices for industry (Figures 19,20) are somewhat erratic, particularly in the east, in part because any efficiency changes are due

Table 22. Industrial Output Energy, by Fuel, Base Case.

```
              BASE CASE;              ;

INDUSTRY:
IN UNITS OF   10**15 OUTPUT BTU/YR

         AVERAGE VALUES FOR THE PERIOD ENDING IN

                        1980    1985    1990    2000    2010    2020


ELECTRICITY;          0.3972  0.6575  0.9721  0.8656  2.1588  3.2864
COAL;                 0.2420  0.4240  0.4649  1.1901  1.5115  1.9719
GAS;                  0.4672  0.5202  0.6723  0.6790  0.5039  0.6573
OIL;                  0.6228  0.5014  0.7240  1.2324  0.8644  0.6571
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 21. Thus, the differences between the plotted lines are the entries in Table 22.)

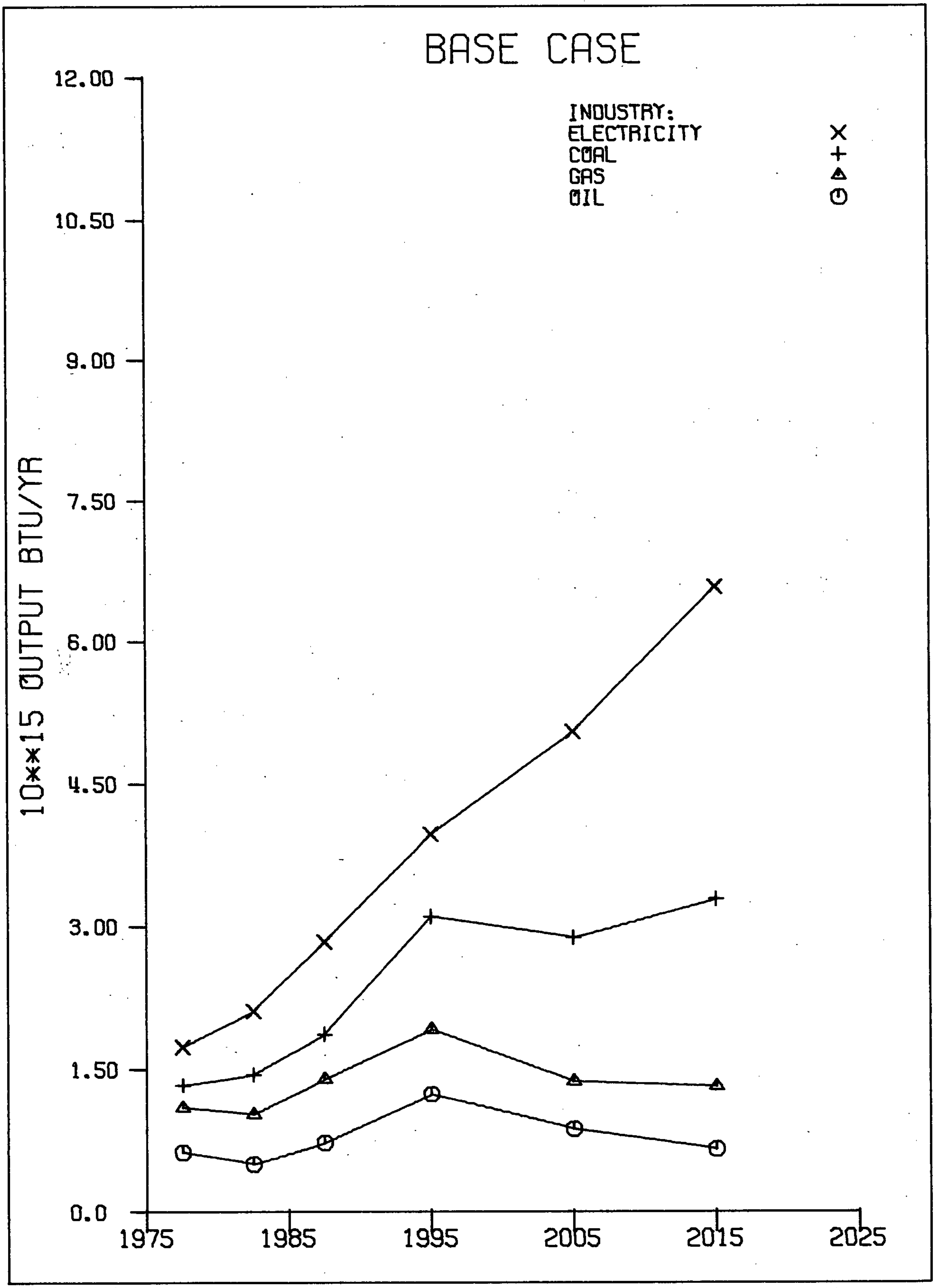

Figure 21. Industrial Output Energy, by Fuel, Base Case.

solely to the changing fuel mix, and because of the bulges in oil and gas prices in the first two periods in the east.

The somewhat erratic behaviour (ups and downs) of electricity, gas and oil use in industry is due to the model structure. There are upper and lower bounds on the shares of industrial output energy in the model. A lower bound indicates non-substitutable uses of the fuel. Above the lower bound, there is perfect inter-fuel substitutability, up to a point (the upper bound). These share bounds spread apart until 2000 and are constant after that. At the optimal solution, the industrial fuel mix in a period is the least cost mix, given all the optimal fuel prices. It is therefore not surprising to see the erratic behaviour of some fuels. Table 23 gives the calculated shares of the four fuels in industrial output energy, at the optimal solution of the base case.

Table 23. Shares of Fuels in Industrial Output Energy, Base Case.

(Note: The symbols "(L)" and "(U)" indicate the shares which are at their lower or upper bounds, respectively.)

		Period Ending					
Fuel	Region	1980	1985	1990	2000	2010	2020
Electricity	West	.23(L)	.22(L)	.21(L)	.2(L)	.2(L)	.5(U)
	East	.23(L)	.34(U)	.39	.22	.5(U)	.2(L)
Coal	West	.08(U)	.14(U)	.19(U)	.3(U)	.3(U)	.3(U)
	East	.16(L)	.22(U)	.16	.3(U)	.3(U)	.3(U)
Gas	West	.44	.43	.42	.4	.1(L)	.1(L)
	East	.21(L)	.19(L)	.18	.1(L)	.1(L)	.1(L)
Oil	West	.24(L)	.21(L)	.17(L)	.1(L)	.4	.1(L)
	East	.40(U)	.25(L)	.28	.38	.1(L)	.1(L)

The upper and lower bounds were taken from estimates by Hedlin, Menzies and Associates (1976) of <u>future technical possibilities</u> in the industrial sector. An alternative method of modelling fuel shares might involve econometric estimation of substitution parameters in a function giving industrial output energy for different fuel inputs. Although such an approach would likely produce smoother projections of fuel shares, it would be based on past technical possibilities, a serious drawback when making projections into the distant future. The best approach theoretically, would be to distinguish industrial output energy demand by major functional end uses, and to construct a process model of energy supply and use for these functional end use demands. This deficiency in the model's structure can likely be corrected only by a large effort in the categorization of industrial uses of energy, together with estimates of demand curves for these categories. Since there is apparently no reliable data in this area, the present formulation of the industrial sector of the model is the best possible now.

6.7. DFC Heating

Oil heating (Figures 22,23) is phased out as rapidly as possible in the west (zero after 1985). However in the east, there is new oil heating capacity installed in the first period, and oil heating is consequently phased out later in the east than in the west (zero after 1990). Gas heating plays a big role in the west until 2010, and in the east until 2000. Depletion of the low cost reserves, and the rising gas prices make alternative fuels more economical after these dates. Electric resistance heating is phased out quickly in the west (zero after 1985), in favour of gas, and later cogeneration and solar, but it plays an increasingly important role in the east, becoming the single most important heating source in the east after 2000, when gas becomes too expensive.

Heating by cogeneration with coal-fired electricity production is used in the west after 2000 (the model allows it after 1980), but not at all in the east because cogeneration with nuclear electricity production is not allowed in the base case, and because there is no new coal-fired electricity capacity

Table 24. DFC Heating, West, Base Case.

```
             BASE CASE;              ;

DFC HEATING, WEST:
IN UNITS OF   10**15 OUTPUT BTU/YR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980     1985     1990     2000     2010     2020


SOLAR;               0.0000   0.0000   0.0000   0.0000   0.0000   0.3461
COGENERATION;        0.0000   0.0000   0.0000   0.0000   0.0497   0.2379
HEAT PUMP;           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
ELECTRIC RESIS.;     0.0478   0.0293   0.0000   0.0000   0.0000   0.0000
GAS;                 0.3082   0.4207   0.5525   0.6198   0.6291   0.2400
OIL;                 0.0782   0.0384   0.0000   0.0000   0.0000   0.0000
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 22. Thus, the differences between the plotted lines are the entries in Table 24.)

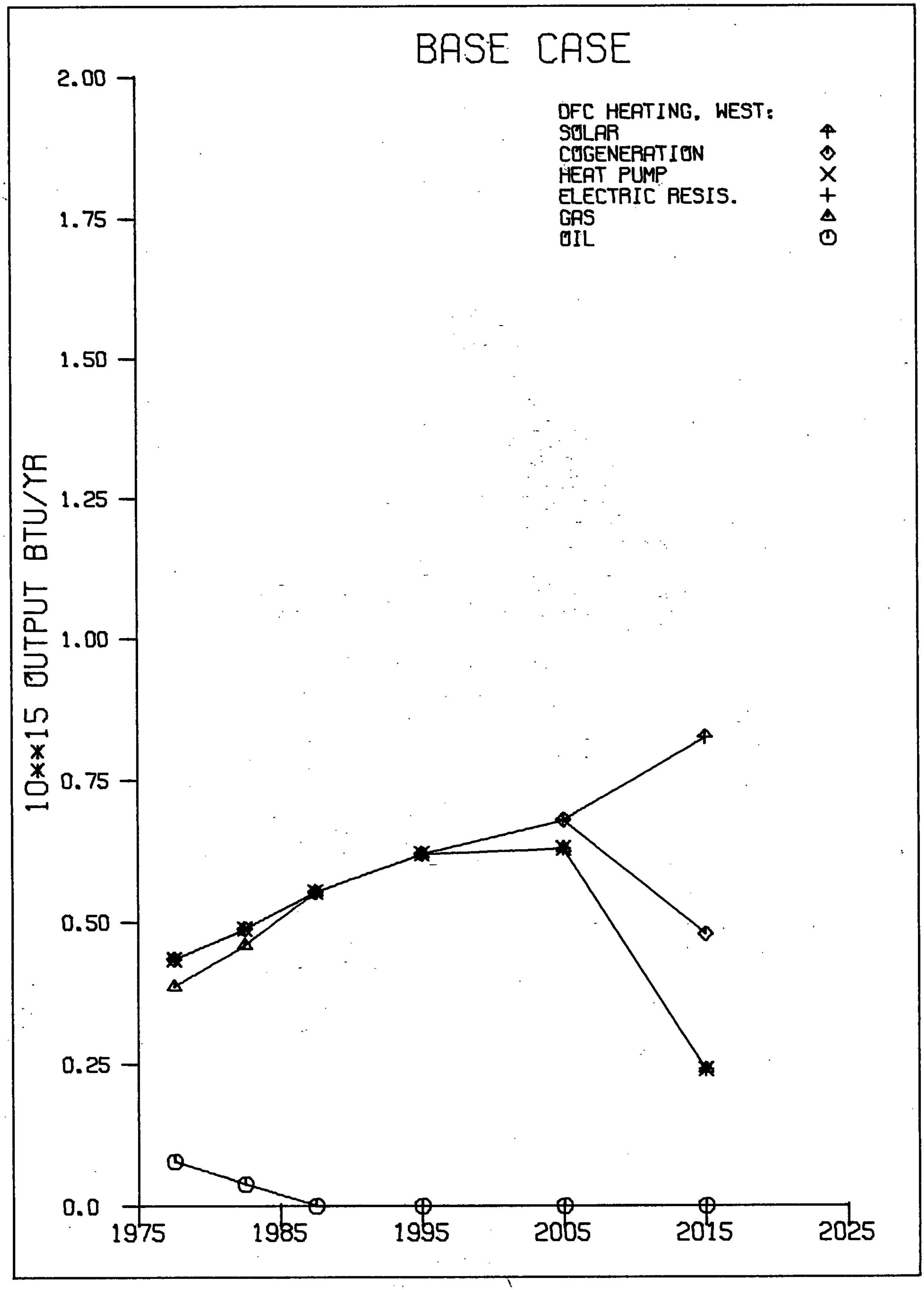

Figure 22. DFC Heating, West, Base Case.

Table 25. DFC Heating, East, Base Case.

```
              BASE CASE;            ;

DFC HEATING, EAST:
IN UNITS OF   10**15 OUTPUT BTU/YR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980    1985    1990    2000    2010    2020


SOLAR;              0.0000  0.0000  0.0000  0.0000  0.5048  1.2496
COGENERATION;       0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
HEAT PUMP;          0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
ELECTRIC RESIS.;    0.1570  0.2975  0.2040  0.8042  1.6616  1.7254
GAS;                0.2995  0.4039  0.9929  1.2392  0.2369  0.0000
OIL;                0.8978  0.7313  0.6002  0.0000  0.0000  0.0000
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 23. Thus, the differences between the plotted lines are the entries in Table 25.)

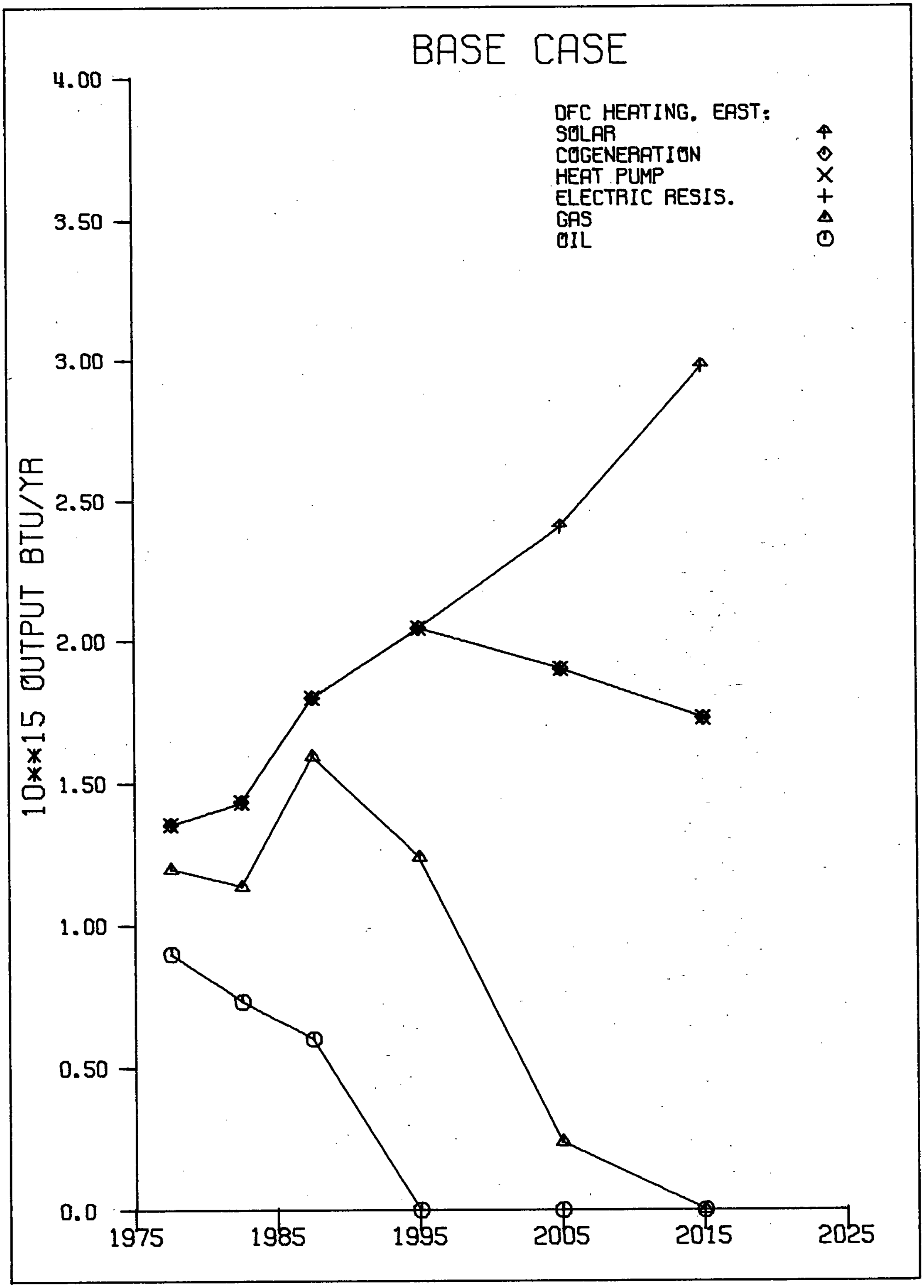

Figure 23. DFC Heating, East, Base Case.

established in the east. The heat pump is not in the solution in either region.

Solar heating is used in the west to its maximum allowed share after 2010, but is at the zero level before 2010. Solar is at its maximum share after 2000 in the east (when electricity prices increase significantly), and zero before then. In both the west and east, solar heating is allowed by the model constraints after 1980.

How close does the heat pump come to being competitive? Table 26 shows what the output energy heating costs would be for the heat pump in the west and east, given the electricity prices calculated in the base case, and all of the assumed conversion efficiencies and costs.

Table 26. Heat Pump Costs (in model units), Base Case

Period ending	1985	1990	2000	2010	2020
West	.8261	.8259	.8277	.8214	.8188
East	.8327	.8283	.8263	.8517	.8517

Since the cost of solar heating is 0.706, in model units, it is clear from the above figures why solar heating is the preferred new technology. It was assumed for both regions that the non-fuel cost of the heat pump for heating purposes was 5/6 of the total cost, since 1/2 of the users would have air conditioning with or without a heat pump, and that the air conditioning function of a heat pump would be used in 1/3 of the year, for a total, average credit of 1/6 of the non-fuel cost. It may be argued that for the half of the users who would have air conditioning in any case, there should be a credit of the full 1/3 of the non-fuel cost of the heat pump. However, this further reduction in the cost would only be 0.0932, in model units, still leaving solar heating less costly, according to the above figures. If the "thermal efficiency" of the heat pump (assumed to be 2.0) can be improved, perhaps by a hybrid heat pump/solar device (which would have the outside coils of the heat pump in a device which is warmed by trapping solar radiation), then the heat pump could be competitive.

6.8. Sectoral Shares

The shares of total output energy (Figure 24) allocated to the two transportation sectors stay approximately constant over all periods, indicating that the growth rates of transportation services are about the same as the growth rate of total output energy. However, since the industrial share increases and the DFC share decreases, we may conclude that the energy services provided in the former sector increase faster than total output energy, and in the latter, slower than total output energy. The rates of growth of output energy are determined by the exogenous assumptions about rates of growth of population and some economic variables, by price and other elasticities, and by prices determined in the solution of the model.

The shares of total secondary energy, the energy inputs to the end use sectors, are shown in Figure 25 . The share consumed in road transportation decreases in the first three periods, reflecting the large efficiency improvements assumed in conventional automobiles. The increasing share of industry and the decreasing share of the DFC sector in total secondary energy consumption follow the pattern observed in the sectoral shares of output energy.

6.9. Fuel Shares

The shares of total output energy (Figure 26) provided by electricity and coal both increase fairly steadily, except for a lull in the third period corresponding to temporary drops in eastern industrial coal use

Table 27. Sectoral Output Energy Shares, Base Case.

```
                BASE CASE;              ;

OUTPUT SHARES:
IN UNITS OF   FRACTION

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                       1980     1985     1990     2000     2010     2020


DFC;                  0.4948   0.4654   0.4455   0.3965   0.3737   0.3620
INDUSTRY;             0.4145   0.4413   0.4652   0.5115   0.5291   0.5425
ROAD TRANSPORT;       0.0690   0.0713   0.0684   0.0700   0.0742   0.0723
OTHER TRANSPORT;      0.0218   0.0219   0.0209   0.0220   0.0231   0.0232
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 24. Thus, the differences between the plotted lines are the entries in Table 27.)

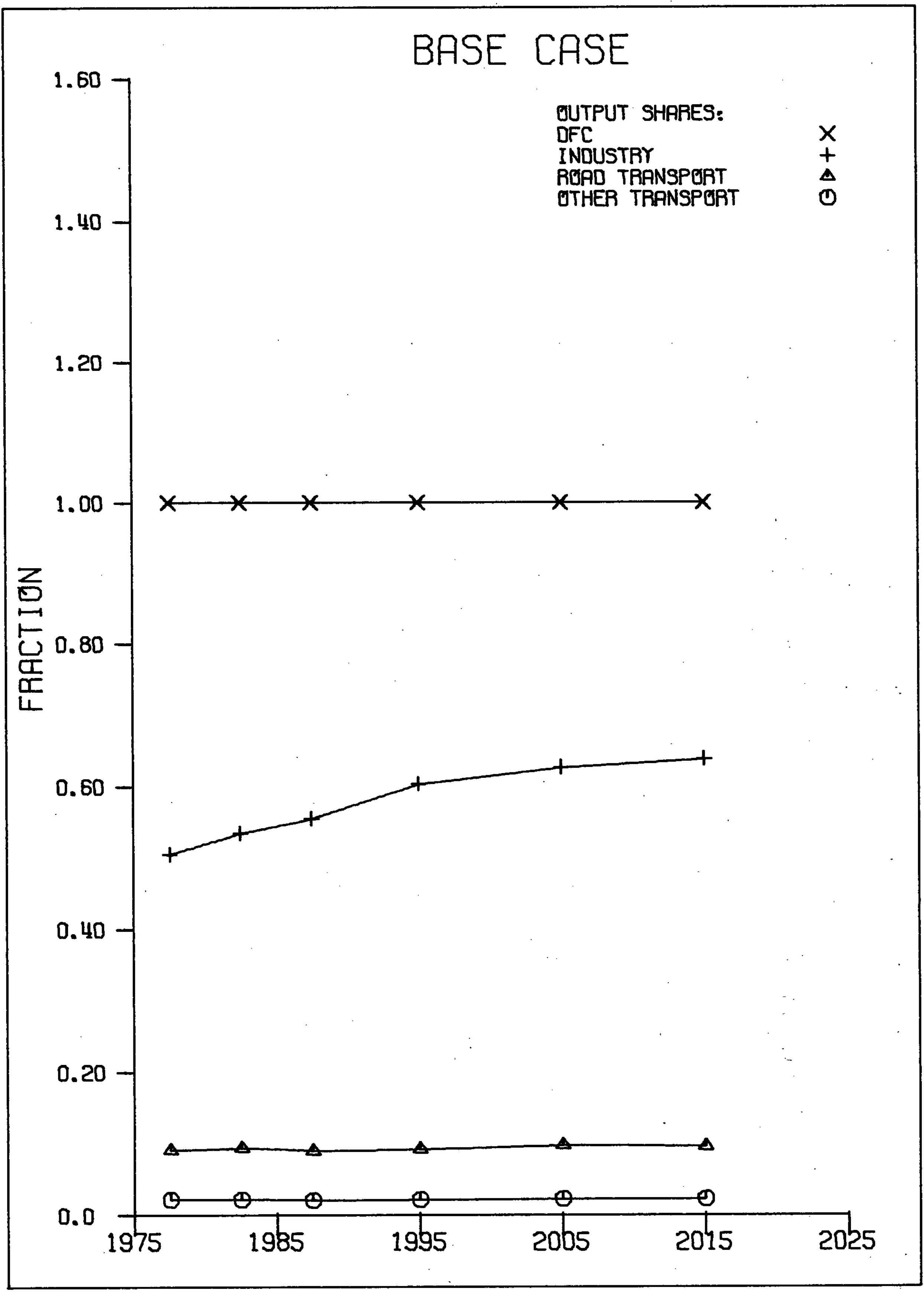

Figure 24. Sectoral Output Energy Shares, Base Case.

Table 28. Sectoral Secondary Energy Shares, Base Case.

```
             BASE CASE;           ;

SECONDARY SHARES:
IN UNITS OF   FRACTION

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980    1985    1990    2000    2010    2020


DFC;                 0.4287  0.4172  0.4157  0.3575  0.3259  0.3059
INDUSTRY;            0.3261  0.3556  0.3875  0.4560  0.4813  0.4976
ROAD TRANSPORT;      0.1897  0.1698  0.1421  0.1297  0.1302  0.1313
OTHER TRANSPORT;     0.0554  0.0575  0.0548  0.0568  0.0626  0.0652
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 25. Thus, the differences between the plotted lines are the entries in Table 28.)

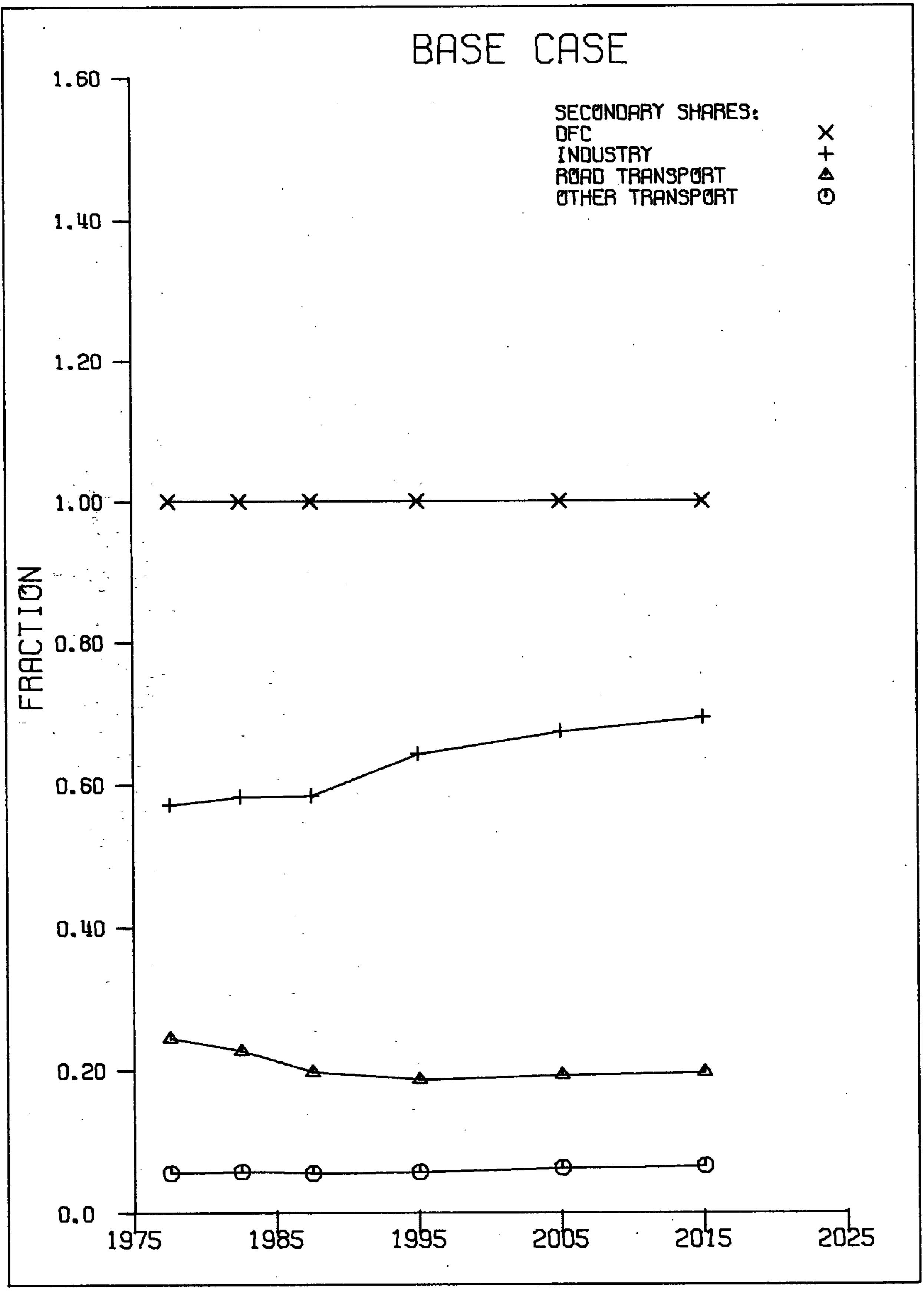

Figure 25. Sectoral Secondary Energy Shares, Base Case.

Table 29. Output Energy Fuel Shares, Base Case.

```
            BASE CASE;           ;

OUTPUT SHARES:
IN UNITS OF   FRACTION

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980     1985     1990     2000     2010     2020


SOLAR;               0.0000   0.0000   0.0000   0.0000   0.0530   0.1305
COGENERATION;        0.0000   0.0000   0.0000   0.0000   0.0052   0.0195
ELECTRICITY;         0.2105   0.2688   0.2528   0.2684   0.4512   0.4579
GAS;                 0.2576   0.2822   0.3642   0.3272   0.1438   0.0734
OIL;                 0.4739   0.3600   0.3067   0.2509   0.1880   0.1575
COAL;                0.0580   0.0890   0.0763   0.1535   0.1587   0.1613
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 26. Thus, the differences between the plotted lines are the entries in Table 29.)

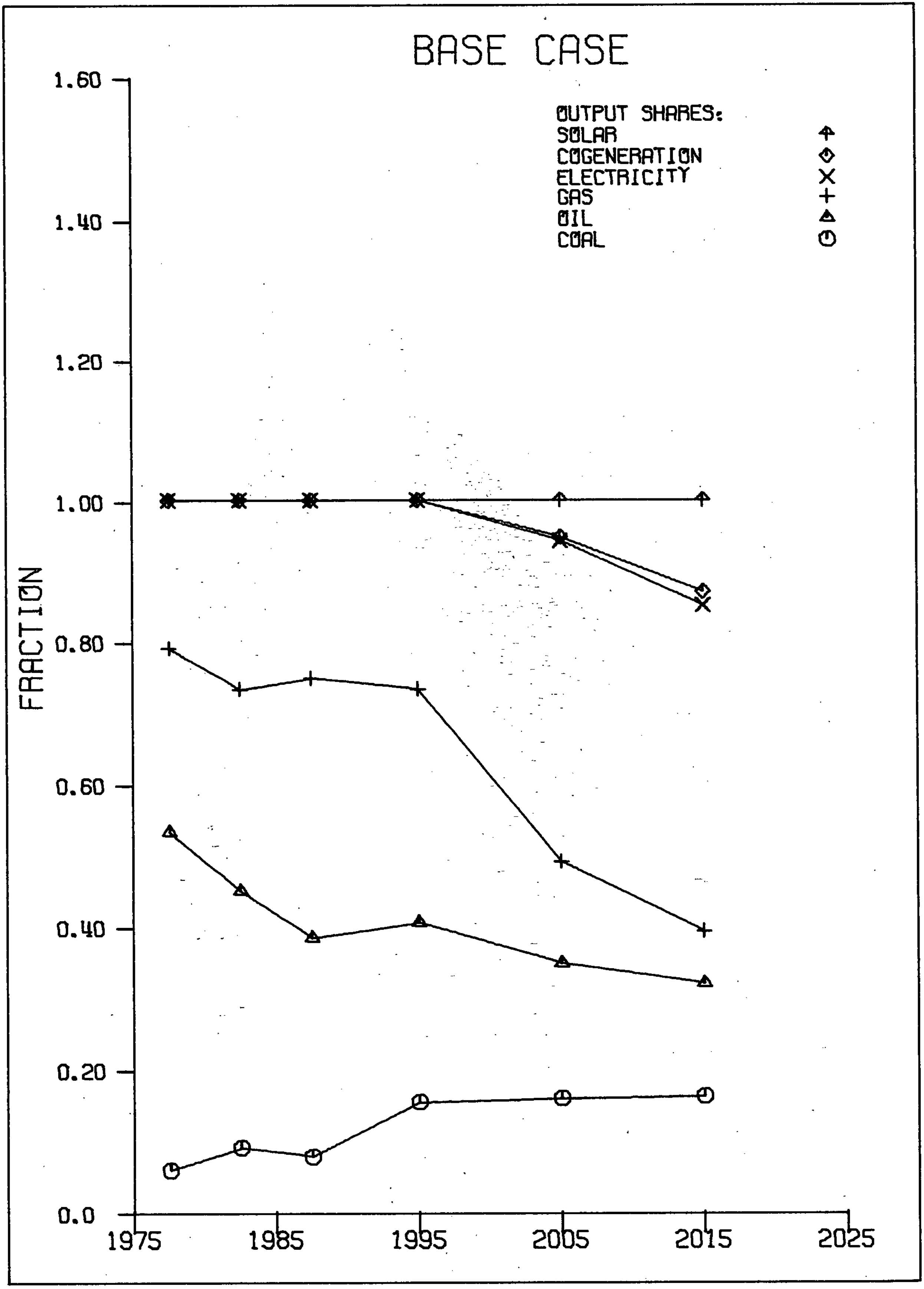

Figure 26. Output Energy Fuel Shares, Base Case.

and in eastern electric resistance heating. The large increase in electricity's share after 2000 corresponds to a switch from oil to electricity in eastern industry, and from gas to electric resistance heating in the east. The share of gas peaks in the period 1986-1990, while oil's share of output energy steadily decreases.

The share of electricity in secondary energy inputs to the end-use sectors (Figure 27) increases steadily, except for a lull in the third period, to 38% in the last period, 2011-2020. Coal's share increases to 15% by the last period. The share of gas peaks at 34% in the period 1986-1990, and oil's share declines steadily from 61% in the first period to 26% in the last period. The shares of cogeneration and solar in secondary energy are less than their shares in output energy because the quantities of output energy are taken to be the same as the quantities of secondary, input energy for these two energy sources, while other fuels generally lose energy in conversion from secondary to output energy.

Primary fuel shares (Figure 28) change in a way similar to the changes observed in secondary and output energy fuel shares in the cases of coal, gas and oil. Hydro's share of primary energy increases to about 15% by 2000, and nuclear's share takes a sharp jump after 2000, when eastern hydro has been expanded to its maximum. The tiny share of "biomass" (this category includes energy production from garbage, wind, tidal power) comes mainly from western electricity production. Solar's share of primary energy is even smaller than its share of secondary energy because the quantities of primary and secondary solar energy (and output, too) are taken to be the same.

In summary, oil becomes less important but remains significant as an energy source; coal increases in importance; there is a major shift to greater reliance on electricity, with nuclear power playing an important part,

Table 30. Secondary Energy Fuel Shares, Base Case.

```
             BASE CASE;           ;

SECONDARY SHARES:
IN UNITS OF   FRACTION

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980    1985    1990    2000    2010    2020


SOLAR;               0.0000  0.0000  0.0000  0.0000  0.0424  0.1091
COGENERATION;        0.0000  0.0000  0.0000  0.0000  0.0042  0.0163
ELECTRICITY;         0.1350  0.1833  0.1783  0.1979  0.3611  0.3827
GAS;                 0.2157  0.2525  0.3402  0.3209  0.1514  0.0774
OIL;                 0.6065  0.4945  0.4197  0.3510  0.2948  0.2596
COAL;                0.0428  0.0697  0.0619  0.1301  0.1460  0.1549
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 27. Thus, the differences between the plotted lines are the entries in Table 30.)

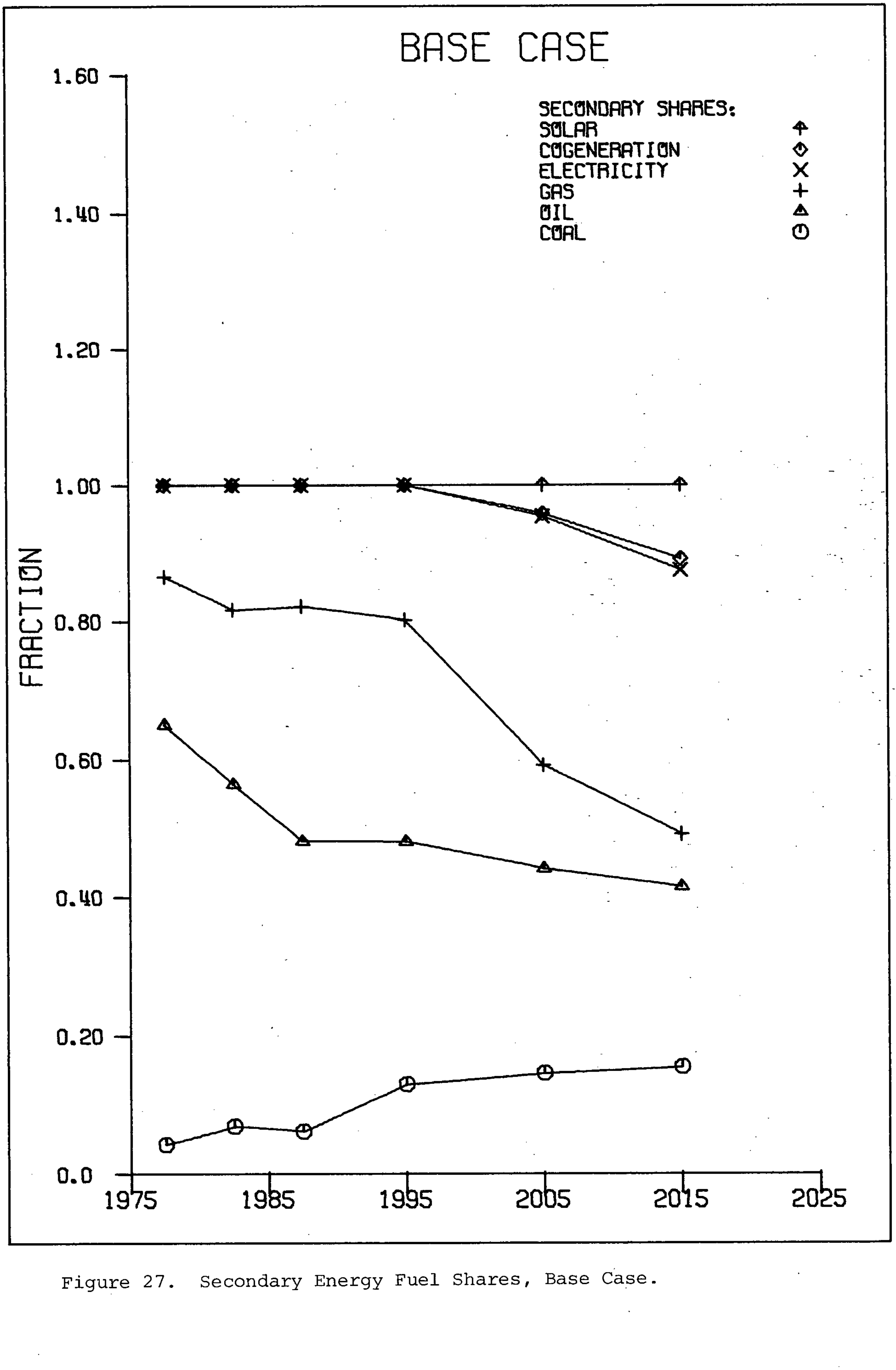

Figure 27. Secondary Energy Fuel Shares, Base Case.

Table 31. Primary Energy Fuel Shares, Base Case.

```
            BASE CASE;           ;

PRIMARY FUEL SHARES:
IN UNITS OF   FRACTION

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980    1985    1990    2000    2010    2020


SOLAR;               0.0000  0.0000  0.0000  0.0000  0.0391  0.1011
BIOMASS;             0.0004  0.0003  0.0003  0.0001  0.0000  0.0000
HYDRO;               0.0953  0.1280  0.1281  0.1470  0.1400  0.1437
NUCLEAR;             0.0088  0.0207  0.0247  0.0351  0.2188  0.2303
GAS;                 0.2508  0.2912  0.3586  0.3312  0.1535  0.0778
OIL;                 0.5613  0.4572  0.3986  0.3419  0.2933  0.2598
COAL;                0.0834  0.1025  0.0897  0.1446  0.1553  0.1873
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 28. Thus, the differences between the plotted lines are the entries in Table 31.)

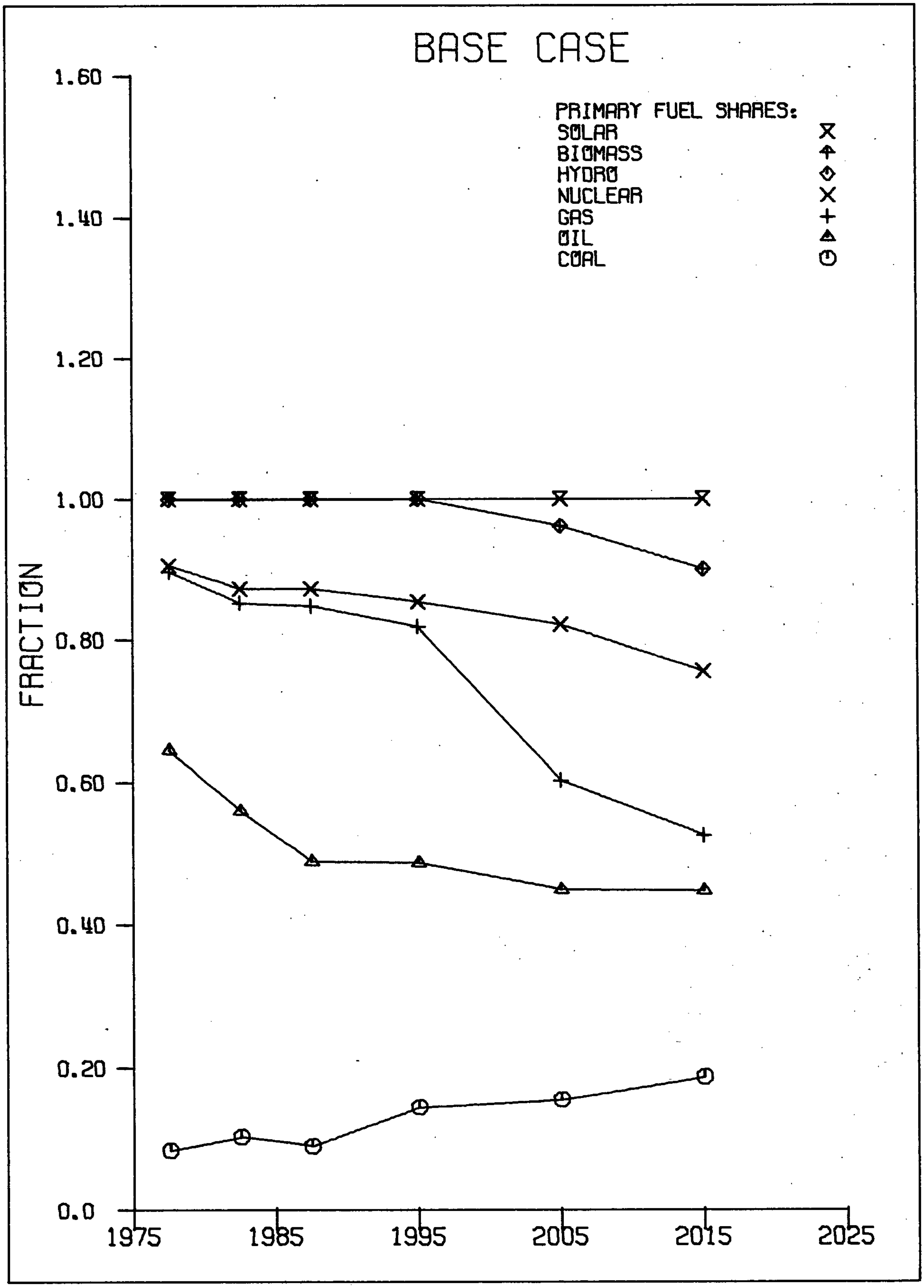

Figure 28. Primary Energy Fuel Shares, Base Case.

especially after the turn of the century; gas peaks in importance in the period 1986-1990 and declines rapidly after 2000; and solar energy becomes significant only after the turn of the century.

6.10. Total Energy

Total output energy (Figure 29) increases at the rate of 3.7% per year between 1978 and 1995, and at 2.3% per year between 1995 and 2015. Total secondary energy increases at an average 2.9% per year between 1978 and 1995, and at 1.7% per year between 1995 and 2015. Total primary energy grows at the rate of 2.5% per year between 1978 and 1995, and at 1.5% per year between 1995 and 2015.

The primary energy contributions of hydro and nuclear electricity are evaluated at 3,412 BTUs per kilowatt-hour, which is the amount of usable energy in one kilowatt-hour. Other authors (e.g. Energy, Mines and Resources, 1977a) have used a different accounting convention -- 10,000 BTUs per kilowatt-hour -- for the reason that approximately 10,000 BTUs of fossil fuel input is necessary to produce one kilowatt-hour of electricity. Thus, the generation of one kilowatt-hour of electricity by hydro or nuclear would have required 10,000 BTUs of fossil fuels if fossil fuels had been used. The "10,000" convention facilitates international comparisons of primary energy use, when the focus is on exhaustible, fossil fuels. However, the "10,000" convention masks changes in the overall efficiency of primary energy use by obscuring the effects of fossil fuel use to generate electricity. It should be noted that the adoption of one convention or another has no effect on the solution of the model -- the only effect is on the calculation of total primary energy for the report on the results of the model.

The rates of change of primary, secondary and output energy, (Figure 30) are the average annual rates obtained by comparing total energy in each period

Table 32. Total Energy, Base Case.

```
             BASE CASE;          ;

TOTAL ENERGY:
IN UNITS OF   10**15 BTU PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980     1985     1990     2000     2010     2020


PRIMARY;            7.7796   8.3782  10.0368  11.8286  12.9086  15.7803
SECONDARY;          6.5064   6.9898   8.6347  10.5149  11.8984  14.6298
OUTPUT;             4.1730   4.7656   6.0896   7.7554   9.5239  12.2283
```

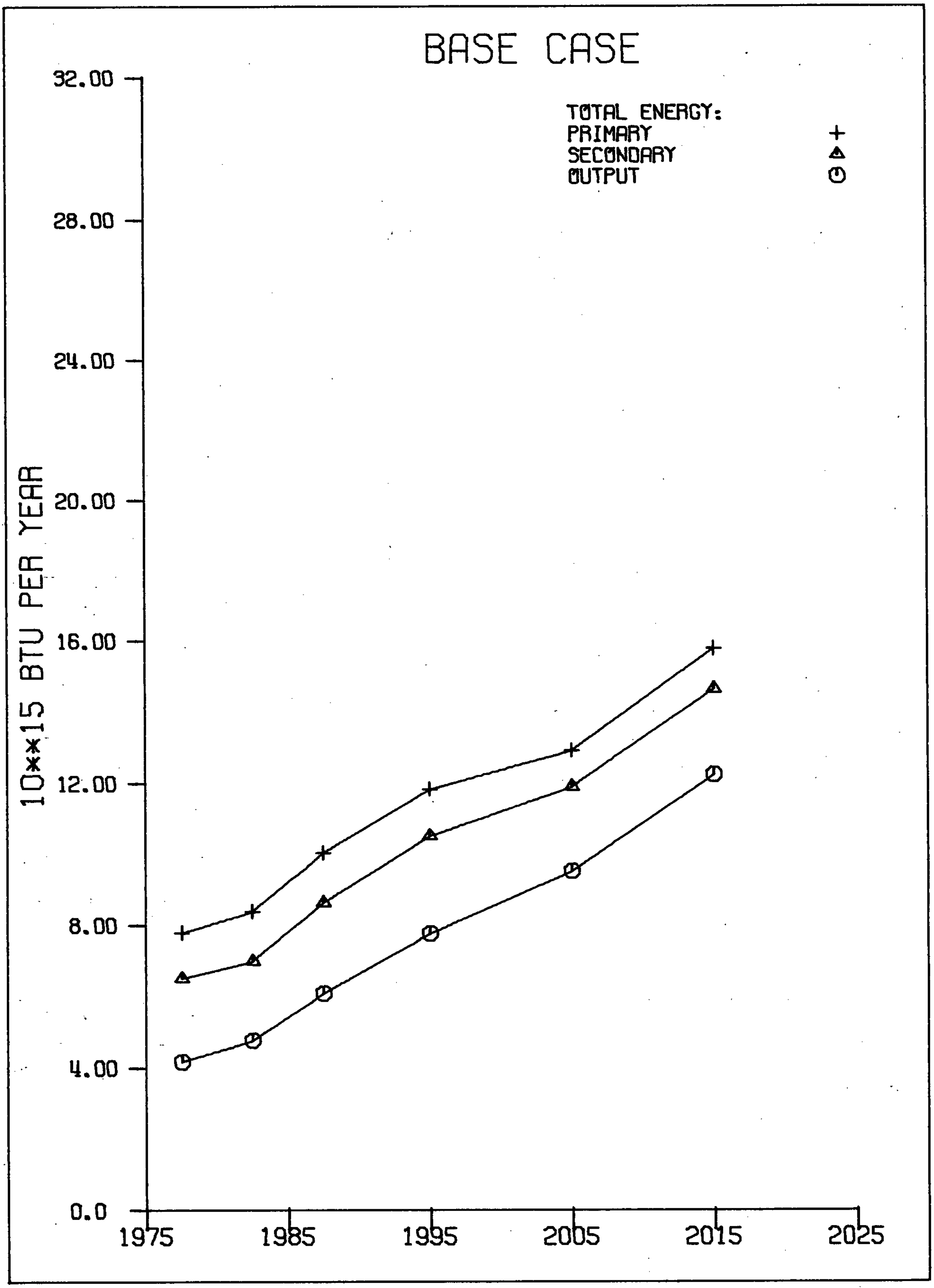

Figure 29. Total Energy, Base Case.

Table 33. Total Energy, Percent Annual Change, Base Case.

```
              BASE CASE;            :

TOTAL ENERGY:
IN UNITS OF   % CHANGE PER YEAR

         AVERAGE VALUES FOR THE PERIOD ENDING IN

                    1980     1985     1990     2000     2010     2020


PRIMARY;          4.1609   1.4936   3.6784   2.2138   0.8776   2.0289
SECONDARY;        5.1685   1.4437   4.3172   2.6608   1.2437   2.0880
OUTPUT;           5.8897   2.6914   5.0252   3.2757   2.0754   2.5309
```

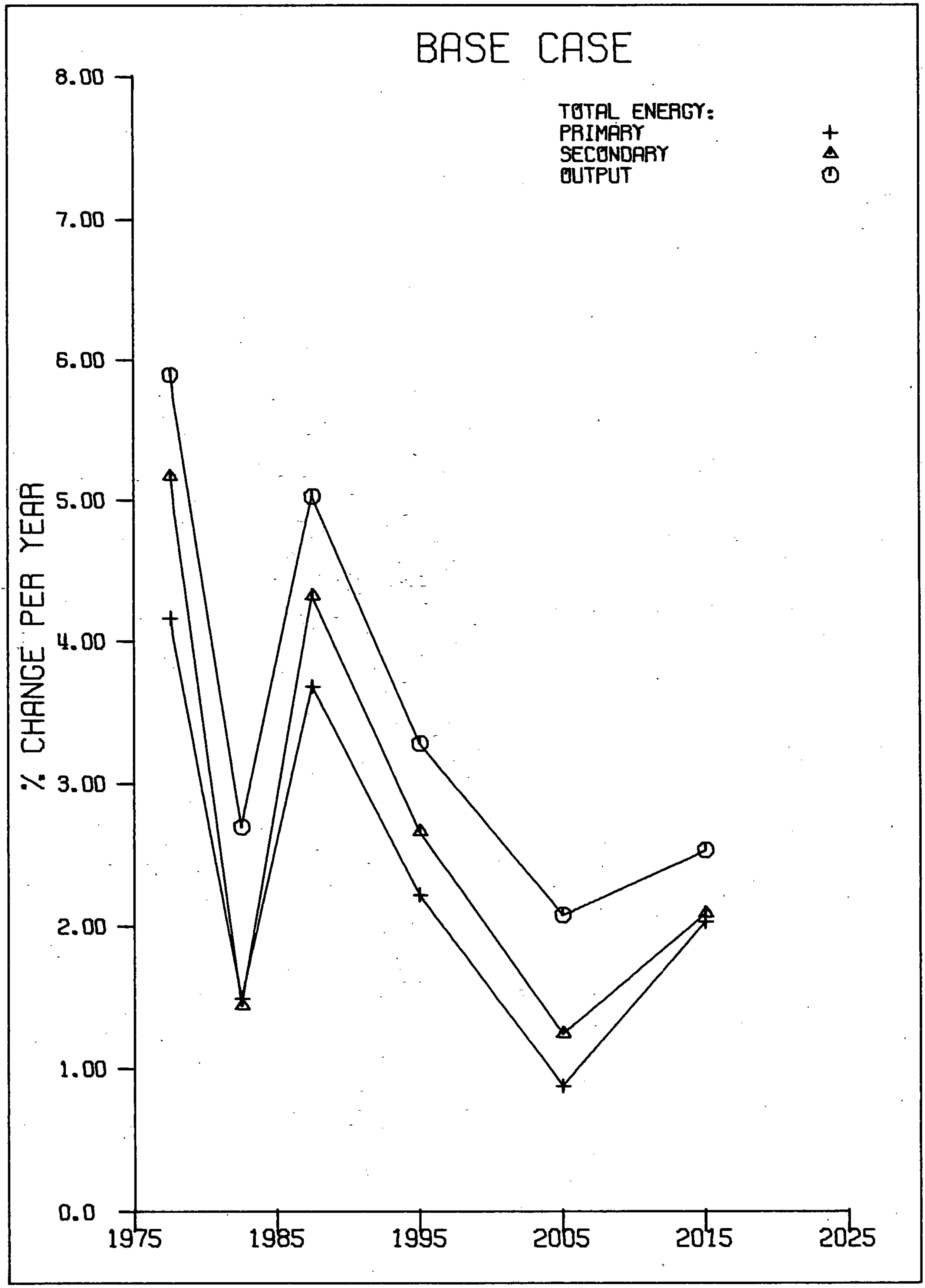

Figure 30. Total Energy, Percent Annual Change, Base Case.

to the previous period. The drop in rates of change in the second period coincides with higher coal, oil and gas prices in the east, as well as the slower economic growth which is assumed for this period. The rise in rates of change in the third period coincides with a drop in coal, oil and gas prices in the east, and higher assumed economic growth rates. The temporary drop in rates of increase in the period ending in 2010 is apparently due to a large jump in oil and gas prices (especially gas) and in the eastern electricity price. The eastern gas and electricity prices reach a plateau and do not change in the final period, which means that only the economic and demographic factors in the demand function can have an effect on the rate of increase of demand for output energy between the last two periods.

The rate of growth of secondary energy is less, in all periods, than the rate of growth of output energy, and the rate of growth of primary energy is even less than that of secondary energy in most periods. These observations indicate an increasing, overall energy system efficiency in the base case, both in the end-use sectors and at the intermediate level of secondary energy. The increasing efficiency reflects such things as the rapid growth in hydroelectricity and nuclear power (rather than total reliance on fossil fuels for electricity), the introduction of cogeneration in the west, the switch to efficient electric resistance heating in the east (away from oil and gas heat), the use of solar heat (whose energy content is evaluated at the same amount at the primary, secondary and output stages), and the assumed improving efficiencies in transportation.

Chapter 7. The High Demand and Low Demand Cases

7.1. The Assumptions

The base case assumptions are the best estimates of all parameters. One key element of uncertainty is the exogenous projection of the economic and demographic variables which, along with prices, determine demands for output energy. In order to test the sensitivity of some conclusions to the assumptions about these exogenous demand-related variables, the model has been solved for high and low estimates of the future levels of the economic and demographic variables. The assumptions on the supply side are the same as in the base case (since the sensitivity analysis here is for demand-related variables), except for some different exogenous projections of production from the tar sands. (The linear process model of supply adjusts to the altered demand conditions, except for the exogenously-projected tar sands production. Thus, to be consistent, the tar sands projections must be altered in a reasonable way.)

The assumptions for the low, base and high cases are presented in Table 34, below.

The high case estimates of population and economic growth are based on the high case assumptions of the National Energy Board, described in Douglas and Nichols (1979), which is also the source of the base case estimates. The National Energy Board's estimates, derived using the CANDIDE model of the Canadian economy, should be internally consistent (coming from CANDIDE), and they represent a plausible,"respectable" range of projections of the future of the Canadian economy. The low case estimates are based on this author's judgement, since there were no low projections of these variables prepared for the National Energy Board. (Their approach to their low demand case was to take the base case estimates of demographic and economic variables, and project high energy prices, which are exogenous in their model.)

The National Energy Board (1978) base case projection of tar sands production to 1995 is used as the base case exogenous projection here, and as the lower limit from 1980 to 2000 for projection in the high case. The low case projection of the National Energy Board (1978) is the basis for the values assumed for tar sands production in this low case.

Table 34. Low, Base and High Case Assumptions.

Period Ending		1980	1985	1990	2000	2010	2020	(for end effects)
Population Growth, West, % per year	High	1.5	1.3	1.2	1.2	0.8	0.8	0.6
	Base	1.5	1.2	1.1	0.9	0.6	0.5	0.3
	Low	1.5	1.1	1.0	0.6	0.4	0.2	0.0
Population Growth, East, % per year	High	1.2	1.0	0.9	0.9	0.8	0.8	0.6
	Base	1.2	0.9	0.8	0.7	0.6	0.5	0.3
	Low	1.2	0.8	0.7	0.5	0.4	0.2	0.0
Income per Capita Growth, % per year	High	3.7	2.3	2.9	3.0	3.1	2.7	2.5
	Base	3.7	1.9	2.3	2.5	2.3	2.3	2.3
	Low	3.7	1.5	1.7	2.0	2.0	2.0	2.0
Real Domestic Product Growth, West, %/yr.	High	3.5	4.9	4.3	4.2	4.2	3.8	3.6
	Base	3.5	4.0	3.7	3.8	2.9	2.8	2.6
	Low	3.5	3.5	3.2	2.8	2.4	2.2	2.0
Real Domestic Product Growth, East, %/yr.	High	3.2	4.5	4.0	4.0	4.2	3.8	3.6
	Base	3.2	3.7	3.4	3.6	2.9	2.8	2.6
	Low	3.2	3.2	2.9	2.6	2.4	2.2	2.0
Capital/Output Ratio Growth, % per year	High	2.0	2.1	2.8	2.0	1.0	0.5	0.0
	Base	2.0	2.1	2.8	1.0	0.5	0.0	0.0
	Low	2.0	2.1	2.0	1.0	0.5	0.0	0.0
Tar Sands Production 10^9 bbl/yr	High	=.0362	≥.0744	≥.1534	≥.2756	---	---	---
	Base	=.0362	=.0744	=.1534	=.2756	---	---	---
	Low	=.0362	≥.0706	≥.1380	≥.2205	---	---	---

7.2. The Results of the High Case

Generally speaking, production and use levels are higher in the high case than in the base case, but the overall patterns (peaks, introduction of new sources, etc.) are the same as in the base case. Some noteworthy exceptions to these general observations are:

- some oil and coal sources are exhausted sooner in the high case;
- gas production and use are at roughly the same levels in the high case as in the base case, except for the last period;
- solar heat is introduced one period earlier in each region (after 1990 in the east, and after 2000 in the west, in the high case); and
- oil and gas prices rise slightly faster in the medium term (1985 to 2000) than in the base case.

Some conclusions drawn from an examination of the base case solution are strengthened by the results of the high case. As in the base case, northwestern arctic oil is not used until after 2000 in the high case in spite of the higher demand (but northeastern offshore oil is used one period sooner, 1991-2000, in the high case). Imports of oil and coal cease after 1985 in the high case, as in the base case. The crude oil price still does not reach its upper limit of $12 per barrel until the last period, 2011-2020, in spite of the higher demand. As in the base case, natural gas from the northeast offshore is not needed until after 2000, and gas from the northwest arctic is not used until after 2010.

The two primary fuels which appear to make up the extra supply required to meet the higher demands are nuclear electricity and coal. A related observation is that electricity prices are not affected very much by the increased demands in the high case (compared to the base case), because of the virtually limitless supplies of nuclear power in the east and coal for electricity in the west. Thus, the base case conclusion that electricity prices are stable, is strengthened.

Plots and tables from the high and low cases relating to this discussion may be found on pages 134 to 161.

7.3. The Results of the Low Case

Compared to the base case, there are, of course, generally lower levels of production and use of energy, and the overall pattern is similar. Some exceptions are:

- oil from the northwest arctic is introduced one period later (after 2010) than in the base case; and
- western conventional oil supplies are used less in the first four periods and more in the last two periods, "stretching out" the cheaper oil supplies.

Solar heating is introduced in the same periods as in the base case in both regions - 2011-2020 in the west, and 2001-2010 in the east. This reinforces the conclusion that solar heat will be a competitive energy source, even if energy demands grow slowly, although it will not be competitive in the near future.

Since nuclear's share of primary energy is less than for base case demand, it may be concluded that nuclear power will play a key role in matching energy supplies and demands. This reinforces the observation made on the high case results, that nuclear made up a good part of the extra energy supply required over the base case requirements.

It is noteworthy that the periods of introduction of natural gas from the northwest arctic and the northeast offshore areas are the same in the low case as in the high case -- the periods ending in 2020 and 2010, respectively. This puts upper bounds on the introduction dates - before

2020 for northwest arctic gas, and before 2010 for northeast offshore gas. The conclusion that these frontier gas sources need not be tapped until after the turn of the century, first discussed with reference to the base case, is therefore a robust conclusion.

An examination of the high, base and low results reveals that eastern gas production (the sum of southeast and northeast offshore production) is the same in the first four periods in all three cases. There are two reasons for this behaviour. First, southeast offshore gas is used at the maximum allowable rates in the first three periods because it is inexpensive, and in the fourth period, the reserve limit and the production decline constraint combine to make another upper limit on production. Secondly, the other component of eastern gas production, the northeast offshore gas, is not brought into the solution until the fifth period in all three cases. Therefore, differences among the cases in eastern gas production do not appear until the fifth period.

There is very little difference in the price series of the low and base cases.

Plots and tables from the high and low cases relating to the above discussion appear on pages 134 to 161.

Table 35, below shows the growth rates of total energy demand per capita for the three cases, at the primary, secondary and output energy levels, using each case's population projection.

Table 35. Growth in Total Energy Demands Per Capita, Three Cases

(average growth, percent per year, between midpoints of periods)

Period Ending		1980	1985	1990	2000	2010	2020
Primary	- High	2.9	0.7	3.3	1.5	1.7	2.4
	- Base	2.9	0.5	2.7	1.4	0.3	1.5
	- Low	2.9	0.2	2.1	1.1	0.0	1.1
Secondary	- High	3.9	0.6	3.9	1.9	2.1	2.4
	- Base	3.9	0.4	3.4	1.8	0.6	1.6
	- Low	3.9	0.1	2.7	1.5	0.4	1.2
Output	- High	4.6	1.8	4.6	2.6	3.0	2.8
	- Base	4.6	1.7	4.1	2.5	1.5	2.0
	- Low	4.6	1.4	3.4	1.9	1.2	1.8

The demand for output energy grows, even on a per capita basis, because the demand is also related to several economic variables, which grow faster than population, partly because of technological change.

Table 36. Crude Oil Production, High Case.

```
              HIGH CASE;            ;

OIL PRODUCTION:
IN UNITS OF    10**9 BBL PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                        1980     1985     1990     2000     2010     2020


IMPORTS;               0.2796   0.1138   0.0000   0.0000   0.0000   0.0000
FROM BIOMASS;          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
FROM COAL;             0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
EASTERN;               0.0008   0.0100   0.0500   0.2023   0.1925   0.0647
TAR SANDS;             0.0362   0.0744   0.1534   0.2756   0.2516   0.8018
WEST ARCTIC;           0.0000   0.0000   0.0000   0.0000   0.2803   0.1317
WESTERN;               0.5572   0.5081   0.5641   0.3045   0.0801   0.0007
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 31. Thus, the differences between the plotted lines are the entries in Table 36.)

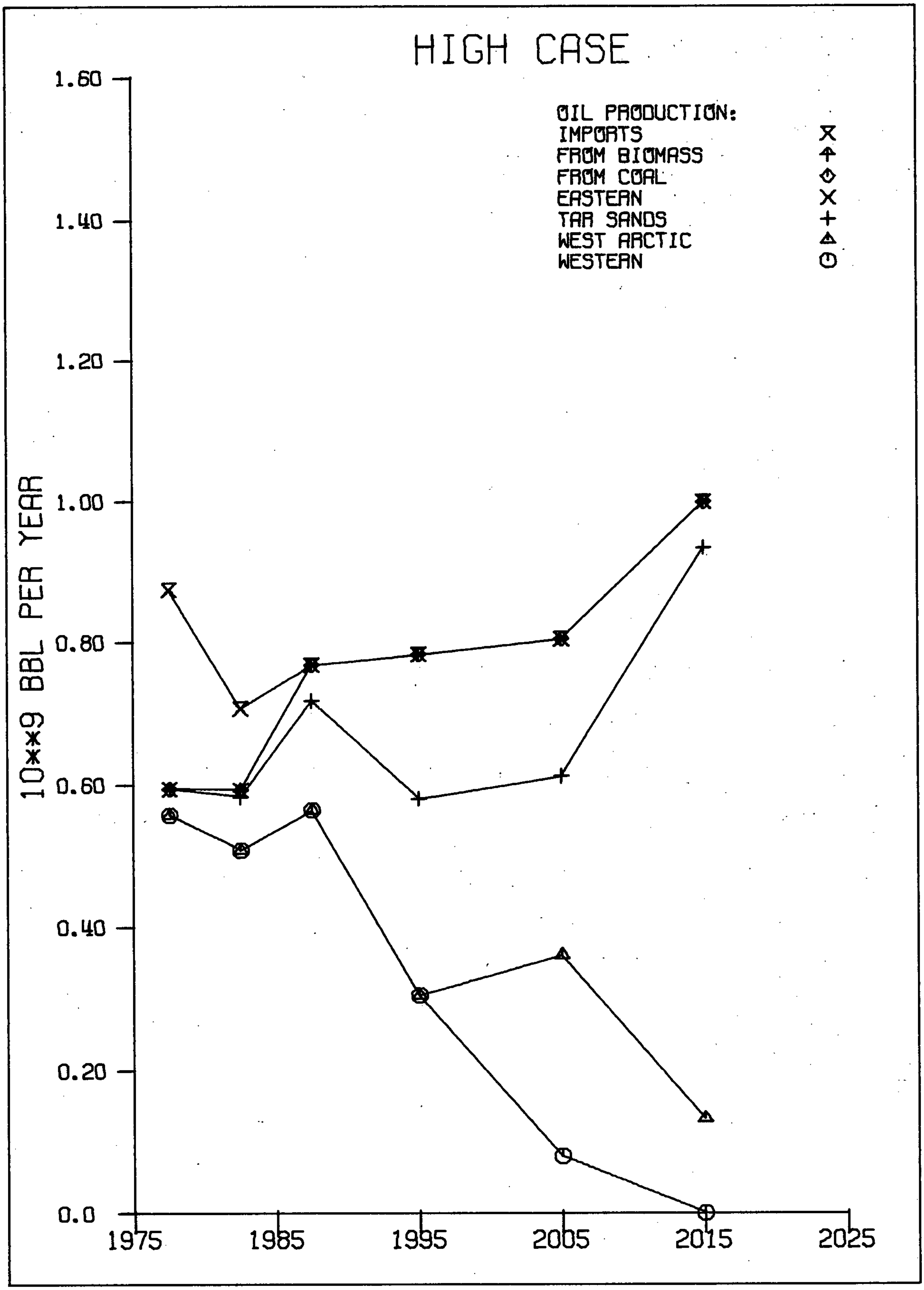

Figure 31. Crude Oil Production, High Case.

Table 37. Crude Oil Production, Low Case.

```
             LOW CASE;               ;

OIL PRODUCTION:
IN UNITS OF   10**9 BBL PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                       1980     1985     1990     2000     2010     2020


IMPORTS;              0.2728   0.1065   0.0000   0.0000   0.0000   0.0000
FROM BIOMASS;         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
FROM COAL;            0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
EASTERN;              0.0008   0.0100   0.0500   0.1772   0.2058   0.0740
TAR SANDS;            0.0362   0.0706   0.1380   0.2205   0.1965   0.1419
WEST ARCTIC;          0.0000   0.0000   0.0000   0.0000   0.0000   0.2917
WESTERN;              0.5499   0.4821   0.4430   0.2086   0.1790   0.0618
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 32. Thus, the differences between the plotted lines are the entries in Table 37.)

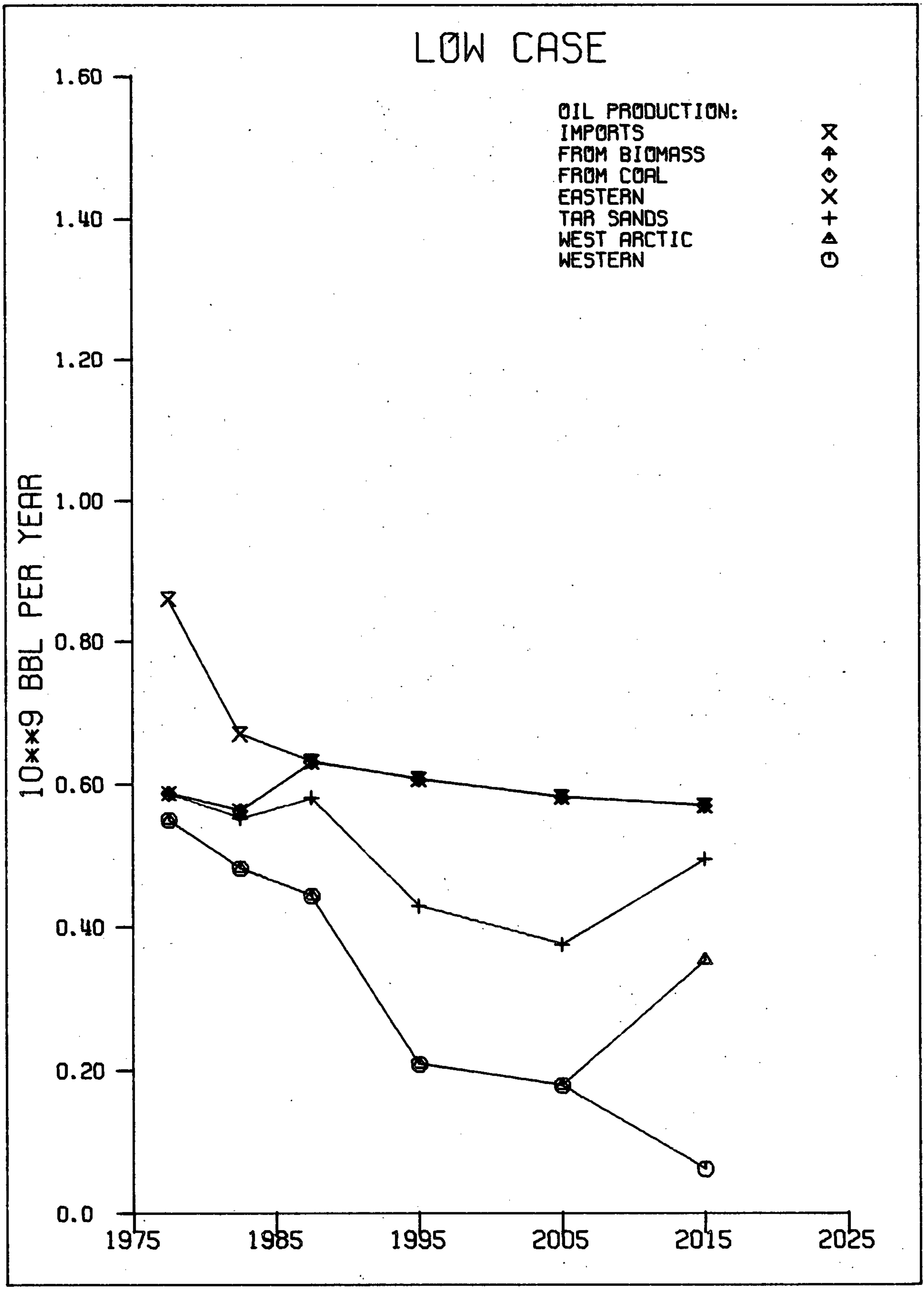

Figure 32. Crude Oil Production, Low Case.

Table 38. Crude Oil Prices, High Case.

```
              HIGH CASE;            ;

CRUDE OIL PRICES:
IN UNITS OF   1975$ PER BBL

          AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980     1985     1990     2000     2010     2020


EXPORTS;           14.6000  17.8000  21.6000  32.0000  32.0000  32.0000
IMPORTS;           10.8000  14.8000  19.3000  32.0000  32.0000  32.0000
EAST;               8.1506  10.3586   9.2055  10.5151  11.7794  12.5000
WEST;               5.3935   8.5321   8.7055  10.0156  11.2794  11.9998
```

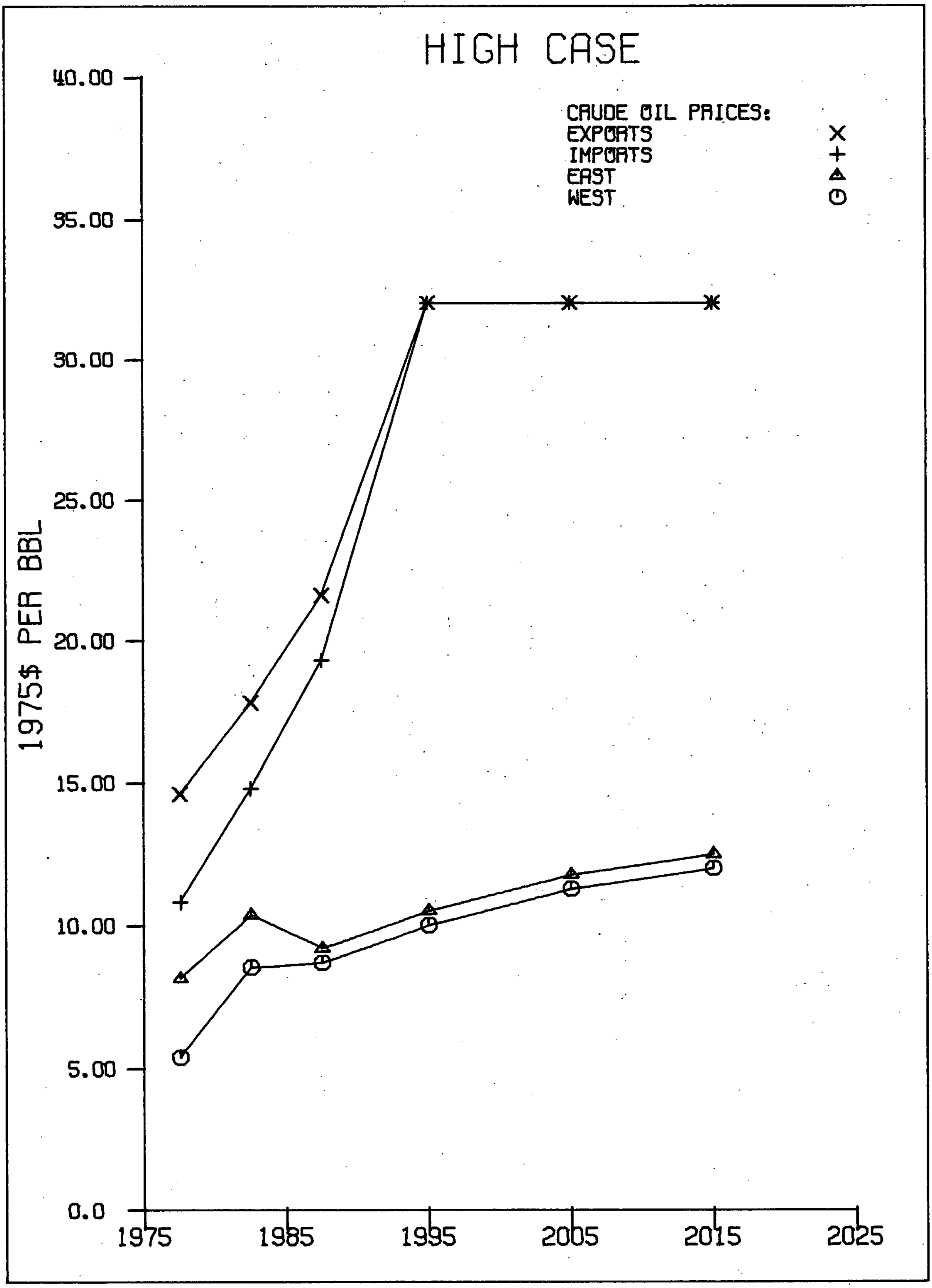

Figure 33. Crude Oil Prices, High Case.

Table 39. Crude Oil Prices, Low Case.

```
              LOW CASE;               ;

CRUDE OIL PRICES:
IN UNITS OF   1975$ PER BBL

         AVERAGE VALUES FOR THE PERIOD ENDING IN

                        1980     1985     1990     2000     2010     2020


EXPORTS;              14.6000  17.8000  21.6000  32.0000  32.0000  32.0000
IMPORTS;              10.8000  14.8000  19.3000  32.0000  32.0000  32.0000
EAST;                  8.0181  10.0808   9.1703   8.8665  10.9143  12.5000
WEST;                  5.1497   8.1714   8.6702   8.3671  10.4143  11.9998
```

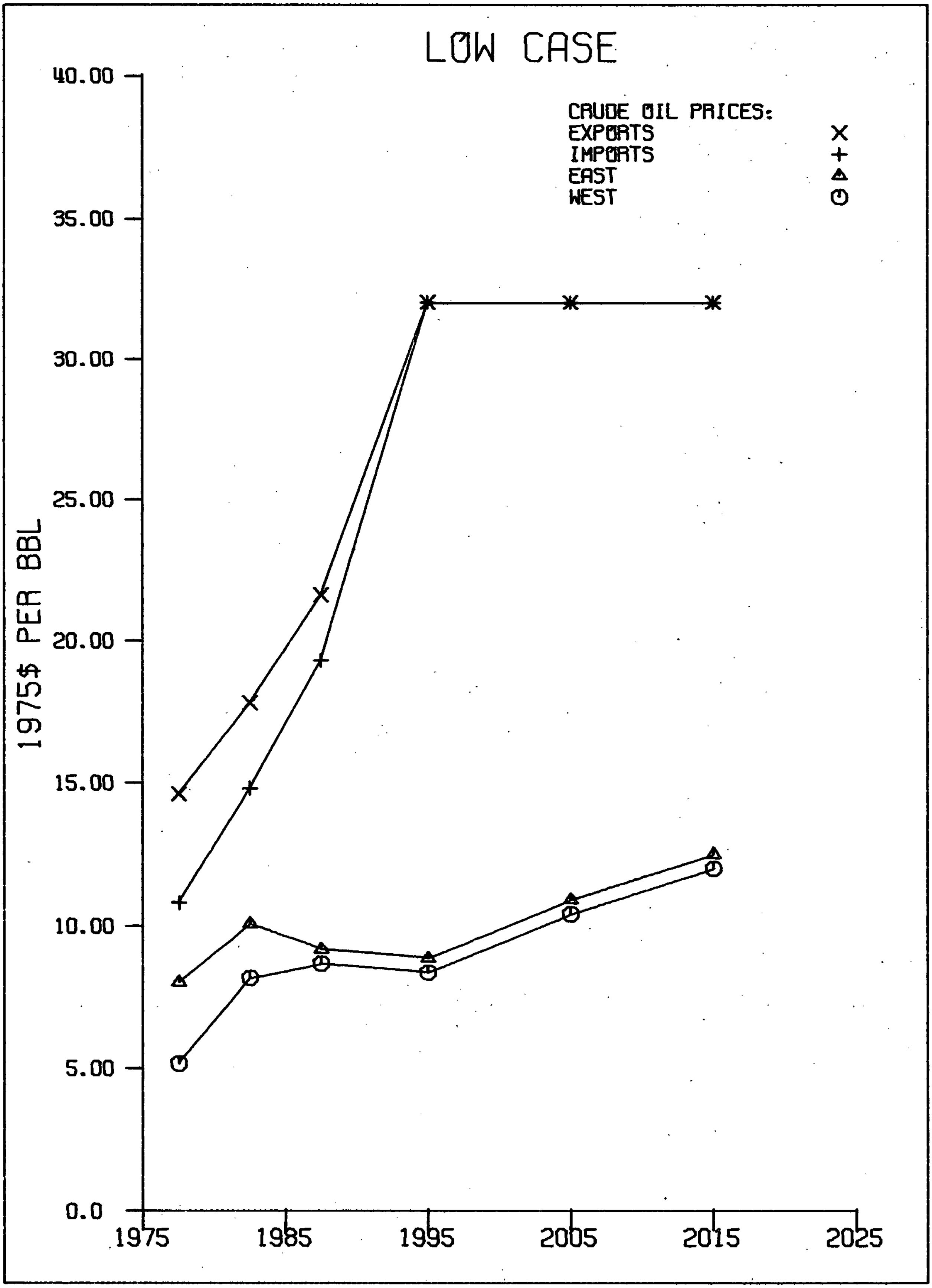

Figure 34. Crude Oil Prices, Low Case.

Table 40. Gas Production, High Case.

HIGH CASE; ;

GAS PRODUCTION:
IN UNITS OF TCF PER YEAR

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
FROM BIOMASS;	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004
FROM COAL;	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EASTERN;	0.0002	0.0002	0.4800	0.7703	0.8816	0.9498
WEST ARCTIC;	0.0000	0.0000	0.0000	0.0000	0.0000	0.4734
WESTERN;	2.9493	4.0447	3.7841	3.0256	1.1770	0.2083

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 35. Thus, the differences between the plotted lines are the entries in Table 40.)

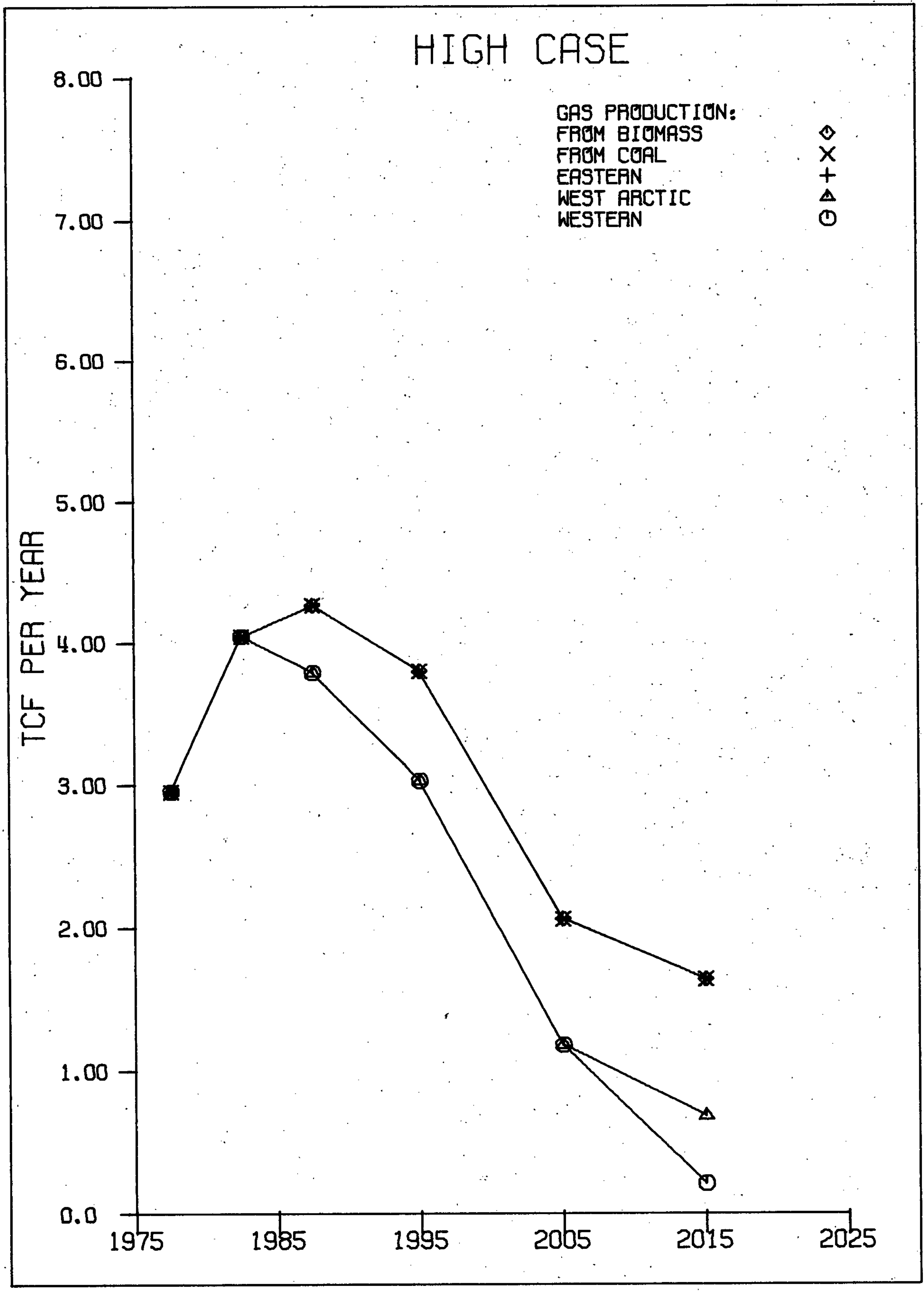

Figure 35. Gas Production, High Case.

Table 41. Gas Production, Low Case.

```
             LOW CASE;               ;

GAS PRODUCTION:
IN UNITS OF   TCF PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                       1980    1985    1990    2000    2010    2020


FROM BIOMASS;        0.0000  0.0000  0.0000  0.0000  0.0004  0.0004
FROM COAL;           0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
EASTERN;             0.0002  0.0002  0.4800  0.7703  0.5997  0.4779
WEST ARCTIC;         0.0000  0.0000  0.0000  0.0000  0.0000  0.2369
WESTERN;             2.9565  4.0057  3.6569  3.0310  1.2249  0.2345
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 36. Thus, the differences between the plotted lines are the entries in Table 41.)

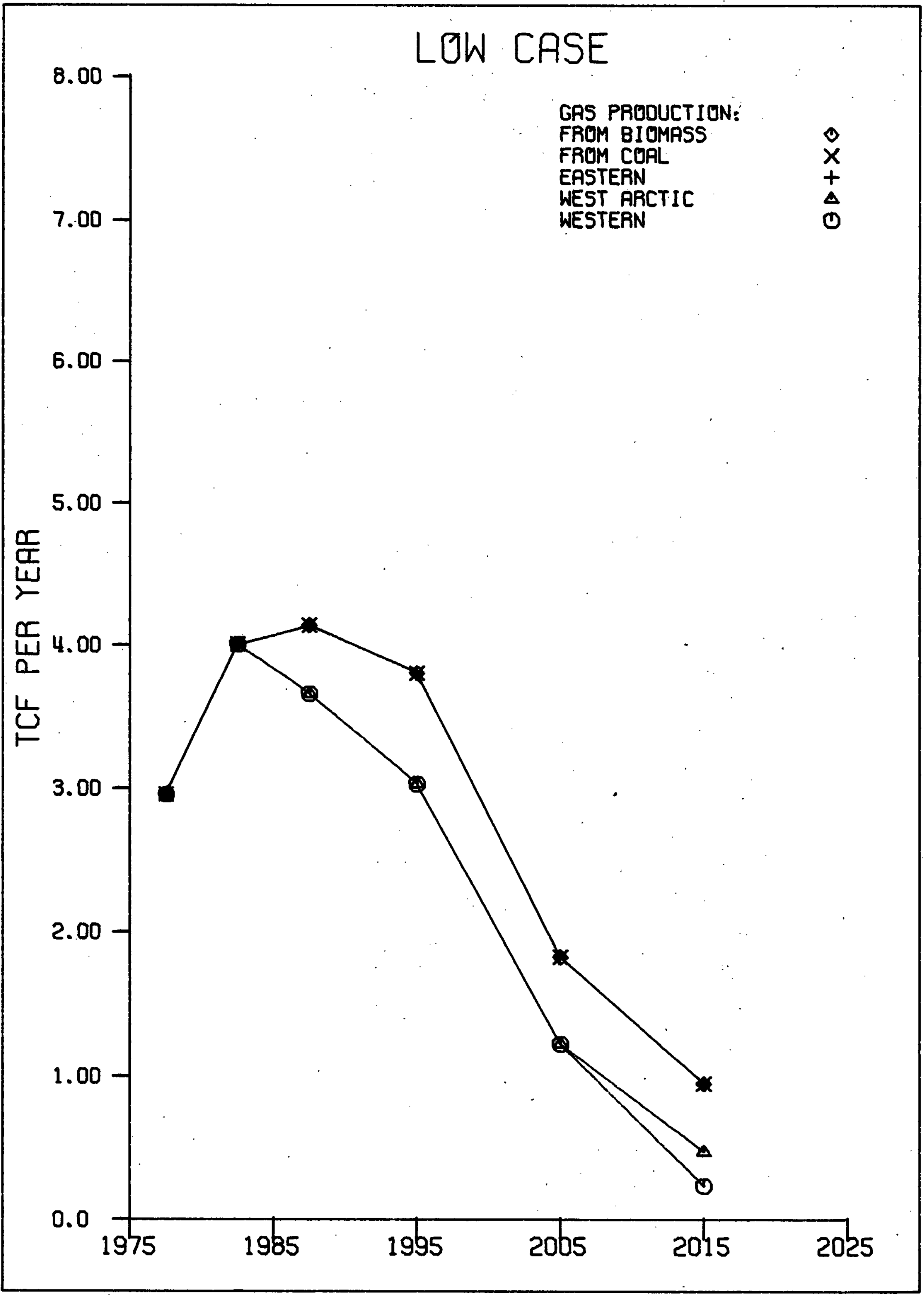

Figure 36. Gas Production, Low Case.

Table 42. Gas Prices, High Case.

```
             HIGH CASE;           ;

GAS PRICES:
IN UNITS OF   1975$ PER MCF

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                    1980    1985    1990    2000    2010    2020


EAST,AT TORONTO;  2.1009  2.5780  2.0856  2.4036  3.0397  3.1039
WEST, WELLHEAD;   0.9547  1.0024  1.0360  1.7346  2.3785  2.5003
Corrected, Toronto; 1.52    1.58    1.61    2.40    3.04    3.10
```

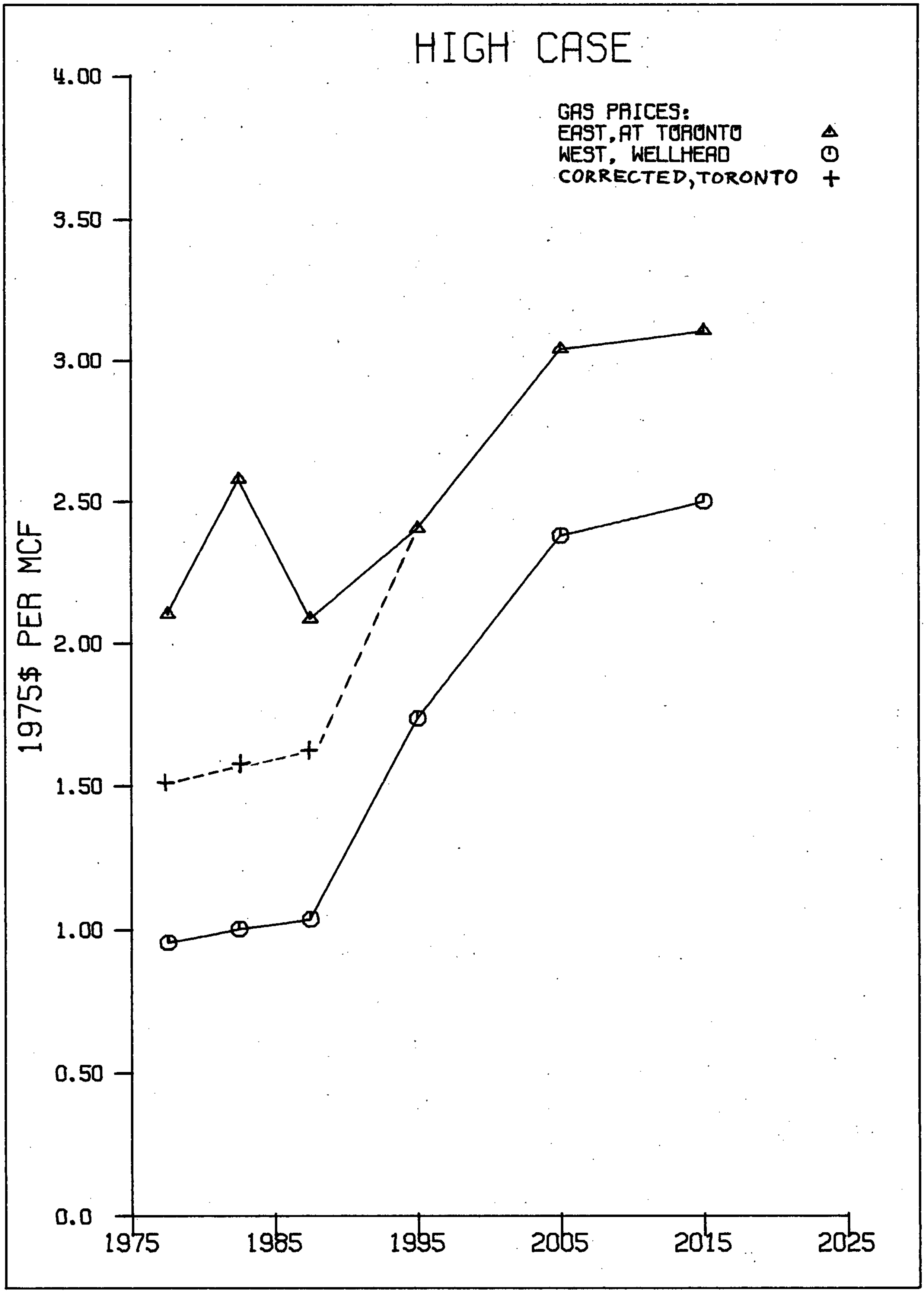

Figure 37. Gas Prices, High Case.

Table 43. Gas Prices, Low Case.

LOW CASE; ;

GAS PRICES:
IN UNITS OF 1975$ PER MCF

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
EAST,AT TORONTO;	2.1612	2.4803	1.9189	2.0884	3.0005	3.0005
WEST, WELLHEAD;	0.9176	0.9627	1.0227	1.4555	2.2610	2.5003
Corrected, Toronto;	1.48	1.53	1.60	2.09	3.00	3.00

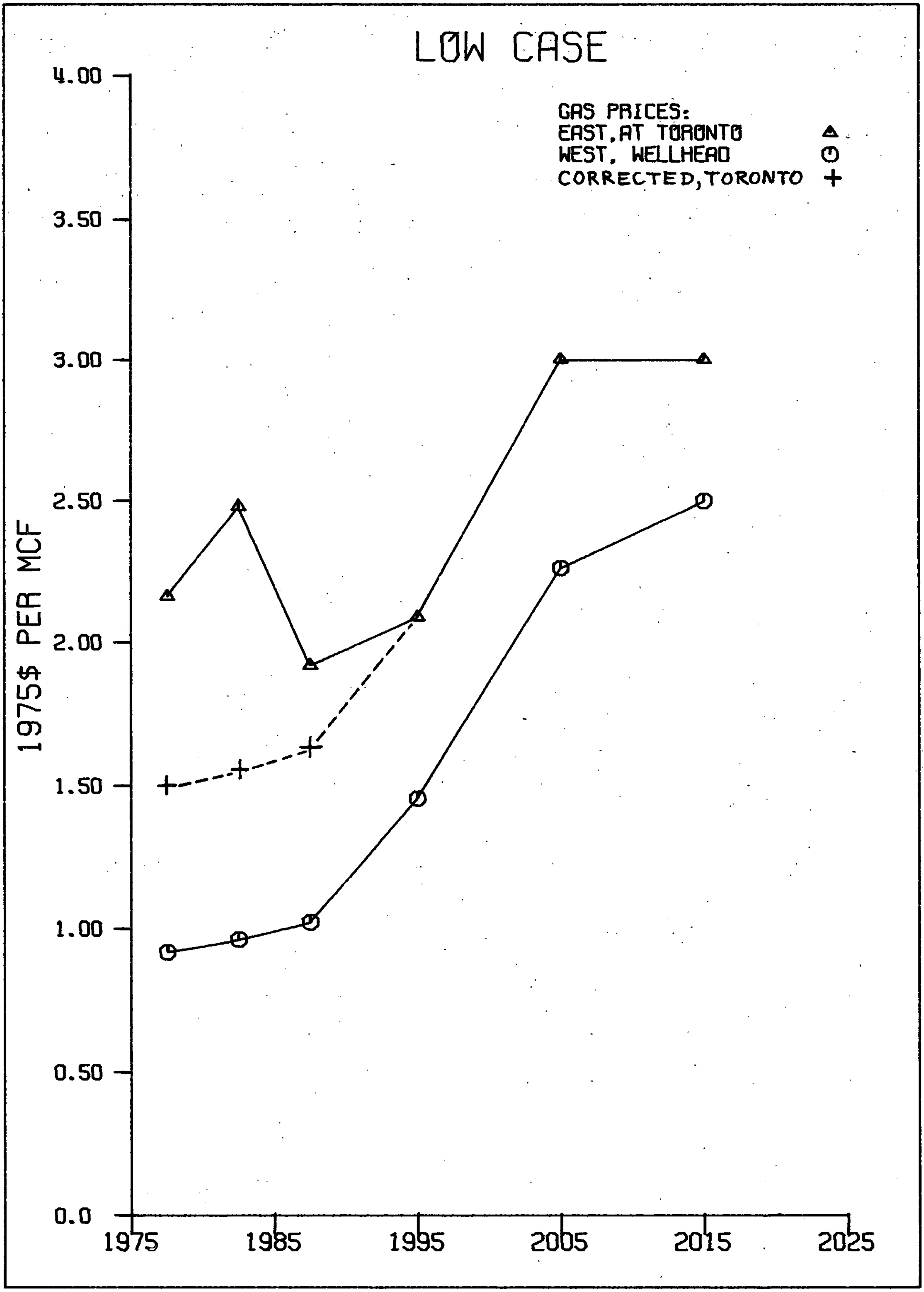

Figure 38. Gas Prices, Low Case.

Table 44. Secondary Energy Fuel Shares, High Case.

```
              HIGH CASE;          ;

SECONDARY SHARES:
IN UNITS OF   FRACTION

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                         1980     1985     1990     2000     2010     2020


SOLAR;                  0.0000   0.0000   0.0000   0.0143   0.0437   0.0914
COGENERATION;           0.0000   0.0000   0.0000   0.0000   0.0056   0.0227
ELECTRICITY;            0.1350   0.1810   0.1715   0.1872   0.3728   0.3788
GAS;                    0.2147   0.2508   0.3307   0.2999   0.1313   0.0765
OIL;                    0.6076   0.4981   0.4376   0.3652   0.2896   0.2612
COAL;                   0.0427   0.0700   0.0602   0.1335   0.1569   0.1694
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 39. Thus, the differences between the plotted lines are the entries in Table 44.)

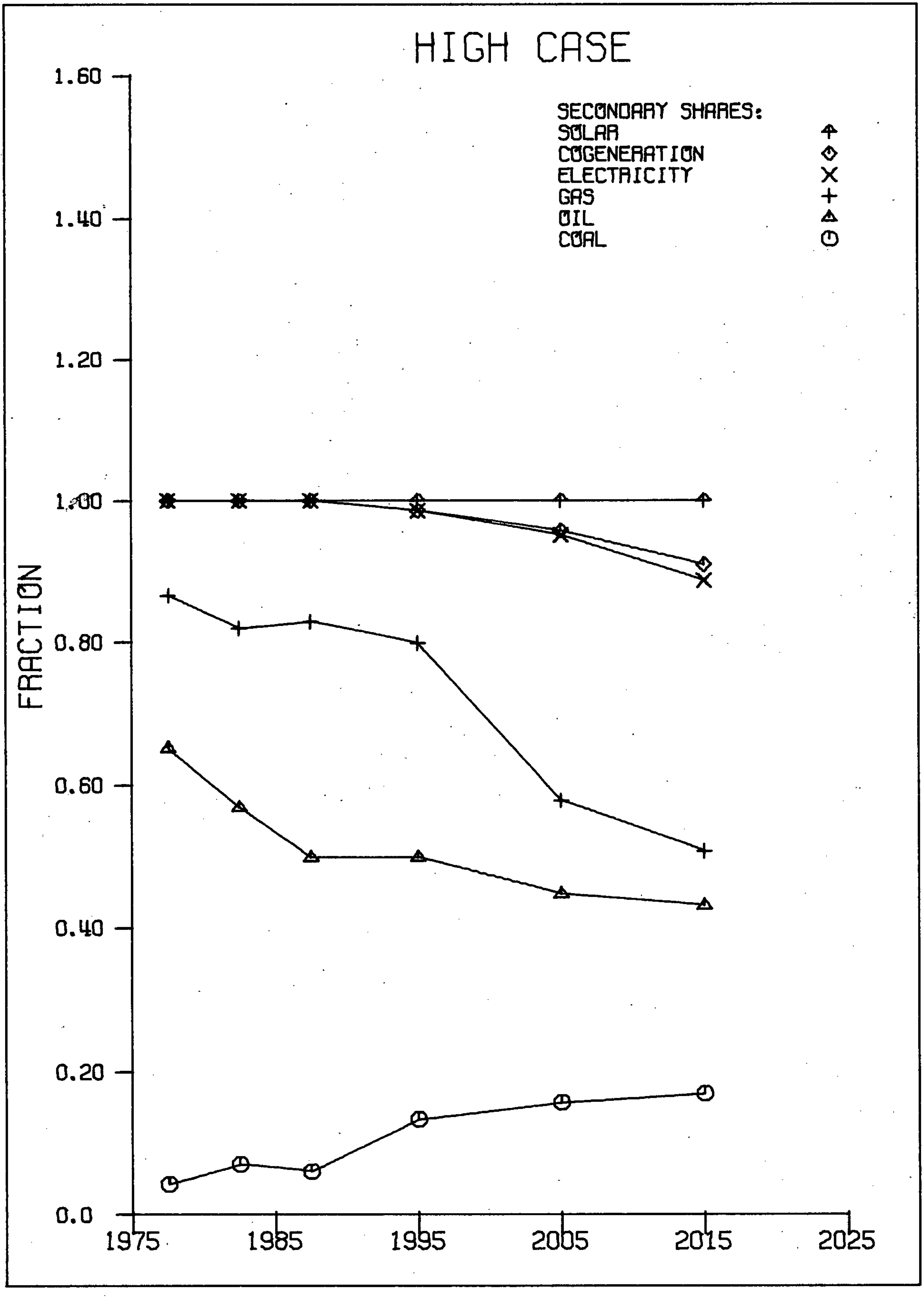

Figure 39. Secondary Energy Fuel Shares, High Case.

Table 45. Secondary Energy Fuel Shares, Low Case.

LOW CASE; ;

SECONDARY SHARES:
IN UNITS OF FRACTION

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
SOLAR;	0.0000	0.0000	0.0000	0.0000	0.0436	0.1137
COGENERATION;	0.0000	0.0000	0.0000	0.0000	0.0043	0.0160
ELECTRICITY;	0.1420	0.1867	0.1837	0.1816	0.3373	0.3822
GAS;	0.2166	0.2553	0.3543	0.3574	0.1680	0.0775
OIL;	0.5985	0.4883	0.3976	0.3355	0.3064	0.2607
COAL;	0.0429	0.0696	0.0644	0.1256	0.1404	0.1498

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 40. Thus, the differences between the plotted lines are the entries in Table 45.)

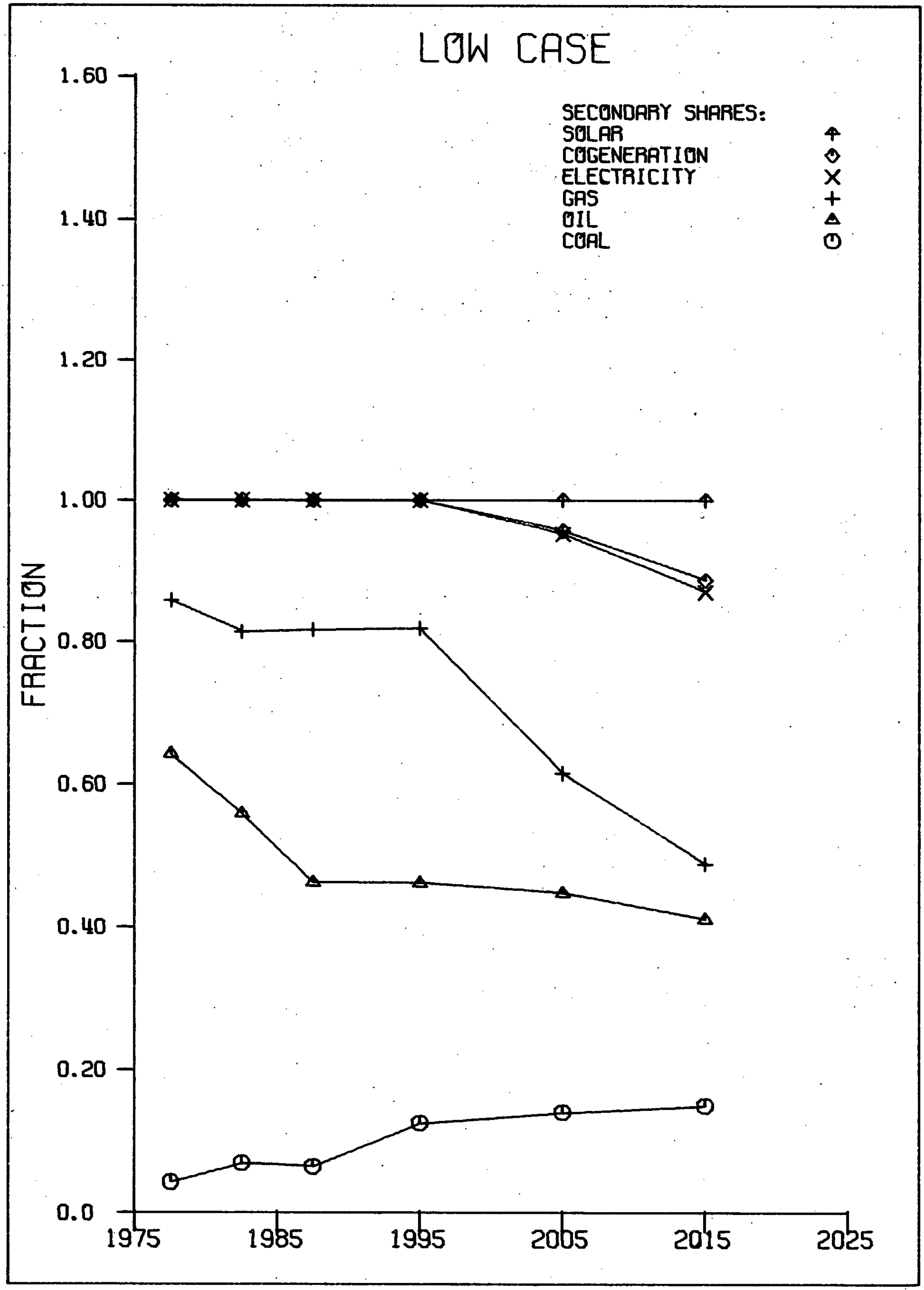

Figure 40. Secondary Energy Fuel Shares, Low Case.

Table 46. Primary Energy Fuel Shares, High Case.

HIGH CASE; ;

PRIMARY FUEL SHARES:
IN UNITS OF FRACTION

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
SOLAR;	0.0000	0.0000	0.0000	0.0128	0.0405	0.0847
BIOMASS;	0.0004	0.0003	0.0003	0.0001	0.0000	0.0000
HYDRO;	0.0953	0.1265	0.1236	0.1395	0.1194	0.1071
NUCLEAR;	0.0089	0.0204	0.0236	0.0329	0.2503	0.2560
GAS;	0.2499	0.2892	0.3490	0.3104	0.1326	0.0765
OIL;	0.5624	0.4609	0.4158	0.3565	0.2891	0.2612
COAL;	0.0832	0.1026	0.0878	0.1478	0.1681	0.2145

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 41. Thus, the differences between the plotted lines are the entries in Table 46.)

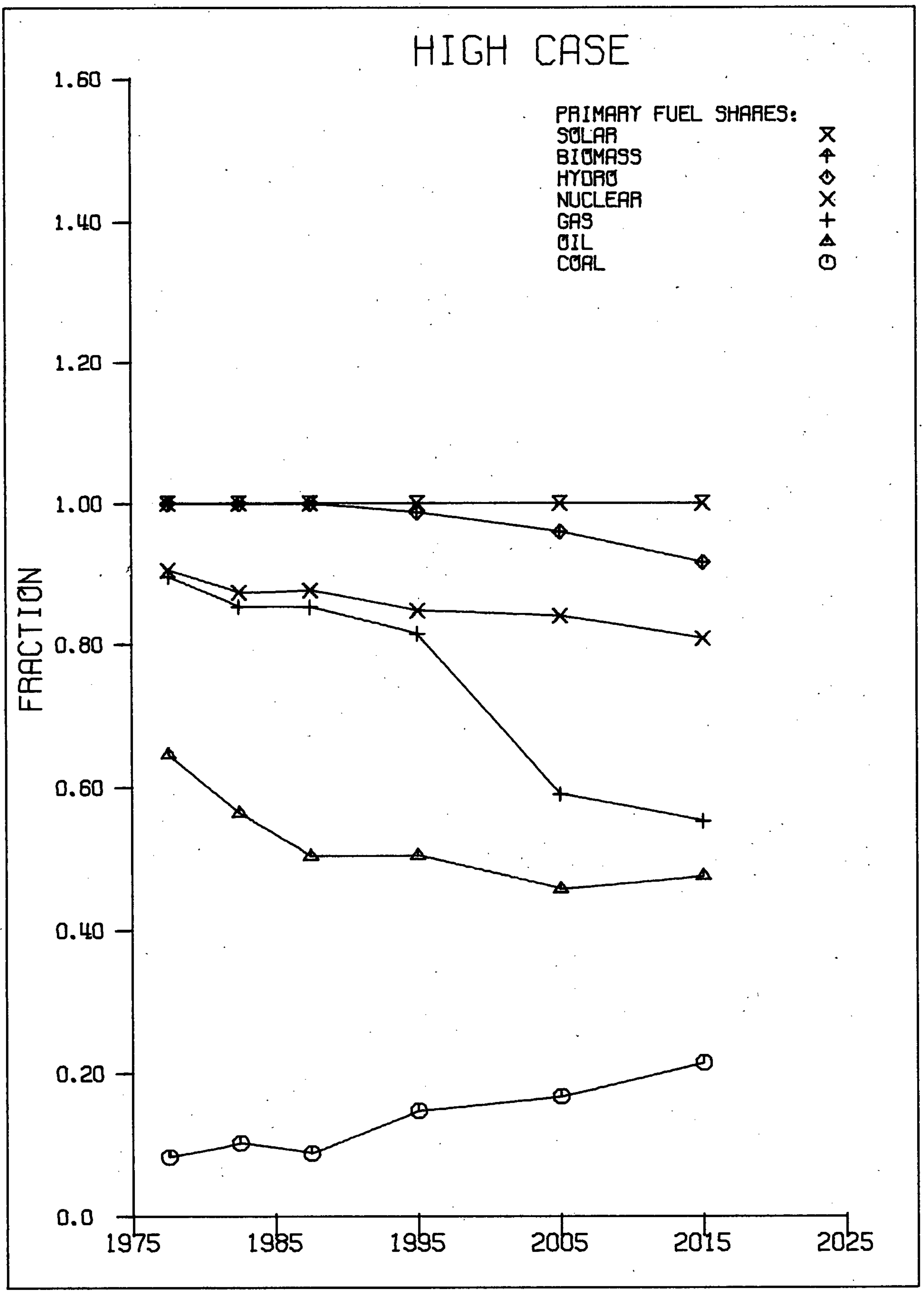

Figure 41. Primary Energy Fuel Shares, High Case.

Table 47. Primary Energy Fuel Shares, Low Case.

```
             LOW CASE;           ;

PRIMARY FUEL SHARES:
IN UNITS OF   FRACTION

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                         1980    1985    1990    2000    2010    2020


SOLAR;                  0.0000  0.0000  0.0000  0.0000  0.0401  0.1053
BIOMASS;                0.0004  0.0003  0.0003  0.0001  0.0000  0.0000
HYDRO;                  0.1002  0.1301  0.1315  0.1337  0.1589  0.1660
NUCLEAR;                0.0102  0.0211  0.0253  0.0313  0.1763  0.2083
GAS;                    0.2518  0.2945  0.3729  0.3678  0.1712  0.0779
OIL;                    0.5539  0.4511  0.3773  0.3261  0.3041  0.2606
COAL;                   0.0837  0.1028  0.0927  0.1409  0.1494  0.1819
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 42. Thus, the differences between the plotted lines are the entries in Table 47.)

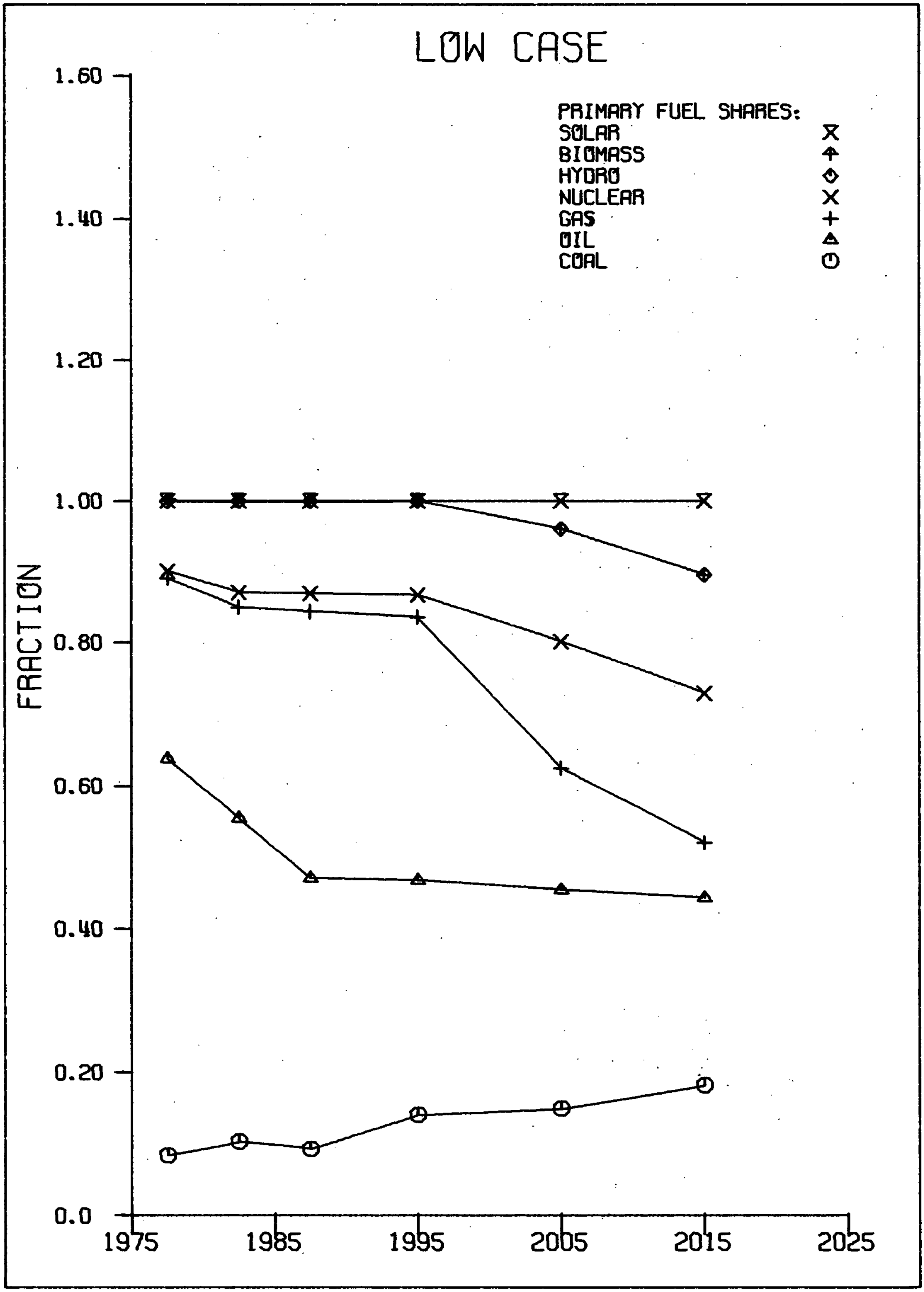

Figure 42. Primary Energy Fuel Shares, Low Case.

Table 48. Total Energy, High Case.

```
             HIGH CASE;           ;

TOTAL ENERGY:
IN UNITS OF    10**15 BTU PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980    1985    1990    2000    2010    2020

PRIMARY;           7.7803  8.5048 10.5024 12.6197 16.1401 22.1788
SECONDARY;         6.5072  7.1052  9.0571 11.2611 14.9247 20.5556
OUTPUT;            4.1747  4.8368  6.3592  8.3191 12.0677 17.2103
```

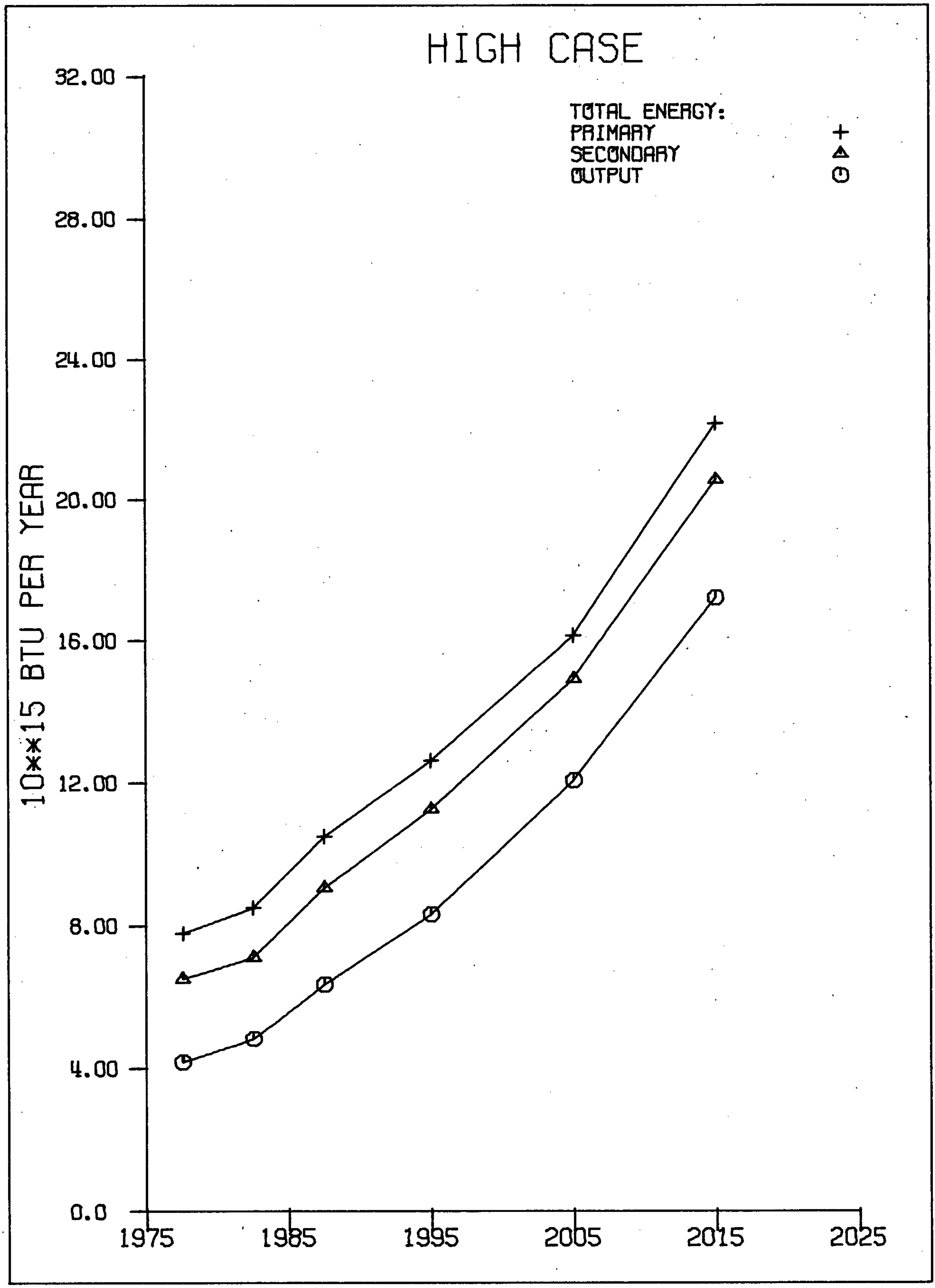

Figure 43. Total Energy, High Case.

Table 49. Total Energy, Low Case.

```
              LOW CASE;           ;

TOTAL ENERGY:
IN UNITS OF    10**15 BTU PER YEAR

         AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980    1985    1990    2000    2010    2020


PRIMARY;            7.7524  8.2129  9.4743 10.6642 11.0860 12.6733
SECONDARY;          6.4808  6.8390  8.1230  9.4369 10.1908 11.7338
OUTPUT;             4.1699  4.6710  5.7482  6.9101  8.0804  9.8033
```

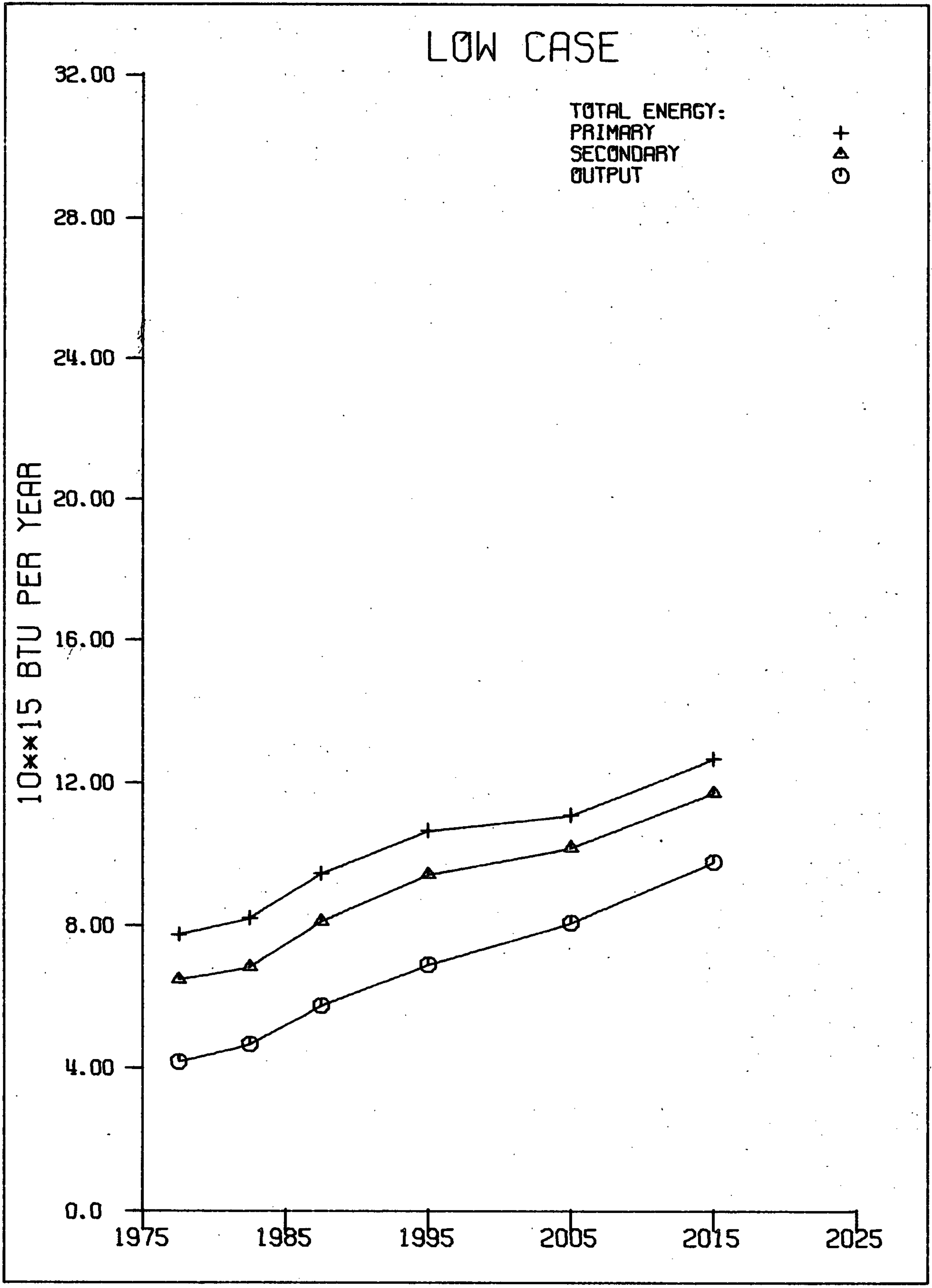

Figure 44. Total Energy, Low Case.

Chapter 8. Analysis of Some Energy Policy Questions

8.1. The Impacts of a No-New-Nuclear Policy

To examine the effects of a moratorium on the construction of new nuclear power facilities, the model was solved with additional limits fixing new nuclear electricity capacity at zero after 1985. Upper bounds were placed on new nuclear capacity in the east in the first two periods, at the base case solution's level in 1976-1980, and slightly below the base case level in 1981-1985. For reasons that will become apparent shortly, the fixing of tar sands production until 2000 was changed to lower bounding, but at the same level. All other assumptions were those of the base case.

There were unexpected results. The east, which in the base case relies heavily on nuclear power especially after 2000, does not switch mainly to coal-fired electricity production. Instead, the main change is a massive switch away from electricity production and use after 1985 in the east. Oil, notably from the tar sands, largely takes the place of electricity in the industrial sector and in the domestic, farm and commercial sector. There is increased use of western conventional oil in the early periods, followed by increased use of oil from the western arctic and especially from the tar sands after the year 2000. Since western coal, with its high transportation cost, is the alternative source for new electric capacity after eastern hydro is used to its maximum, electricity is more expensive than oil in end uses. Oil heating regains its importance in the east after 2000, replacing heavy reliance on electric resistance heating. There is some heating by cogeneration with the small amount of new coal-fired electricity production, and solar heating is introduced after 1990 in the east, one period earlier than in the base case. At the primary energy level, there is a big switch from nuclear energy to oil and somewhat to coal. Oil prices rise more quickly to the backstop price, \$12/bbl, because of the more rapid exhaustion of the cheaper sources than in the base case. Tables 50 to 53 and Figures 45 to 48 illustrate these trends.

There are no significant changes in the west, compared to the base case, apart from changes in oil production discussed above.

The economic benefits of allowing nuclear power can be estimated by comparing the values of the objective function in the solutions of the base case and the no-new-nuclear case. The objective function is the discounted sum of consumers' plus producers' surplus. (The dual equilibrium method to mitigate end effects is an approximation to the infinite horizon problem.) The difference in the two values of the objective function is approximately $\$1.7 \times 10^9$ (1975\$, discounted to 1975 using a 10% per annum discount rate). This is a surprisingly small value when one considers the importance of nuclear power in the base case solution. In per capita terms, the cost of following the no-new-nuclear route is only \$77 per person (assuming a population of 22 million), discounted to 1975, and in 1975\$. Discounting to 1980, and converting to 1980\$, this cost is only about \$300 per person, or \$30 per person per year, using 10% discount rate. Manne (1977, 1979) used the ETA-MACRO model to calculate the economic effects of banning additional civilian nuclear power plants in the United States after 1975. The present value of the losses in aggregate consumption (not of energy, but of all non-investment goods and services) from 1975 through 2050, also discounted at 10% per year, is $\$77 \times 10^9$, in 1975\$. The macroeconomic losses are low in the early years, but rise rapidly after the year 2000, when there are binding constraints on coal supplies. Manne concludes that "although a 'no-nuclear' policy would have negligible macroeconomic effects, there would be impacts throughout the energy sector." These general results are the same as the "no-nuclear" results for Canada, discussed above. The estimated value of the losses in the United States, $\$77 \times 10^9$, is higher than the value for Canada, $\$1.7 \times 10^9$, even if the usual factor of 10 is applied for rough economic comparisons between the two countries. Reasons for the higher figure include Manne's earlier cutoff of nuclear (after 1975, versus after 1985 in the model discussed here), and the existence in Canada of a relatively inexpensive alternate fuel -- oil from the tar sands.

The cost of the no-new-nuclear route to nuclear safety may be compared to the cost of the permanent containment of nuclear wastes, since this appears to be the most important consideration in nuclear safety. Aikin, Harrison and Hare (1977), made a very rough estimate of the cost of an underground nuclear waste repository. The capital cost is irrelevent here, since even in the no-new-nuclear alternative, the repository would have to be built, and operated until the old nuclear stations are shut down. The operating cost estimated by Aikin, Harrison and Hare (1977), \$100 million per year, is based on a projection of nuclear power development in the year 2000. The operating cost in the no-new nuclear alternative, until the plants are shut down, would presumably be much less than \$100 million per year, since the maximum nuclear level, in 1981-1985, is considerably less than in 2000. The extra cost of the containment of nuclear wastes in the nuclear alternative is therefore approximately

$$((\$100\text{x}10^6)/0.10) \times (1.10)^{-15} = \$0.24 \times 10^9,$$

discounted to 1975 at the rate of 10% per year, under the assumption that the repository would not begin operation until 1991. This cost is small compared to the cost of the no-new-nuclear path, $\$1.7\text{x}10^9$, calculated above.

These cost calculations do not necessarily suggest that the nuclear path should be favoured as the cheaper alternative. Since the estimated costs of safety are quite low in either case, it may be concluded that the issue should not be decided on economic grounds. Rather, the closest attention should be paid to the technical feasibility of the nuclear safety proposals by the nuclear advocates, and to the health effects of nuclear power production. Some key plots are shown in Figures 45 to 48, with the corresponding Tables 50 to 53.

The above analysis of the no-new-nuclear path depends on assumptions about the cost and availability of oil from the tar sands. If there are in fact upper limits on tar sands production (due to physical and environmental limits such as water shortages, or inability to treat the waste water), or if synthetic crude oil is much more expensive than was assumed (due perhaps to cost escalations in periods of rapid increases in capacity), the cost of the no-new-nuclear path would be greater. Inclusion of upper limits on tar sands production, or an increasing marginal cost for expansion of tar sands capacity would likely bring about a smaller shift to tar sands, and a greater shift to other fuels, such as natural gas (in the medium term, at least, before supplies are nearly exhausted) and coal. As a step in this direction, the no-new-nuclear case was solved again, but with oil from the tar sands at a cost of $13.50/bbl, rather than $12/bbl. Still the tar sands play a big role in replacing electricity in general, and nuclear power in particular, but frontier natural gas adopts much of the replacement role initially, before the last period, 2011-2020.

Another assumption which influences the no-new-nuclear case, but in a way which does not affect the main conclusions above, is the constraint limiting the share of new eastern electricity generation which may be met by hydro. In the first period, this constraint has no effect different from the base case, since there is no severe restriction on nuclear in this period. In the second period, the upper limit on new nuclear capacity, smaller than the level calculated in the base case, brings about a forced decrease in hydro, through the hydro share constraint. This is unrealistic since in reality, restrictions on nuclear would likely increase hydro's share, perhaps by Quebec exporting hydroelectricity to Ontario. Similarly, in the third period, there is no new nuclear capacity allowed, and no coal-fired electricity is added, which together force zero new hydro capacity, through the share constraint. After the third period, there is some coal-fired electricity capacity added, which allows new hydro to be added, until the upper limit on hydro generation is reached after the year 2000, one period later than in the base case. This deficiency does not affect the conclusions of the switch from nuclear to tar sands and from electricity in general to oil, since the main switch is after 2000, when hydro is at its upper limit in the no-new-nuclear case. Furthermore, the calculation of the economic benefits of allowing nuclear power would lead to even lower benefits if the restrictions on hydro were relaxed, since the no-new-nuclear route would be less costly. Thus, the overly-restrictive assumptions about hydro reinforce the conclusion that the economic benefits of allowing nuclear power are negligible.

Table 50. Crude Oil Production, No-new-nuclear Case.

```
            BASE CASE;            NO NEW NUCLEAR;

OIL PRODUCTION:
IN UNITS OF   10**9 BBL PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980     1985     1990     2000     2010     2020


IMPORTS;             0.2791   0.1141   0.0000   0.0000   0.0000   0.0000
FROM BIOMASS;        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
FROM COAL;           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
EASTERN;             0.0008   0.0100   0.0500   0.1772   0.2058   0.0740
TAR SANDS;           0.0362   0.0744   0.1534   0.2756   0.4122   1.1234
WEST ARCTIC;         0.0000   0.0000   0.0000   0.0000   0.2803   0.1317
WESTERN;             0.5566   0.5056   0.5714   0.3039   0.0793   0.0000
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 45. Thus, the differences between the plotted lines are the entries in Table 50.)

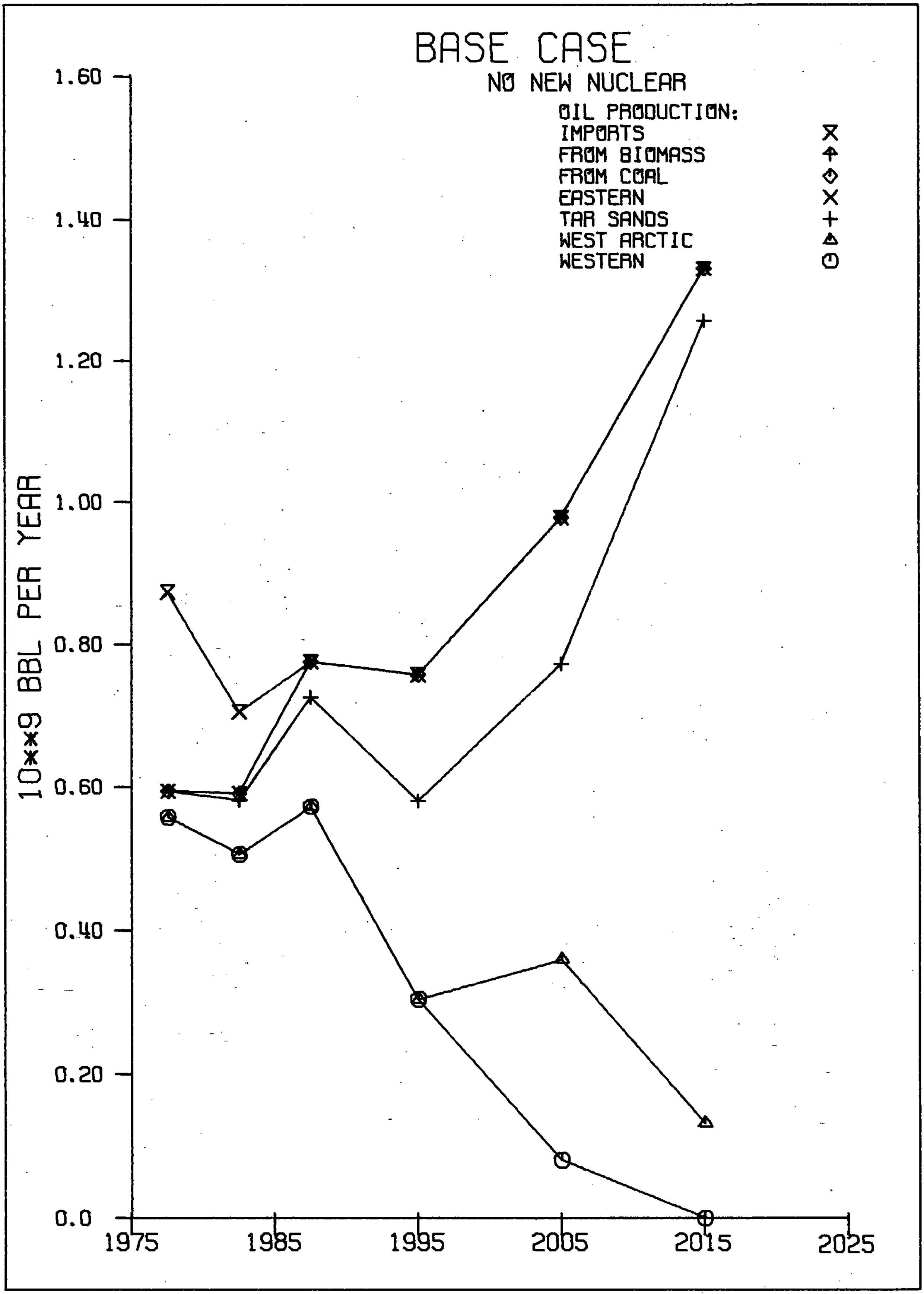

Figure 45. Crude Oil Production, No-new-nuclear Case.

Table 51. Oil Use, No-new-nuclear Case.

```
              BASE CASE;           NO NEW NUCLEAR;

OIL USE:
IN UNITS OF   10**9 BBL PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980    1985    1990    2000    2010    2020


EXPORTS;            0.1194  0.0304  0.0146  0.0067  0.0000  0.0000
OTHER TRANSPORT;    0.0620  0.0688  0.0804  0.0997  0.1247  0.1646
ROAD TRANSPORT;     0.2123  0.2039  0.2098  0.2308  0.2627  0.3311
INDUSTRY;           0.1501  0.1331  0.2416  0.2980  0.3833  0.5052
DFC;                0.2562  0.2024  0.1582  0.0569  0.1347  0.2303
ELECTRICITY;        0.0172  0.0160  0.0142  0.0095  0.0000  0.0000
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 46. Thus, the differences between the plotted lines are the entries in Table 51.)

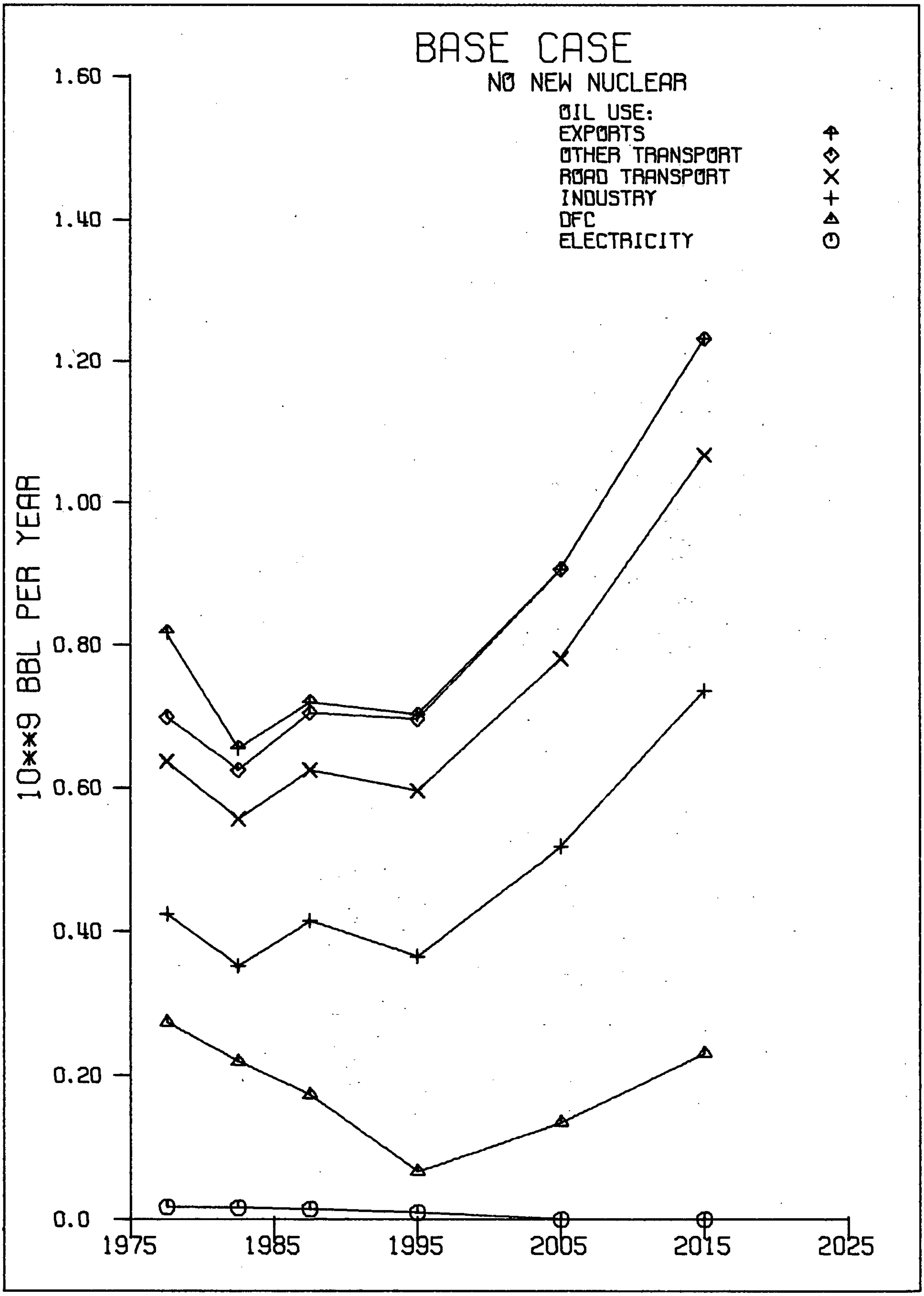

Figure 46. Oil Use, No-new-nuclear Case.

Table 52. Eastern Electricity Production, No-new-nuclear Case.

```
               BASE CASE;          NO NEW NUCLEAR;

ELECTRICITY, EAST:
IN UNITS OF   10**12 KWH PERYEAR

          AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980    1985    1990    2000    2010    2020


FROM BIOMASS;        0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
NUCLEAR;             0.0201  0.0427  0.0427  0.0421  0.0275  0.0000
OIL AND GAS;         0.0124  0.0128  0.0117  0.0076  0.0000  0.0000
COAL;                0.0228  0.0223  0.0205  0.0368  0.0979  0.1254
HYDRO;               0.1666  0.2331  0.2165  0.2406  0.4420  0.4420
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 47. Thus, the differences between the plotted lines are the entries in Table 52.)

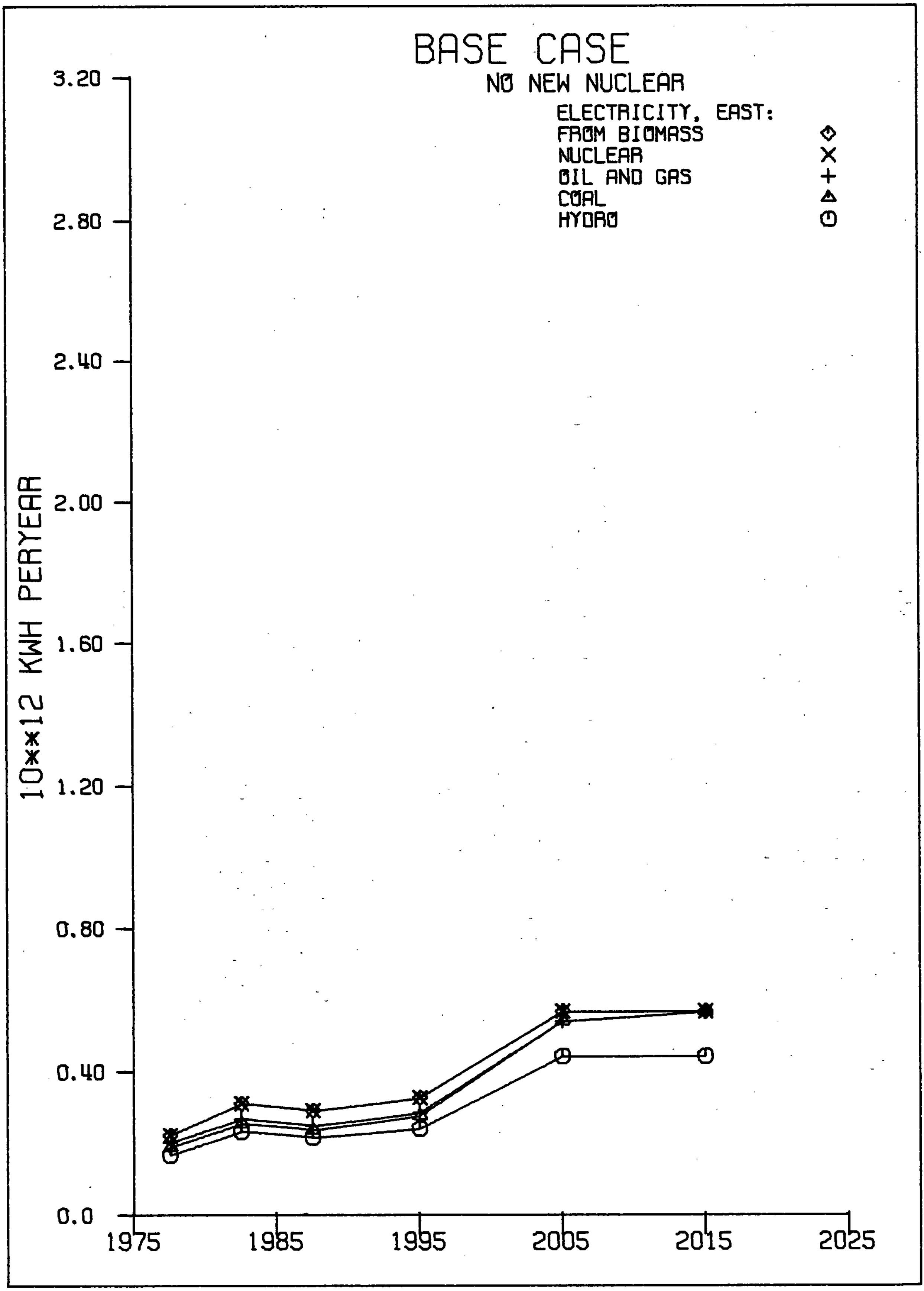

Figure 47. Eastern Electricity Production, No-new-nuclear Case.

Table 53. Primary Energy Fuel Shares, No-new-nuclear Case.

```
              BASE CASE;           NO NEW NUCLEAR;

PRIMARY FUEL SHARES:
IN UNITS OF   FRACTION

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980    1985    1990    2000    2010    2020


SOLAR;              0.0000  0.0000  0.0000  0.0177  0.0361  0.0925
BIOMASS;            0.0004  0.0003  0.0003  0.0002  0.0000  0.0000
HYDRO;              0.0952  0.1170  0.0927  0.0905  0.1578  0.1333
NUCLEAR;            0.0088  0.0175  0.0146  0.0125  0.0071  0.0000
GAS;                0.2500  0.2926  0.3605  0.3416  0.1419  0.0680
OIL;                0.5624  0.4705  0.4419  0.3787  0.4264  0.4606
COAL;               0.0832  0.1020  0.0900  0.1589  0.2307  0.2457
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 48. Thus, the differences between the plotted lines are the entries in Table 53.)

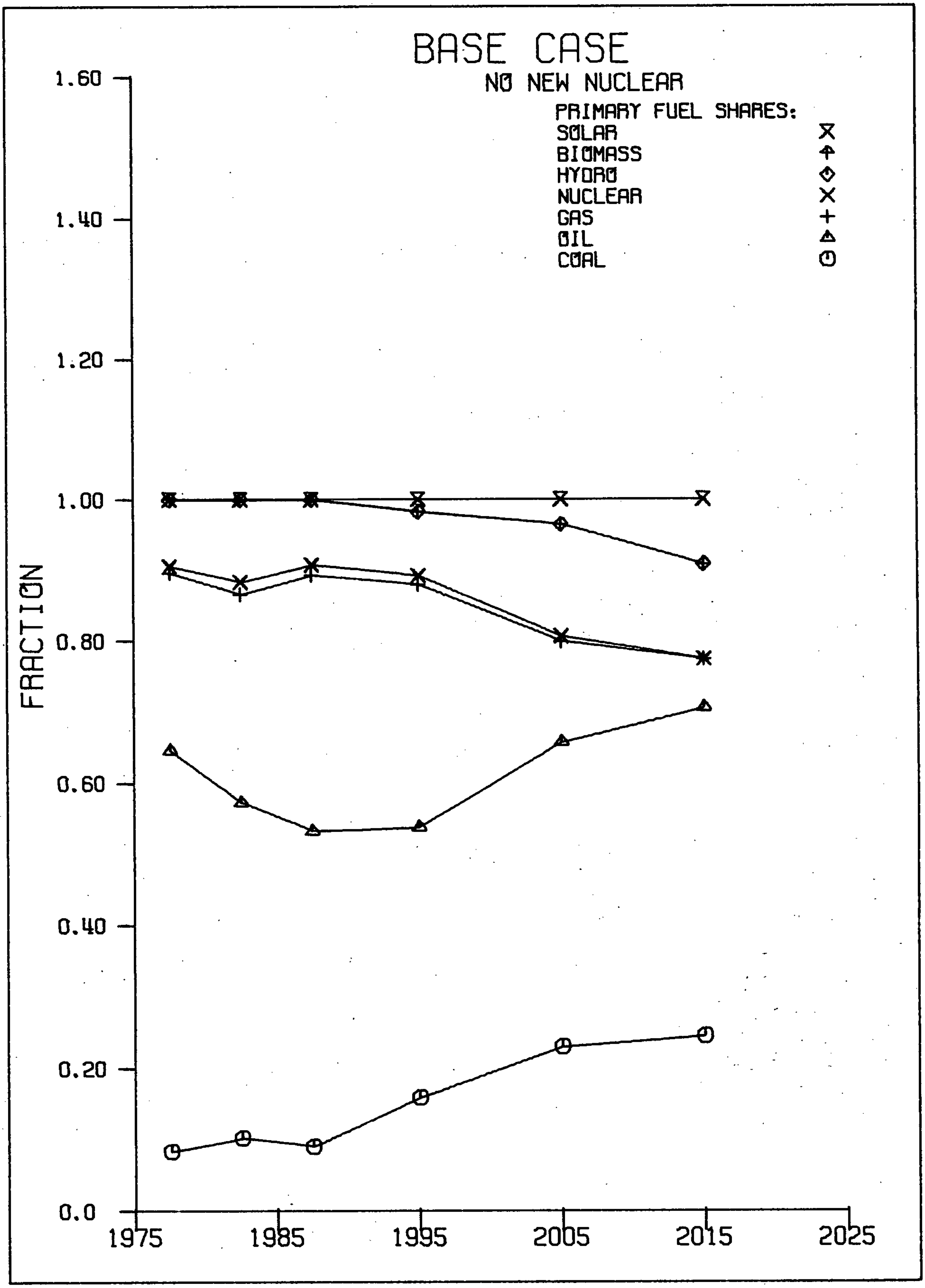

Figure 48. Primary Energy Fuel Shares, No-new-nuclear Case.

8.2. Allowing Heating by Cogeneration with Nuclear Power

It was assumed in the base case that heating by cogeneration with nuclear electricity is not allowed, because the public might not accept it. To investigate this, the base case was run again, but allowing cogeneration with nuclear power. It was assumed that the maximum ratio of heat to electrical output in nuclear cogeneration is half the maximum ratio in coal-fired cogeneration - i.e. for every kilowatt-hour of nuclear electricity, up to 2,132.5 BTU of heat can be supplied to the domestic, farm and commercial sector. This lower figure for nuclear cogeneration was chosen because, according to Berthin (1980), there is less heat available in a CANDU generation system for this purpose than in a coal-fired electricity generation station. The cost of using nuclear cogenerated heat was assumed to be the same as for cogeneration using coal. As with coal cogeneration,it was assumed that new capacity of heat by cogeneration with nuclear can only be established with new nuclear electricity capacity. Judging by Berthin's study, it is likely that nuclear facilities would have to be closer to population centres than at present, for the district heating scheme to work with the costs Berthin estimates.

Under these assumptions, nuclear cogeneration begins in the east as soon as it is allowed (after 1980), and reliance on this heating method becomes quite heavy after 2000, indicating that nuclear cogeneration is competitive in the east.

The main heating method displaced is electric resistance heating, although it is still very important. Solar heating enters the solution one period later (2011-2020) than in the base case. One curious consequence of the displacement of electric resistance heating is that the generation of electricity by nuclear power is considerably lower than in the base case.

Table 54. DFC Heating, East, Nuclear Cogeneration Case.

BASE CASE; NUCLEAR COGEN.;

DFC HEATING, EAST:
IN UNITS OF 10**15 OUTPUT BTU/YR

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
SOLAR;	0.0000	0.0000	0.0000	0.0000	0.0000	0.1439
COGENERATION;	0.0000	0.0594	0.0594	0.1535	1.2633	1.8313
HEAT PUMP;	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ELECTRIC RESIS.;	0.1989	0.2938	0.2003	0.6660	0.9618	1.0768
GAS;	0.3000	0.4026	0.9879	1.2308	0.2350	0.0000
OIL;	0.8498	0.6834	0.5522	0.0000	0.0000	0.0000

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 49. Thus, the differences between the plotted lines are the entries in Table 54.)

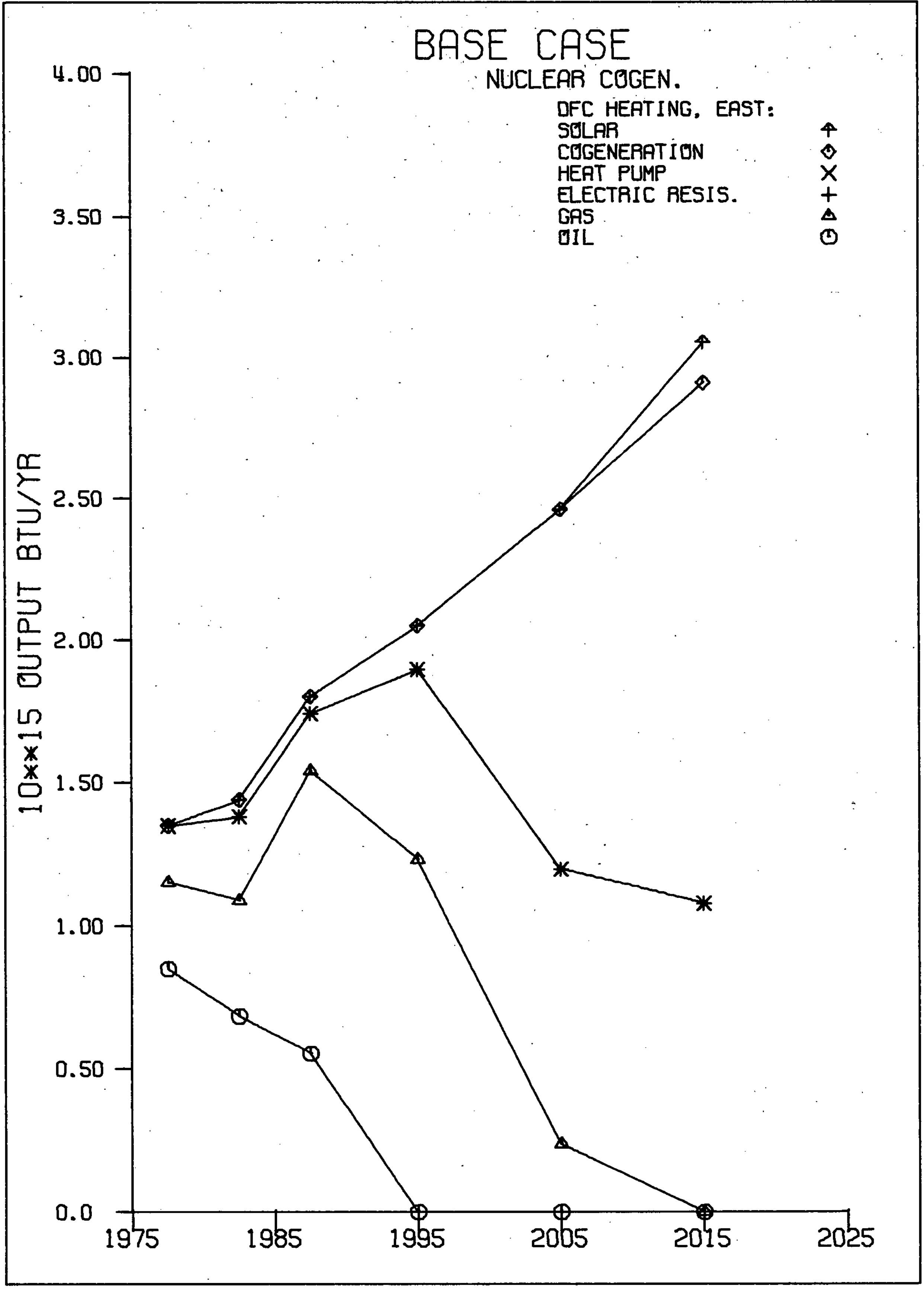

Figure 49. DFC Heating, East, Nuclear Cogeneration Case.

Table 55. Eastern Electricity Production, Nuclear Cogeneration Case.

```
          BASE CASE;           NUCLEAR COGEN.;

ELECTRICITY, EAST:
IN UNITS OF   10**12 KWH PERYEAR

       AVERAGE VALUES FOR THE PERIOD ENDING IN

                      1980    1985    1990    2000    2010    2020


FROM BIOMASS;        0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
NUCLEAR;             0.0230  0.0509  0.0726  0.1162  0.6206  0.8696
OIL AND GAS;         0.0124  0.0128  0.0117  0.0076  0.0000  0.0000
COAL;                0.0228  0.0223  0.0205  0.0145  0.0000  0.0000
HYDRO;               0.1769  0.2620  0.3220  0.4228  0.4420  0.4420
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 50. Thus, the differences between the plotted lines are the entries in Table 55.)

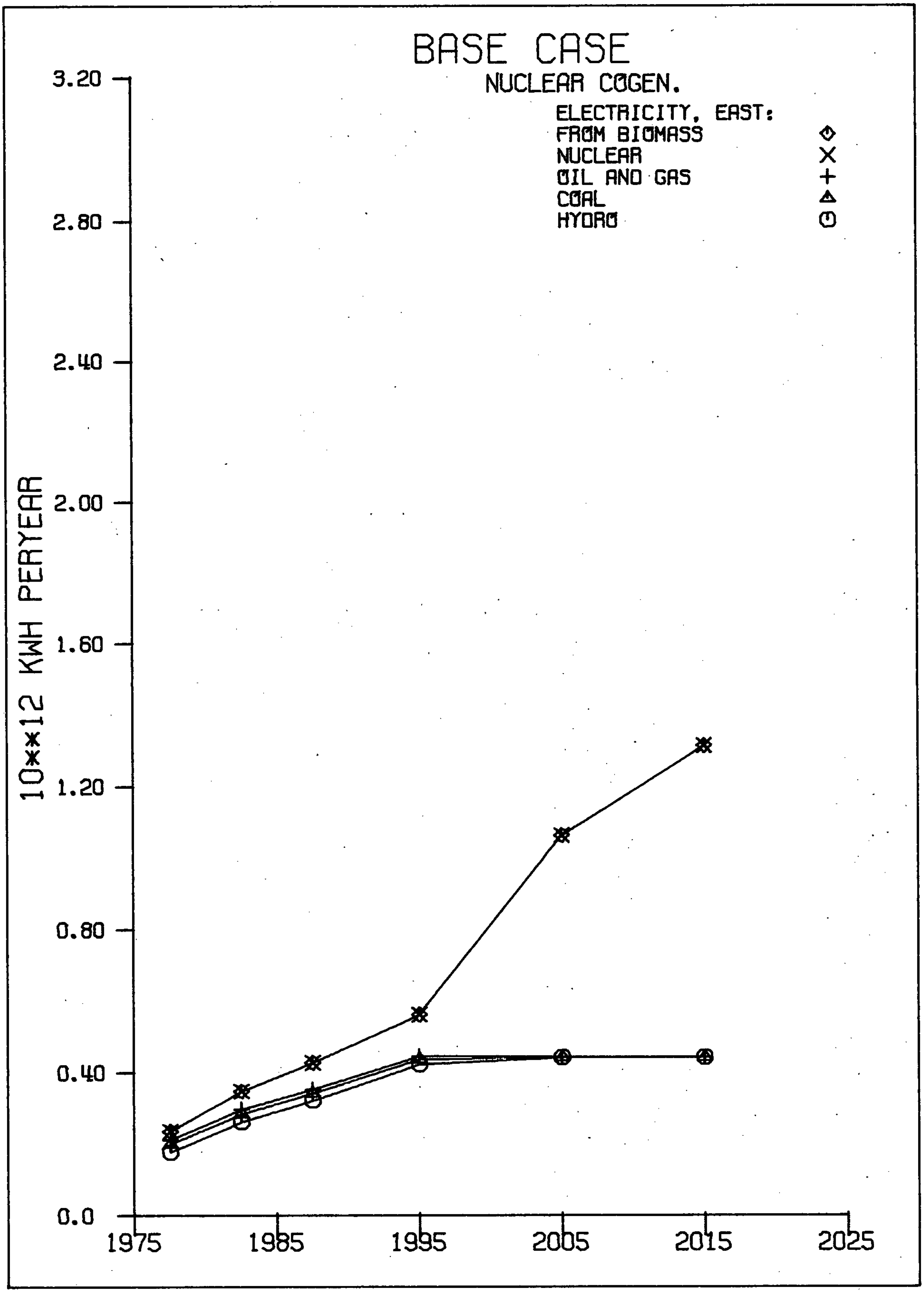

Figure 50. Eastern Electricity Production, Nuclear Cogeneration Case.

Table 56. Secondary Energy Fuel Shares, Nuclear Cogeneration Case.

BASE CASE; NUCLEAR COGEN.;

SECONDARY SHARES:
IN UNITS OF FRACTION

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
SOLAR;	0.0000	0.0000	0.0000	0.0000	0.0000	0.0332
COGENERATION;	0.0000	0.0085	0.0069	0.0146	0.1089	0.1402
ELECTRICITY;	0.1420	0.1835	0.1791	0.1905	0.3025	0.3375
GAS;	0.2169	0.2528	0.3418	0.3204	0.1502	0.0770
OIL;	0.5982	0.4851	0.4100	0.3440	0.2920	0.2576
COAL;	0.0429	0.0701	0.0622	0.1305	0.1464	0.1545

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 51. Thus, the differences between the plotted lines are the entries in Table 56.)

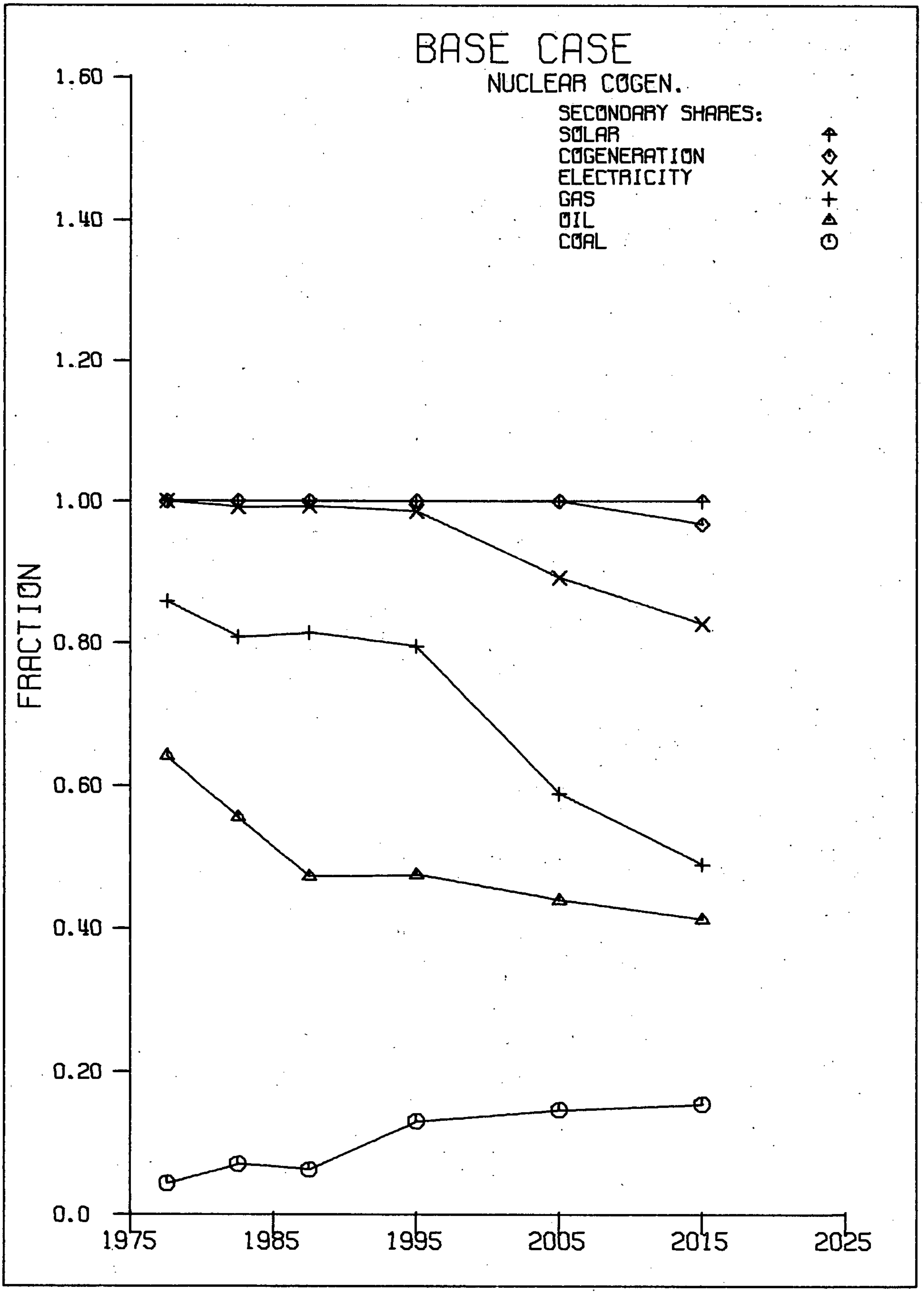

Figure 51. Secondary Energy Fuel Shares, Nuclear Cogeneration Case.

This suggests an unexpected route to lessen future growth in the number of nuclear power stations. If district heating using waste heat from nuclear power stations can be proven to be 100% safe, then the environmental hazards of nuclear power may be reduced in magnitude by adopting this type of heating on a large scale in the east, although the likelihood that nuclear stations would have to be closer to population centres may influence this result.

The difference in the value of the objective function between the base case and the nuclear cogeneration case - i.e. the economic benefit of nuclear cogeneration - is \$0.562 x 10^9, in 1978\$, discounted to 1975 at the rate of 10% per year, or about \$26 per person in 1975. Even when this is converted to 1980\$, and discounting is done to 1980, the benefit is only approximately \$100 per person, or \$10 per person per year. Thus, as with the question of whether to forbid new nuclear power stations, the issue of nuclear cogeneration should not be decided on economic grounds. The important questions are the technical feasibility and safety of the system.

Some key plots for this case are shown in Figures 49, 50 and 51, with the corresponding Tables 54, 55 and 56.

8.3. High Oil Costs (Sensitivity Analysis)

There have recently been suggestions that the costs of syncrude from the tar sands and of conventional oil have been escalating more rapidly than the general rise in prices. Quon (1980) suggests that the real costs of oil production have been increasing as both capital and labour have demanded a higher portion of the perceived economic rent (in the expectation of much higher oil prices). Furthermore, they have actually received higher payments for drilling rig rentals, wages, etc. because of the strong demand for these services (again due to the expectation of much higher oil prices). To investigate this possibility the model was solved with all the base case assumptions except the following higher oil costs:

Oil Source		Base Case Cost	Higher Cost	
western conventional,	"low cost"	$ 4/bbl	$ 4/bbl	(unchanged)
western conventional,	"high cost"	$ 8/bbl	$10/bbl	
northwest frontier,	"low cost"	$10/bbl	$12/bbl	
northwest frontier,	"high cost"	$14/bbl	$16/bbl	
tar sands		$12/bbl	$15/bbl	
southeast offshore		$ 7/bbl	$ 9/bbl	
northeast offshore		$10/bbl	$12/bbl	

The tar sands cost has been increased to approximately the 1980 international price of oil (in 1975$) since the participants in proposed new tar sands projects claim that the world price is needed to make the projects economically viable. Other costs have been increased by $2 per barrel, except the established, low cost western oil.

The results of this sensitivity analysis were not surprising, with one exception -- solar heating is introduced in the east after 1980, although it remains at a very low level until after 2000, when it is first introduced in the base case. Apparently the higher oil costs cause increases in the price of heating in the east just enough to make solar competitive earlier.

Except for the last period, there is lower oil production and use. Tar sands production in the first five periods is at the same level as in the base case because production in the first four periods is fixed exogenously, and drops in the fifth to the same level in both cases because there is no capacity added, but old capacity is removed. Production of "low cost" western oil, the cheapest source, at an unchanged cost, is delayed,

Table 57. Crude Oil Production, High Oil Costs Case.

```
               BASE CASE;          HIGH OIL COSTS;

OIL PRODUCTION:
IN UNITS OF   10**9 BBL PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                        1980     1985     1990     2000     2010     2020


IMPORTS;               0.2553   0.0976   0.0000   0.0000   0.0000   0.0000
FROM BIOMASS;          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
FROM COAL;             0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
EASTERN;               0.0008   0.0100   0.0500   0.1772   0.0784   0.1467
TAR SANDS;             0.0362   0.0744   0.1534   0.2756   0.2516   0.1646
WEST ARCTIC;           0.0000   0.0000   0.0000   0.0000   0.0000   0.2917
WESTERN;               0.5283   0.4477   0.3885   0.1735   0.2330   0.0917
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 52. Thus, the differences between the plotted lines are the entries in Table 57.)

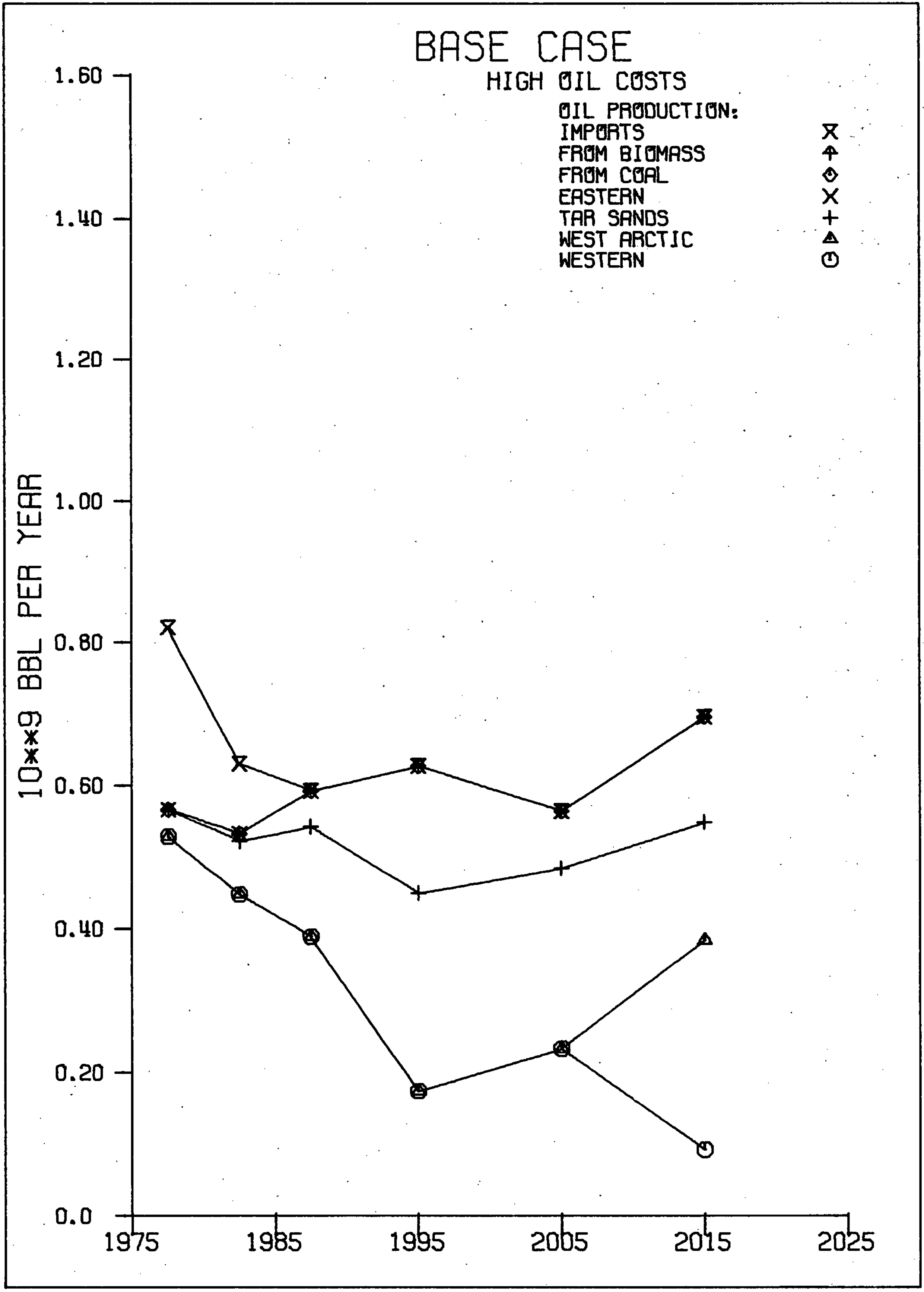

Figure 52. Crude Oil Production, High Oil Costs Case.

Table 58. Crude Oil Prices, High Oil Costs Case.

BASE CASE; HIGH OIL COSTS;

CRUDE OIL PRICES:
IN UNITS OF 1975$ PER BBL

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
EXPORTS;	14.6000	17.8000	21.6000	32.0000	32.0000	32.0000
IMPORTS;	10.8000	14.8000	19.3000	32.0000	32.0000	32.0000
EAST;	8.2645	11.5173	11.2635	10.3818	11.9748	14.0171
WEST;	5.6049	10.0369	10.7639	9.8821	11.4750	13.5176

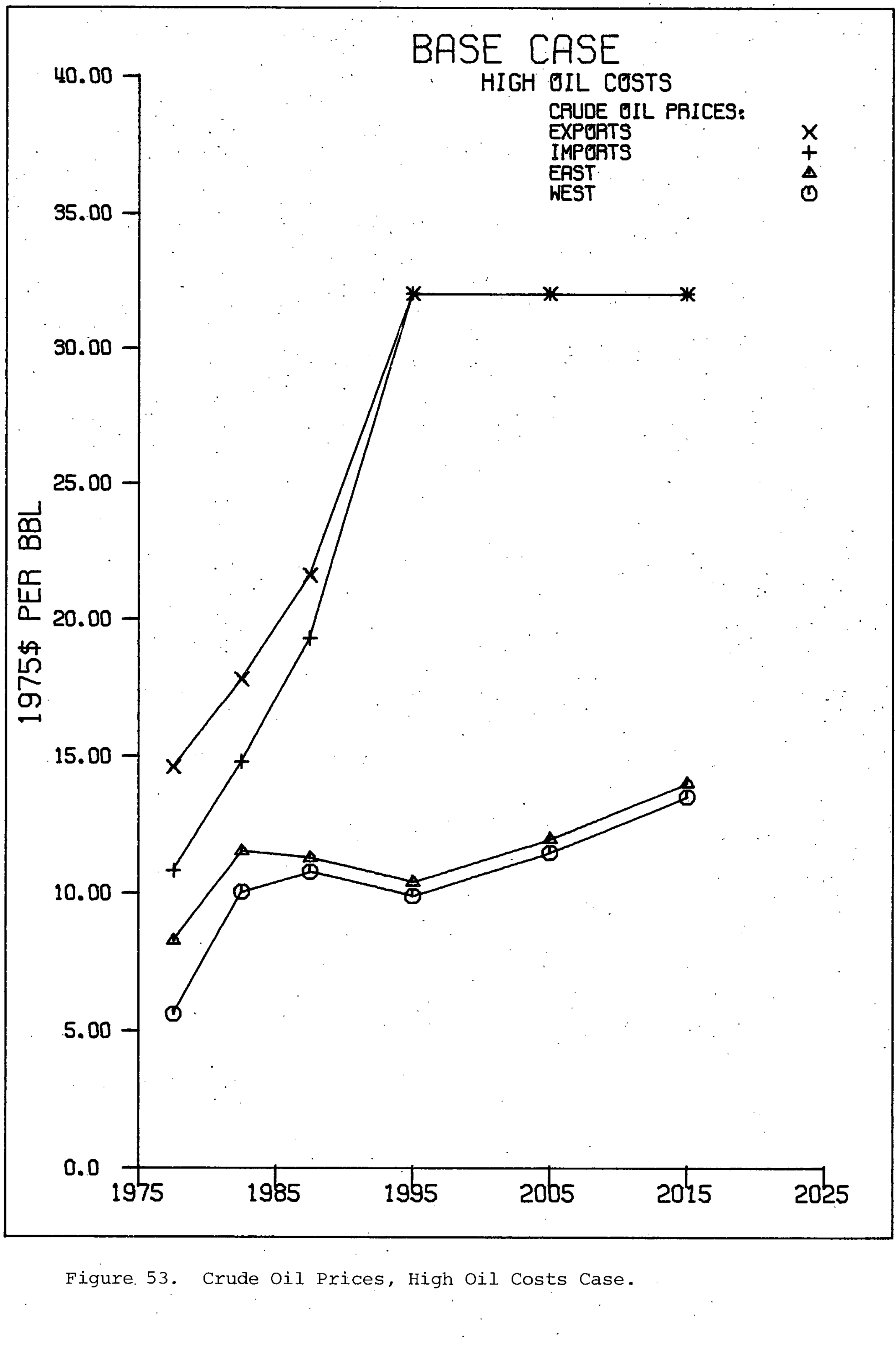

Figure 53. Crude Oil Prices, High Oil Costs Case.

Table 59. Secondary Energy Fuel Shares, High Oil Costs Case.

BASE CASE; HIGH OIL COSTS;

SECONDARY SHARES:
IN UNITS OF FRACTION

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
SOLAR;	0.0000	0.0054	0.0044	0.0018	0.0432	0.1100
COGENERATION;	0.0000	0.0000	0.0000	0.0000	0.0121	0.0191
ELECTRICITY;	0.1602	0.1920	0.1877	0.2062	0.3916	0.3844
GAS;	0.2198	0.2634	0.3580	0.3362	0.1462	0.0740
OIL;	0.5769	0.4699	0.3689	0.3260	0.2592	0.2573
COAL;	0.0432	0.0693	0.0811	0.1298	0.1477	0.1552

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 54. Thus, the differences between the plotted lines are the entries in Table 59.)

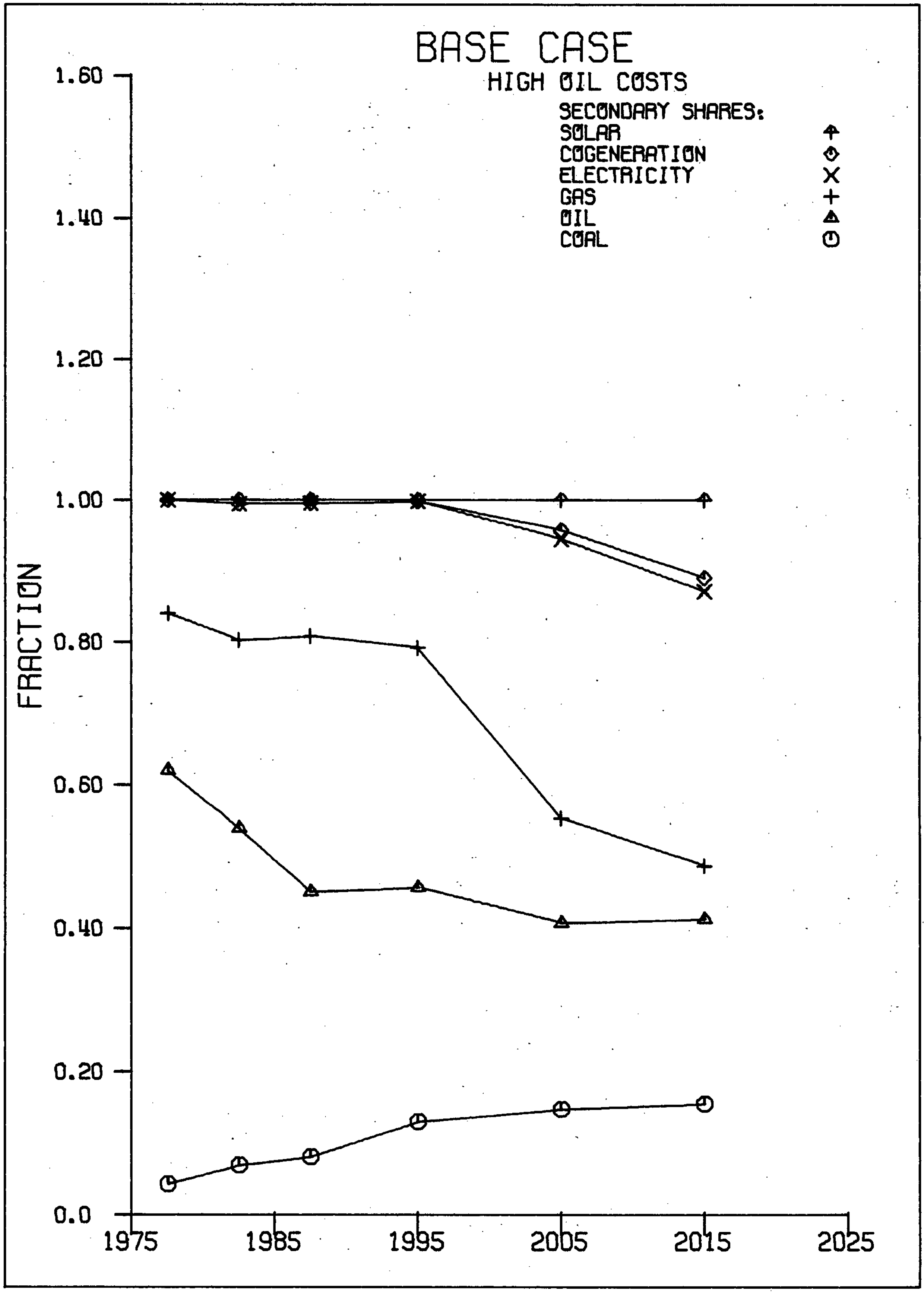

Figure 54. Secondary Energy Fuel Shares, High Oil Costs Case.

compared to the base case -- in effect "saved" for the future, to put off the use of the more expensive sources at the increased costs. The introduction dates of northwestern arctic and northeastern offshore oil are delayed one period due to the assumed higher costs and consequent lower demand and production.

The prices of oil are higher, but the increase over the base case is less than the cost increase (\$2/bbl for all except tar sands) except in the period 1986-1990. The oil price does not reach the backstop cost (tar sands) within the model's time horizon. Gas prices are higher in the east, until the last two periods.

There is a small switch from oil use to greater reliance on gas in the medium term and on electricity from coal and nuclear sources, compared to the base case.

In the two transportation sectors, which depend on oil alone, there is only a slightly reduced demand for oil, due to the quite inelastic demand specified in those sectors.

See Figures 52, 53 and 54 for plots of this case.

8.4. The Impacts of Competitive Coal Gasification

As discussed in chapter 6, coal gasification is not in the base case solution, but is almost competitive in the later periods. To examine the impacts of the introduction of coal gasification, the model was solved with the base case assumptions except that the distribution margin for coal to gasification plants was reduced by one half, to $\$0.40/10^6$ BTU. This is equivalent to reducing the price of gas from coal to \$2.30/mcf, from the price of \$3.00/mcf in the base case, making this gas source cheaper than gas from the northwest arctic. Another change in the assumptions for this

Table 60. Coal Production, Coal Gas Case.

```
            BASE CASE;          CHEAP COAL GAS;

COAL PRODUCTION:
IN UNITS OF   10**8 TONS PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                     1980     1985     1990     2000     2010     2020


IMPORTS;            0.1580   0.1465   0.0000   0.0000   0.0000   0.0000
EASTERN;            0.0482   0.0964   0.1928   0.3453   0.3267   0.2070
WESTERN;            0.2642   0.3743   0.5037   0.8817   1.6627   4.0277
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 55. Thus, the differences between the plotted lines are the entries in Table 60.)

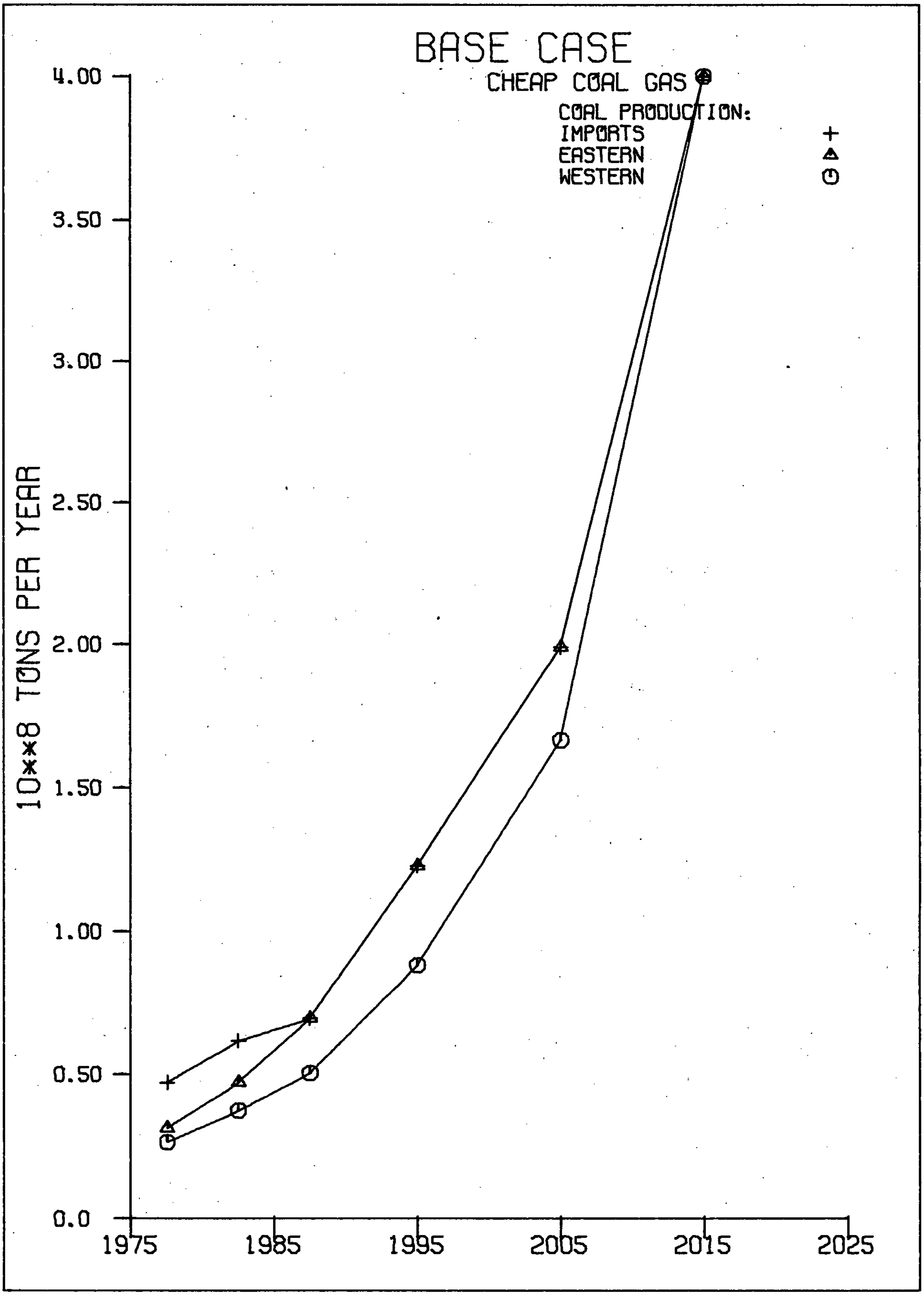

Figure 55. Coal Production, Coal Gas Case.

Table 61. Gas Production, Coal Gas Case.

BASE CASE; CHEAP COAL GAS;

GAS PRODUCTION:
IN UNITS OF TCF PER YEAR

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
FROM BIOMASS;	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004
FROM COAL;	0.0000	0.0000	0.0000	0.0000	0.3861	2.1806
EASTERN;	0.0002	0.0002	0.4800	0.7703	0.4578	0.1317
WEST ARCTIC;	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WESTERN;	2.9523	4.0228	3.7306	3.0290	1.1982	0.2199

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 56. Thus, the differences between the plotted lines are the entries in Table 61.)

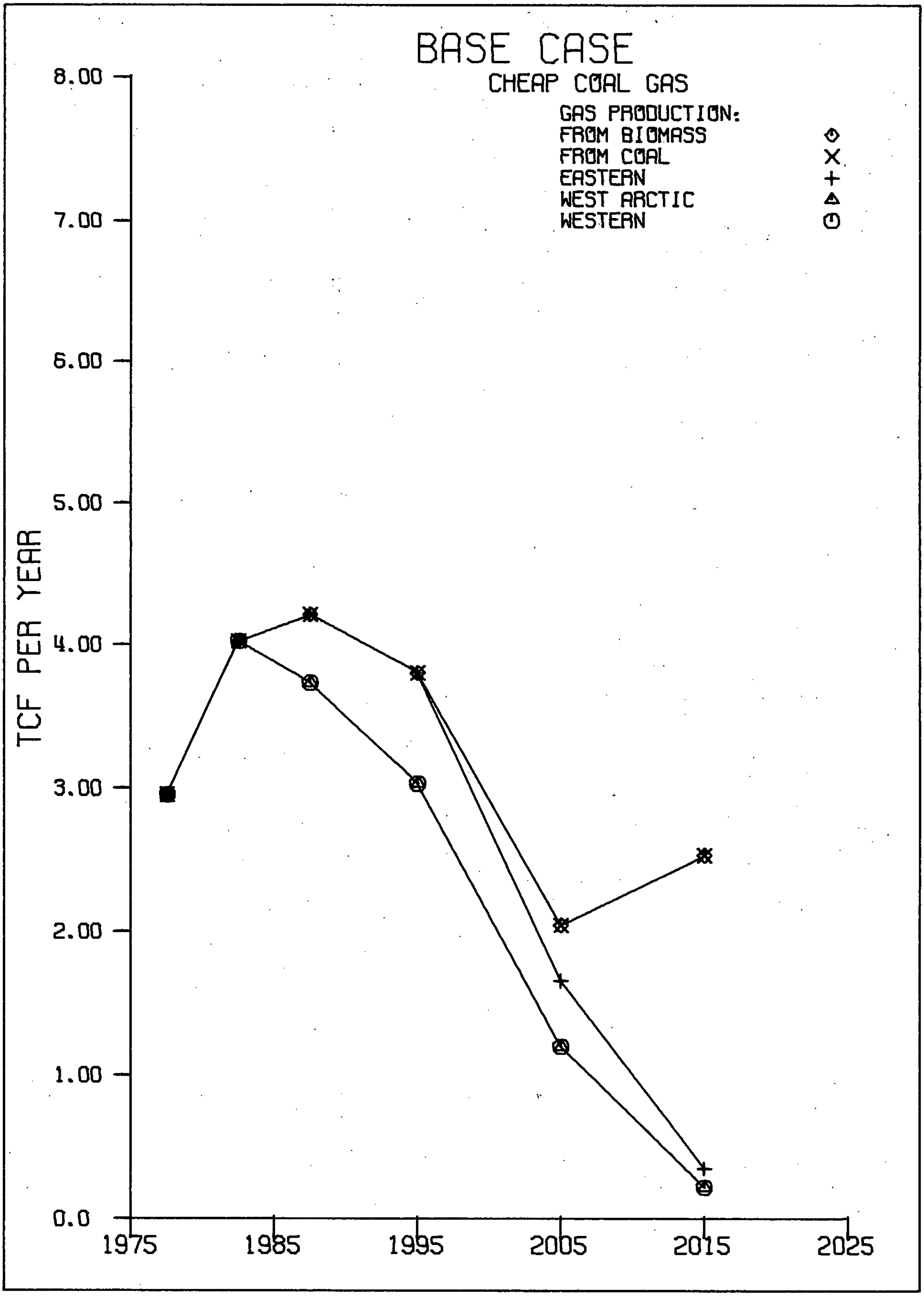

Figure 56. Gas Production, Coal Gas Case.

Table 62. Secondary Energy Fuel Shares, Coal Gas Case.

BASE CASE; CHEAP COAL GAS;

SECONDARY SHARES:
IN UNITS OF FRACTION

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
SOLAR;	0.0000	0.0000	0.0000	0.0000	0.0421	0.0829
COGENERATION;	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ELECTRICITY;	0.1351	0.1836	0.1782	0.2038	0.3575	0.3422
GAS;	0.2156	0.2527	0.3406	0.3318	0.1619	0.1711
OIL;	0.6066	0.4941	0.4193	0.3346	0.2929	0.2523
COAL;	0.0428	0.0696	0.0619	0.1298	0.1456	0.1515

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 57. Thus, the differences between the plotted lines are the entries in Table 62.)

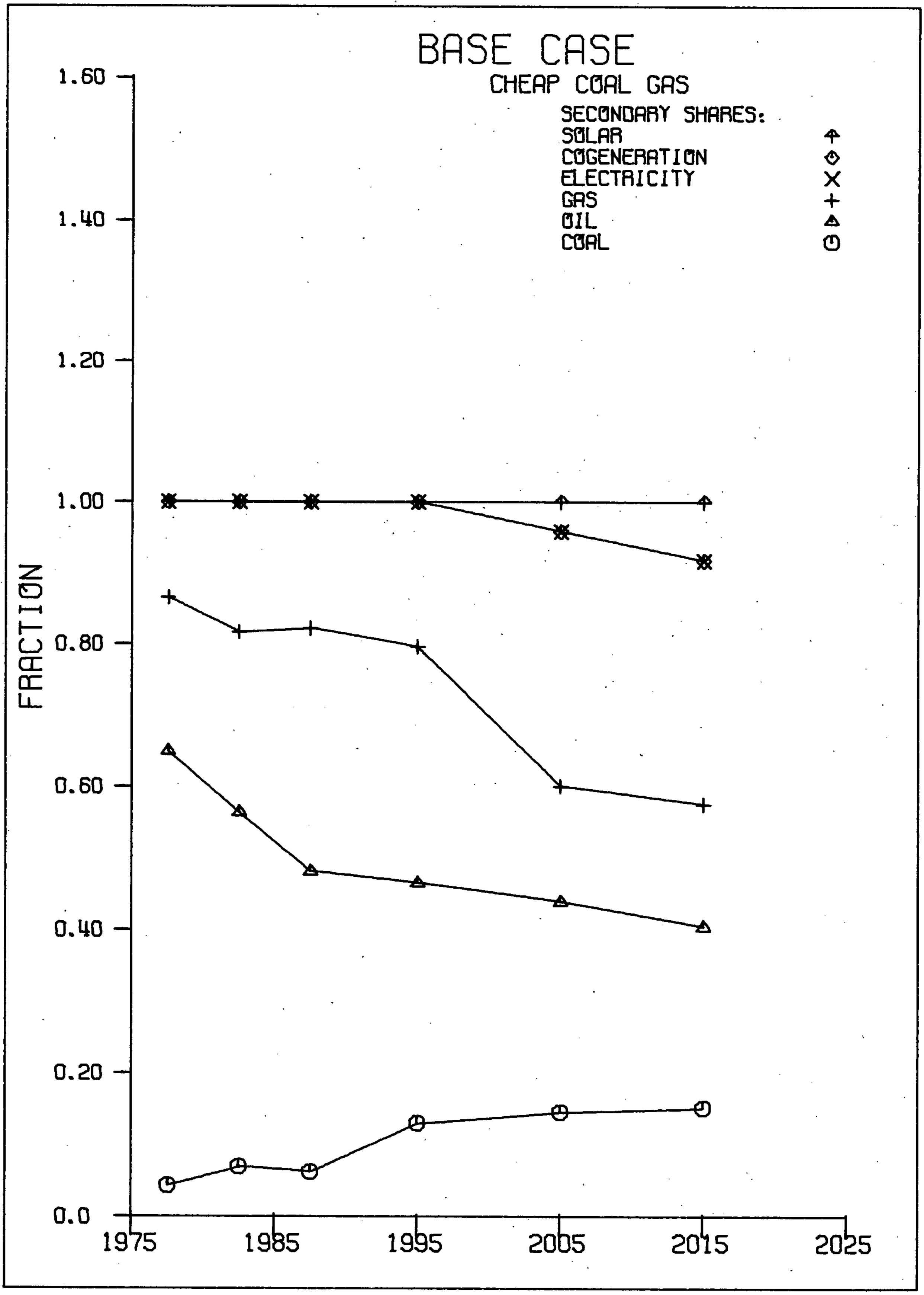

Figure 57. Secondary Energy Fuel Shares, Coal Gas Case.

Table 63. Primary Energy Fuel Shares, Coal Gas Case.

BASE CASE; CHEAP COAL GAS;

PRIMARY FUEL SHARES:
IN UNITS OF FRACTION

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
SOLAR;	0.0000	0.0000	0.0000	0.0000	0.0378	0.0704
BIOMASS;	0.0004	0.0003	0.0003	0.0001	0.0000	0.0000
HYDRO;	0.0953	0.1281	0.1280	0.1512	0.1358	0.1069
NUCLEAR;	0.0088	0.0208	0.0246	0.0362	0.2106	0.2057
GAS;	0.2508	0.2915	0.3591	0.3422	0.1291	0.0206
OIL;	0.5614	0.4569	0.3982	0.3257	0.2843	0.2315
COAL;	0.0834	0.1024	0.0898	0.1446	0.2023	0.3648

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 58. Thus, the differences between the plotted lines are the entries in Table 63.)

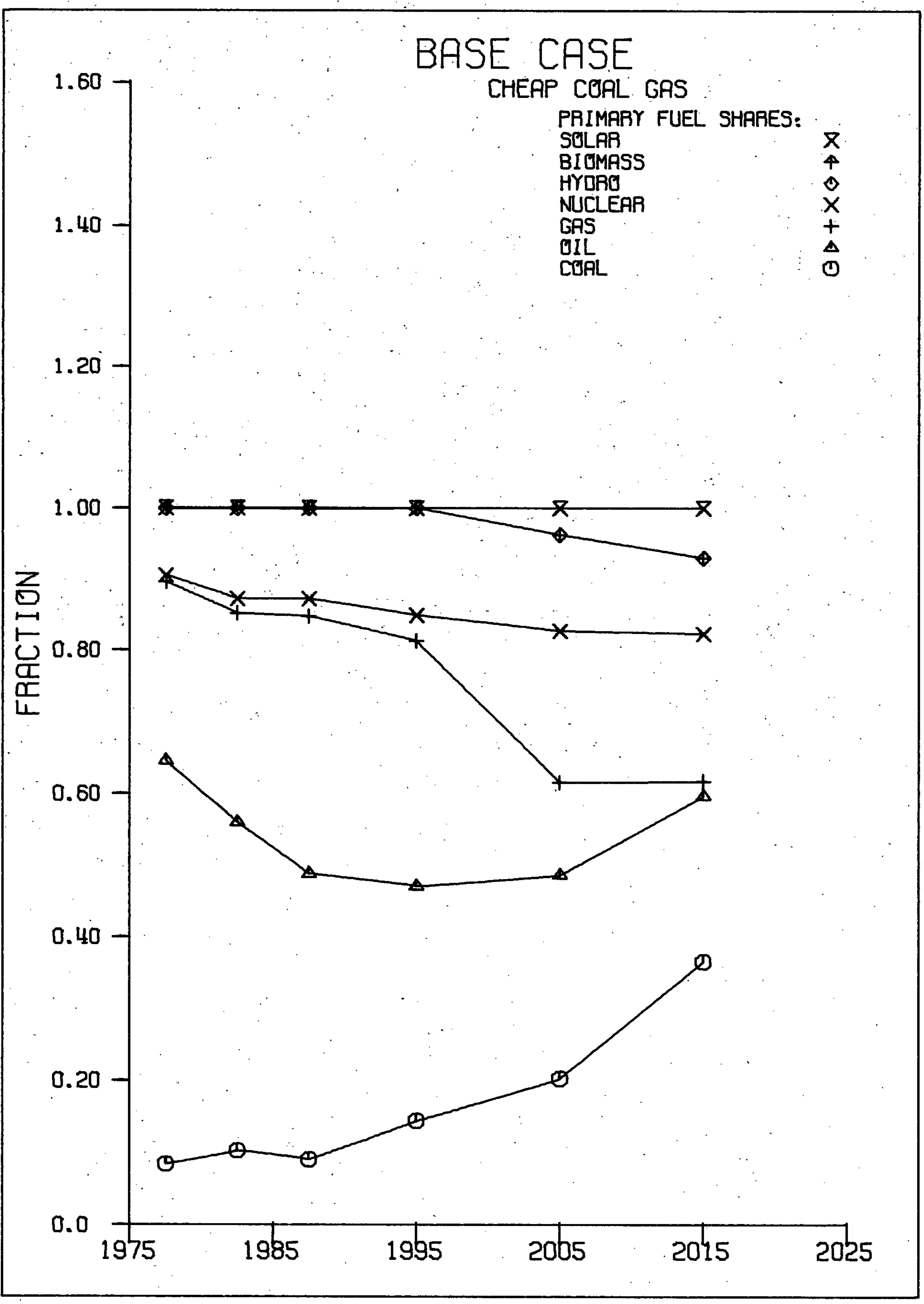

Figure 58. Primary Energy Fuel Shares, Coal Gas Case.

case was to make the 1991-2000 tar sands projection into an upper limit on production in that period, in order to allow for some switching to gas from oil.

Under these assumptions, coal gasification is introduced after 2000, bringing about much higher coal production then. Since this is a backstop source of gas at $2.30/mcf (as long as the huge coal supplies last), the more expensive northern frontier sources (in the west and the east) are left out of the solution. Total gas production and use are larger in the period 2011-2020, with the industrial and domestic, farm and commercial sectors taking the extra gas. There is much less electricity produced in 2011-2020 in the west, with industrial electricity use largely switched to gas. Heating by cogeneration and by solar in the west are left out of the solution, in favour of gas heating, unlike the base case solution.

At the secondary energy level, after 2000, there is a switch away from heat by cogeneration, solar heat and electricity, towards the use of gas, compared to the base case. At the primary energy level, the switch is away from solar, hydro, crude oil and natural gas, especially in the last period, to coal. The share of coal in total primary energy rises to 36% in the last period, compared to 19% in the base case.

Tables 60 to 63 and Figures 55 to 58 give the relevant detailed output for this case.

8.5. The Impacts of the Electric Automobile.

The electric auto does not enter the base case solution. To study the impacts of the electric auto on the energy system, the base case was solved with a lower cost associated with the electric auto. The amount of the cost reduction was chosen to be just large enough to make the electric auto competitive, after examination of the base case output. This lowering of the cost is equivalent to

(a) lowering the initial cost difference between the electric and conventional autos from $1500 to $364, but keeping the road tax on electricity used by electric cars;

(b) lowering the initial cost differences from $1500 to $1,127 and eliminating the electricity road tax; or

(c) combinations of (a) and (b).

In addition, the projected value of tar sands production in the period 1991-2000 was changed to an upper limit, to allow for the likelihood of lower oil consumption.

There are no surprises in the solution. Oil production is lower than in the base case, especially from the tar sands, after 1990. Coal production is higher in the last two periods (after 2000) in the west, fuelling higher electricity production for the electric auto. Electricity production is higher in the east, as well, after 2000. The share of electricity in secondary energy reaches 45% by the last period, 2011-2020, compared to 38% in the base case. At the primary energy level, crude oil's share reaches 18% by the last period, compared to 26% in the base case, with coal, nuclear and hydro energy taking oil's place. One small side effect of the higher electricity production is the partial displacement of solar heating in the west by an increased quantity of heat by cogeneration with coal-fired electricity production, in the last period.

Refer to Tables 64 to 67, and Figures 59 to 62 for specific details of this case.

Table 64. Transportation, Electric Auto Case.

BASE CASE; CHEAP ELEC. AUTO

TRANSPORTATION:
IN UNITS OF 10**15 BTU PER YEAR

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
OTHER TRANSPORT;	0.0909	0.1044	0.1279	0.1697	0.2196	0.2813
ROAD,ELECTRIC;	0.0000	0.0000	0.0213	0.1860	0.4263	0.5588
ROAD, GASOLINE;	0.2888	0.3379	0.4000	0.3630	0.2841	0.3724

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 59. Thus, the differences between the plotted lines are the entries in Table 64.)

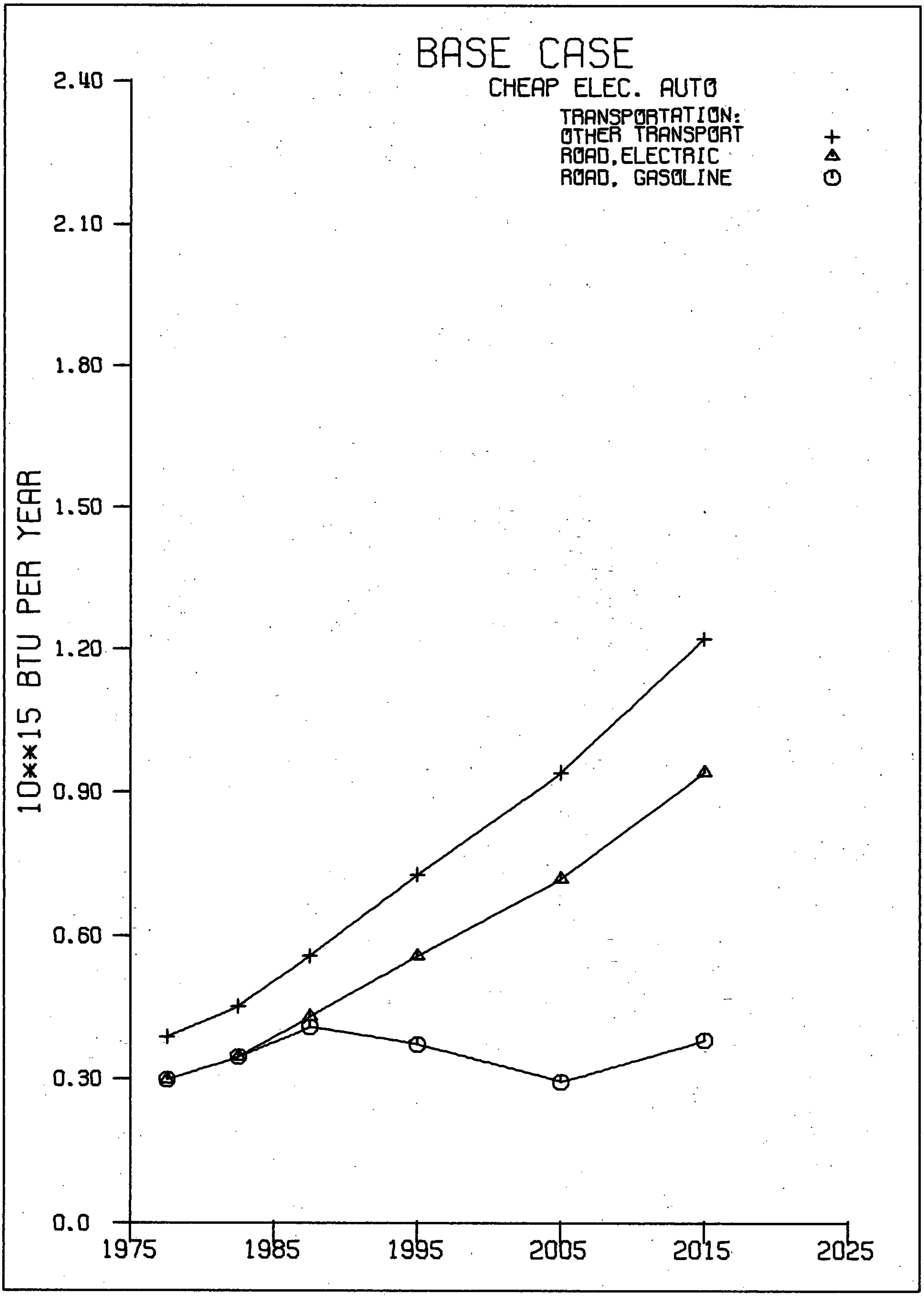

Figure 59. Transportation, Electric Auto Case.

Table 65. Crude Oil Production, Electric Auto Case.

```
             BASE CASE;           CHEAP ELEC. AUTO

OIL PRODUCTION:
IN UNITS OF   10**9 BBL PER YEAR

        AVERAGE VALUES FOR THE PERIOD ENDING IN

                         1980    1985    1990    2000    2010    2020


IMPORTS;                0.2788  0.1107  0.0000  0.0000  0.0000  0.0000
FROM BIOMASS;           0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
FROM COAL;              0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
EASTERN;                0.0008  0.0100  0.0500  0.1772  0.2058  0.0740
TAR SANDS;              0.0362  0.0744  0.1534  0.1505  0.1265  0.1445
WEST ARCTIC;            0.0000  0.0000  0.0000  0.0000  0.0559  0.2597
WESTERN;                0.5572  0.4942  0.5098  0.3136  0.0965  0.0086
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 60. Thus, the differences between the plotted lines are the entries in Table 65.)

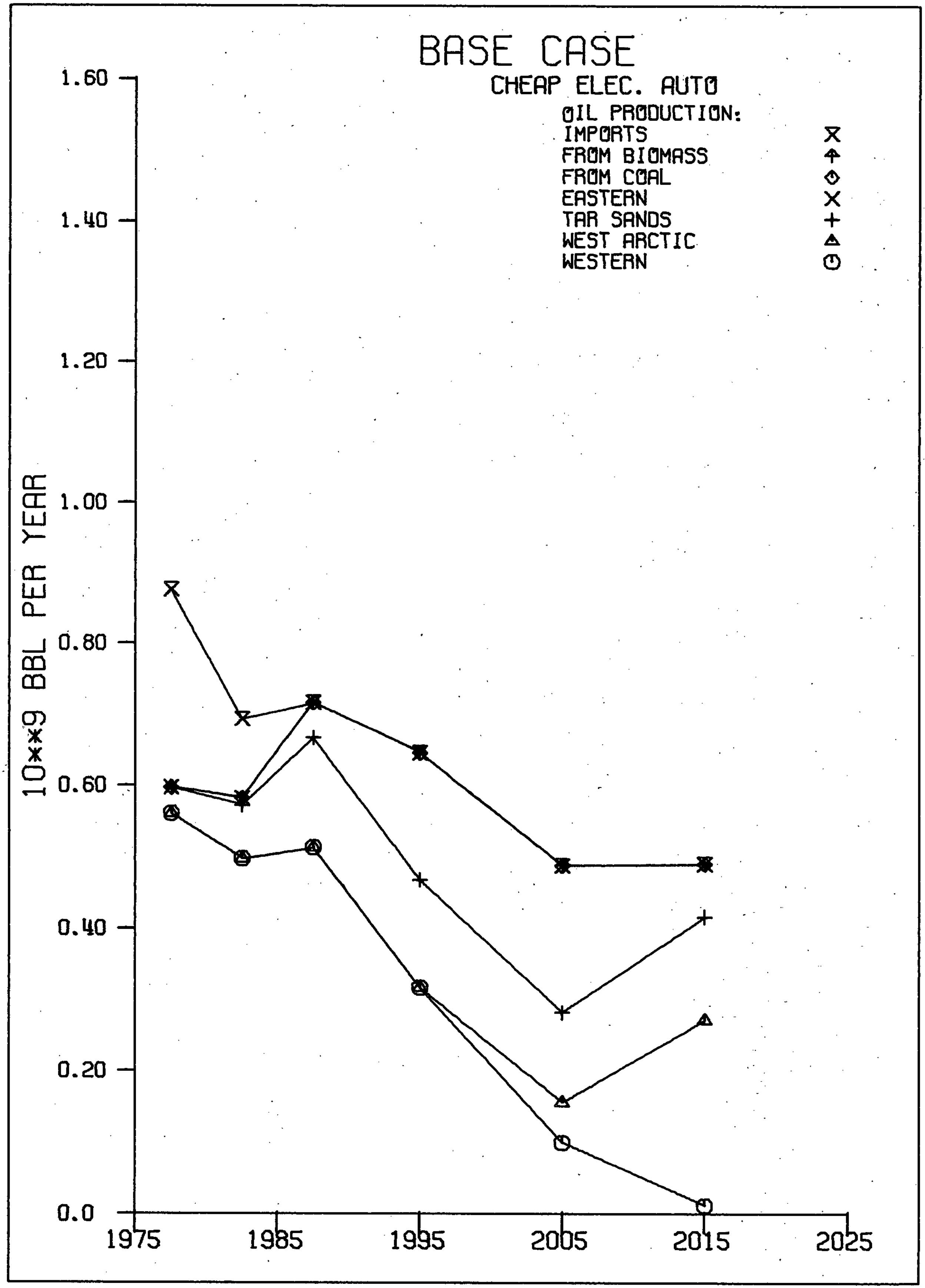

Figure 60. Crude Oil Production, Electric Auto Case.

Table 66. Secondary Energy Fuel Shares, Electric Auto Case.

```
             BASE CASE;          CHEAP ELEC. AUTO

SECONDARY SHARES:
IN UNITS OF   FRACTION

          AVERAGE VALUES FOR THE PERIOD ENDING IN

                          1980     1985     1990     2000     2010     2020


SOLAR;                   0.0000   0.0000   0.0000   0.0000   0.0436   0.1041
COGENERATION;            0.0000   0.0000   0.0000   0.0000   0.0072   0.0262
ELECTRICITY;             0.1349   0.1836   0.1782   0.2112   0.4222   0.4485
GAS;                     0.2154   0.2526   0.3379   0.3296   0.1519   0.0782
OIL;                     0.6070   0.4941   0.4224   0.3277   0.2250   0.1841
COAL;                    0.0427   0.0698   0.0615   0.1315   0.1501   0.1589
```

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 61. Thus, the differences between the plotted lines are the entries in Table 66.)

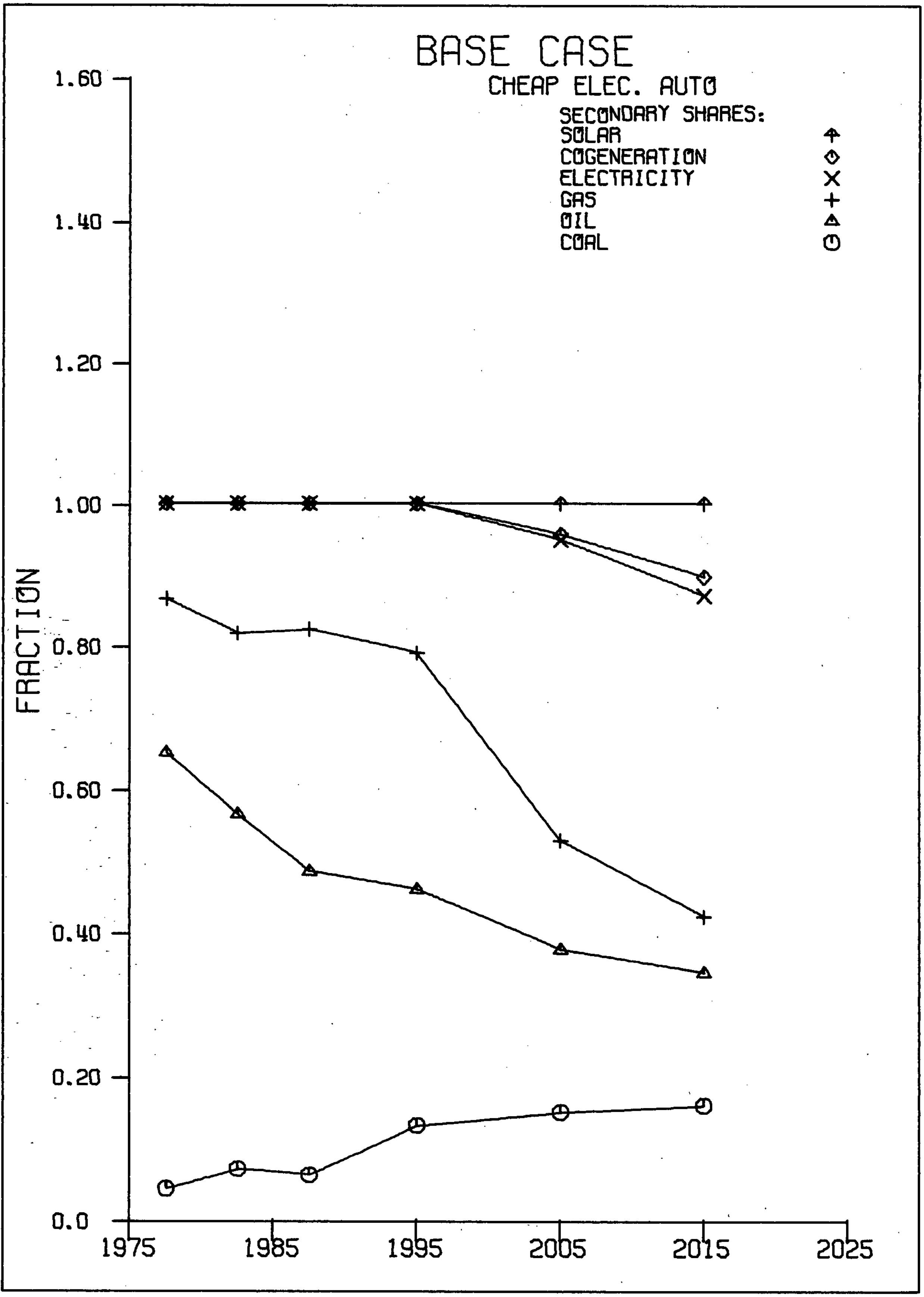

Figure 61. Secondary Energy Fuel Shares, Electric Auto Case.

Table 67. Primary Energy Fuel Shares, Electric Auto Case.

BASE CASE; CHEAP ELEC. AUTO

PRIMARY FUEL SHARES:
IN UNITS OF FRACTION

AVERAGE VALUES FOR THE PERIOD ENDING IN

	1980	1985	1990	2000	2010	2020
SOLAR;	0.0000	0.0000	0.0000	0.0000	0.0400	0.0958
BIOMASS;	0.0004	0.0003	0.0003	0.0001	0.0000	0.0000
HYDRO;	0.0952	0.1281	0.1281	0.1561	0.1562	0.1538
NUCLEAR;	0.0088	0.0208	0.0245	0.0359	0.2575	0.2733
GAS;	0.2505	0.2914	0.3563	0.3387	0.1536	0.0779
OIL;	0.5618	0.4569	0.4010	0.3181	0.2227	0.1829
COAL;	0.0834	0.1026	0.0899	0.1511	0.1701	0.2163

(N.B. The series in this table are summed, one line at a time, starting with the bottom entry of the table, to arrive at the values of the plotted lines in Figure 62. Thus, the differences between the plotted lines are the entries in Table 67.)

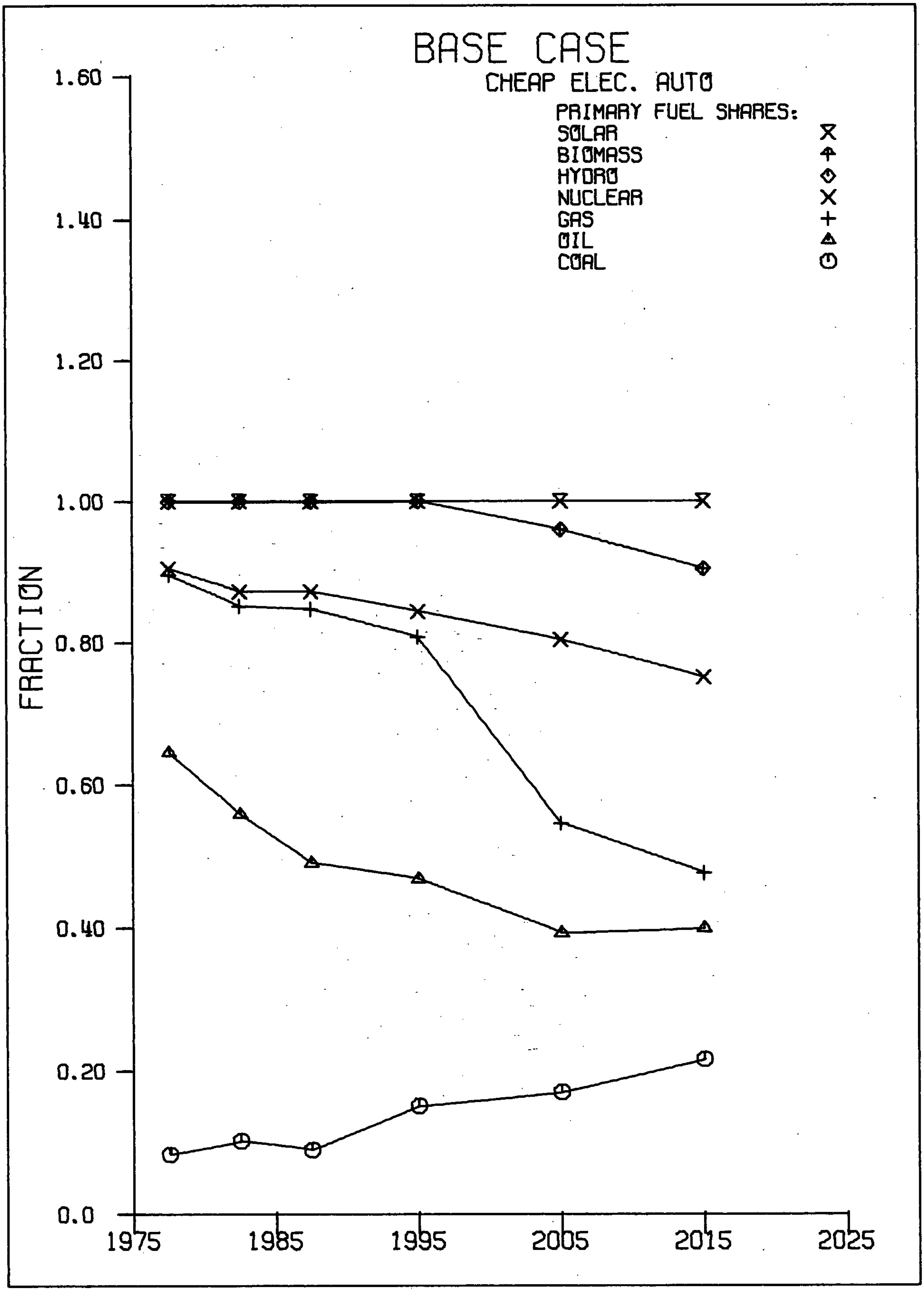

Figure 62. Primary Energy Fuel Shares, Electric Auto Case.

Chapter 9. Summary and Conclusions

This dissertation describes the construction of a model of the energy sector in the Canadian economy using a nonlinear programming algorithm to equilibrate energy supplies and demands in three five-year periods and three ten-year periods, from 1975 to 2020. A linear process model of energy supply, conversion and distribution is linked to a model of the demands for services provided by energy in combination with other inputs such as capital. Upper limits on energy exports in the model present current policies and imply a two price system (domestic and international), which also represents current policies. Other important features of the model are the distinction of two regions, western and eastern (the main energy producing and consuming regions, respectively), and the linear approximations to long-run marginal cost curves for exhaustible hydrocarbon resources.

The main efforts to date have been in the collection of data for the "base case", in the construction of a structure for which data exist, in the computer coding (including routines for reporting the results), and in the testing and debugging of the model.

Apart from the base case, data for low demand and high demand cases were used in other solutions of the model. Examination of the low, base and high cases shed some light on the dates of introduction of various new technologies and frontier petroleum resources, on energy pricing, and on the competitiveness of certain new technologies. As well, some energy policy questions have been analyzed with the aid of the model, namely the questions of banning further nuclear power development and of allowing district heating by cogeneration with nuclear electricity, the effects of higher oil costs (a sensitivity analysis), the impacts of competitive coal gasification, and the impacts of competitive electric automobiles. Some important conclusions drawn from the results of the model are summarized below.

It was found that oil from the northwest Arctic and northeast offshore will not likely be needed until after 2000, although northeast offshore oil is required after 1990 under the high demand assumptions. Coal liquefaction appears to be uneconomical in all periods in the base case. Even under the most favourable assumption about the cost of the coal input, the cost of the oil output would be higher than the price of oil until after the year 2000. The assumption of restricted exports, with the resulting two price system, is a key assumption in all conclusions. For example, if unrestricted exports, or even much higher oil export restrictions were allowed, frontier oil production would begin earlier and coal liquefaction may become competitive. Oil production and use were found to be approximately constant after 1980, due to increasing fuel efficiency in the transportation sectors, and to substitution of other fuels in the other sectors.

Frontier natural gas sources will not be needed until after 2000 under the three demand scenarios (low, base, and high). Gas is a transitional fuel, to be used in place of oil in the medium term, but it will eventually be replaced by other energy sources. Canadian use of natural gas peaks in the period 1991 to 2000, and production (including for export) peaks in the period 1986 to 1990. It was found that the "competitive relationship" of gas and oil is quite different in the two regions -- the ratio of the gas price to the oil price rises over time in each region, but it is higher in the east. Coal gasification is nearly competitive in the base case. Sensitivity analysis indicates that gasification of coal may play an important role after 2000, displacing some electricity, solar heat and heat by cogeneration, compared to the base case.

The model indicates strong demands for coal in industry, for the generation of electricity and heat by cogeneration in the west, and possibly for synthetic fuel production as discussed above.

Hydroelectricity is important in both regions, since it is the least expensive source of electricity. The existence of large supplies of inexpensive coal for electricity in the west and of low cost nuclear electricity in the east ensure fairly stable electricity prices in both regions. The eastern picture changes dramatically under the assumption of no new nuclear development after 1985. The alternate source of eastern electricity - from coal - is so expensive that there is a large switch from electricity to oil in the no-new-nuclear case, compared to the base case. Oil from the tar sands is especially important in this switch after the turn of the century. Comparison of the objective function values revealed that the economic benefits of nuclear power are not great, which indicates that the issue is not one of economics, but of the safety of nuclear power.

The electric automobile will not likely be competitive unless there are technical breakthroughs which lower the initial cost differences between the electric and conventional cars, or the road tax burden is less for electric cars than for conventional ones. Under the assumptions of improvements in the fuel efficiency of conventional cars, the price of transportation (price _per mile_) decreases until 2010, even though the fuel price (price _per gallon_) increases.

Heating in the domestic, farm and commercial sector of the west will likely be done mainly by gas until 2010, with solar and cogeneration taking the place of gas later. In the eastern region, oil and gas are important heating fuels until 2000 and 2010, respectively. Electric resistance and solar heating are the important types of heating in later periods. It appears that the heat pump is not competitive in either region. If district heating by cogeneration with nuclear electricity is allowed (it is not allowed in the base case), total electricity production is lower in the east, particularly nuclear electricity, because electricity for resistance heating is not required in such large amounts. This indicates that one route to improving nuclear safety may be to distribute the waste heat from nuclear stations for residential and commercial heating, provided, of course, that any new risks from circulating radioactive hot water, or from building nuclear stations closer to population centres do not outweigh the safety benefits of decreased nuclear power development.

There are many possible directions for future research. A major effort to construct a data base on the functional end uses of energy in Canada, particularly in industry, would allow the revision of the structures of models such as this one to a more theoretically satisfying structure. The market shares of fuels in the end use sectors could be made more endogenous, for example, by a more detailed process modelling in the end use sectors. This data base work can likely be carried out only by a government agency such as Statistics Canada.

The existing areas of end use process modelling -- DFC heating and road transportation -- could benefit by explicit representation of "vintage effects" in the energy-using processes. For example, automobiles might be distinguished by period of production, with a new-car fuel efficiency for each period. In the present formulation of the model, average fuel efficiency is projected for each period for all cars, regardless of when they were produced. However, this average in reality depends on the rate of introduction of new cars. The vintage approach would avoid this problem.

The policies of unrestricted energy exports and world pricing could be explored by incorporating increasing marginal costs of capacity expansion in key energy sectors (e.g. oil and gas). Apart from straightforward structural changes, the work would involve careful estimation of the cost escalations which can occur by a too rapid construction of, say, tar sands plants.

A stochastic model of oil production might shed light on the optimal rate of development of tar sands, given the uncertainties surrounding the alternative, less costly conventional oil resources. Stochastic modelling may also give insight into optimal export policies, without exogenously restricting exports.

The model discussed here is a partial equilibrium model, viewing the energy - economy linkages as only one-way. It is assumed that the various macroeconomic variables used in the energy demand functions are not themselves affected by events in the energy sector. The model would benefit by an extension to include automatic two-way energy economy interactions. In the early development of this model, a representation of energy economy interactions was attempted, by the method of ETA-MACRO (Manne, 1977). However, this approach had to be abandoned to keep the process detail in the end use sectors because there was no apparent way to make each end-use sector's share of total output energy endogenous.

Probably the most important area of energy-economy interactions is the effect of the demand for investment capital by energy investments, particularly the large projects. Several recent investigations (Energy, Mines and Resources, 1977h,Downs 1977, Rothman, 1980, Waddingham, 1980 and Kalymon, 1980 - also see the discussion by Schwartz, 1980a) have been made by forecasting energy capital needs, total capital investment, and economic growth, and judging whether energy investments will cause any strains to develop. Most conclude that there will be no great difficulties, provided the federal and provincial governments adopt certain policies. Waddingham (1980), however, is relatively pessimistic, forseeing the possibility of capital supply limitations for energy investments. A fruitful area of further research, therefore, would involve the extension of the model to account for constraints on capital availability for energy investments. Ideally, such an extension should include the feedback effect of a large energy-related capital requirement driving up the economy-wide cost of capital, which in turn raises the cost of energy, thus dampening the demand for energy. As a first step, a data base on initial capital costs of new capacities of energy production and conversion processes could be developed, including the data on the lead-time required between investment and beginning of operation. Investment requirements for the solution in each period could then be calculated, examined for "bulges", and compared to projections of capital availability to look for capital supply constraints, as in the approach of the other studies mentioned above.

However, the base case results in this dissertation are unlikely to be constrained by capital requirements. Total secondary energy in the base case increases at an average rate of 2.9% per year between 1978 and 1995, while the rates of growth of secondary energy projected by EMR (1977a) in the various scenarios range from 2.7% to 3.9% per year between 1975 and 1990. The energy projections here are at the low end of the EMR ranges, and the above-mentioned studies were mostly based on the same EMR energy demand projections (except Rothman, 1980). Since the studies were mostly optimistic about financing, the energy projections here should cause even less concern about financing. Nevertheless, a detailed, careful look at the problem would certainly be worthwhile, particularly if the unrestricted trade policy is to be investigated thoroughly.

A systematic study by Canadian energy analysts of the various Canadian energy models, with a careful examination of the structural and data assumptions, would be a great help in assessing the confidence which may be attached to the conclusions of the models. As well, the design of future models could be improved with the suggestions arising from such a study. Survey papers such as those by Fuller and Ziemba (1980), and Manne et al. (1979) can be useful steps in the evaluation process, but the Energy Modeling Forum in the United States provides an example of the method and benefits of deeper studies by researchers from industry, government and universities.

If many new details are incorporated into the model in future research, closer attention will have to be paid to computing methods, to minimize computation costs. Decomposition by region might be attempted, particularly if more than two regions are distinguished (perhaps for a better representation of electricity generation). Time period decomposition might proceed by solving a series of two-period problems -- at each step, one period would be the "present", and the second "period" would represent all time beyond the first period, in the manner of the dual equilibrium method of Grinold (1980). It is possible that the solution obtained by stepping through the time periods in this way may be a good, inexpensively-obtained starting basis for the full problem, in which the optimal solution in all time periods is to be found by a single optimization. The interim solution found by this time decomposition may be of interest itself -- it might be interpreted as a "myopic" solution, representing the behaviour of decision makers who act on the basis of somewhat vague, average notions about the future.

If this model and its variants are to be used continually for analysis of energy policies, it will be necessary to revise the data base periodically as new facts come to light. To cope with the inevitable demands to change the data and the structure of the model, it will be advantageous to construct improved input software to speed up the process of entering the structure and data base. If this model and its variants are to be used actively in energy policy debates, and if they are to be used by researchers wishing to experiment with different aggregations of energy flows, and with different scenarios, ease of specifying new data and structures would be a great, although very "practical", advantage.

This dissertation has outlined the construction of a long-term energy policy model for Canada, and has given examples of the use of the model in the analysis of several energy policy issues. There remain many opportunities for further analysis with this model and for advancement of the capabilities of models in energy policy analysis.

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Appendix A. Derivation of the Demand Equations.

The model calculates equilibrium prices and energy quantities in each region, for every time period, for four end-use sectors -- road transportation, other transportation, industrial, and DFC (domestic, farm and commercial). The bulk of the model is a linear process model of energy supply and distribution. The demands for output energy in each of the four end use sectors are determined as functions of the respective prices, and of exogenous economic and demographic variables. Except for road transportation, the demand equations are adapted from those estimated by Energy, Mines and Resources (EMR). No new econometric estimation of demand equations has been carried out here. Instead, the work of other researchers, especially at EMR, has been used as a guide in the selection of independent variables and elasticities to derive the demand equations used here. These demand equations have been calibrated with data on demands and independent variables from 1970 and 1971, which were assumed to be equilibrium years for the energy sector.

The EMR demand equations, described in Sahi and Erdmann (1980) and Sahi (1979), all incorporate lagged demands as determinants of present demands since the effects of changes in prices and other variables are not immediate. Long term versions of the EMR demand equations can be easily derived, with the interpretation that the calculated demands would be the demands at the given prices, etc., after sufficient time has elapsed for the full response to be made. The long term versions of the demand equations have been used because

1) the model has five and ten-year periods, but typical adjustment times range from 4.6 years to 7.3 years for 90% of the adjustment to be made; and,

2) the linear process model of energy supply incorporates lag effects by forcing the continued use of established capacity of many energy supply and end-use technologies for specified lifetimes.

There is some evidence (Schwartz, 1980b) that the long term elasticities of demand for total output energy in each end use sector reported by Sahi and Erdmann are too low, and represent shorter term responses. The problem may be in the little variation in time series used for estimation. Cross-country studies, with wider variation in the data, generally indicate larger long term elasticities.

Sahi and Erdmann (1980) treat residential and commercial demands separately in the EMR model. The present model combines these two sectors in the DFC sector. Hence, it is necessary to combine the two EMR demand equations in a reasonable way. The EMR demand equation for the residential sector is

$$\begin{aligned} \ln(\mathrm{RDEM}) = {} & \ln(\overline{R}_0) + \ln(H) + (.0927)\ln(\mathrm{IPH}) + y'\ln(\mathrm{SDPH}) - (.1077)\ln(P) \\ & + (.5282)\ln(\mathrm{DD}) - (.7279)\ln(H_{-1}) - (.3845)\ln(\mathrm{DD}_{-1}) + (.7279)\ln(\mathrm{RDEM}_{-1}) , \end{aligned}$$

where RDEM = demand for output energy in the residential sector,

$\overline{R}_0$ = a regional constant,

H = number of households,

IPH = disposable income per household,

SDPH = single dwellings per household,

y' = .1276 (for Ontario), .2337 (for Manitoba), 0 (elsewhere),

DD = degree days (a weather factor), and

P = price of output energy in the residential sector.

The subscript "-1" in the above equation indicates that the variable is lagged one year. Sahi and Erdmann report that $R^2 = .998$ for this equation.

All equations were estimated over the period 1963-1974, pooling time series for seven regions. The long term version of the above equation may be derived by assuming that lagged variables equal the present year variables in the long term. If the weather factor is incorporated into the constant (since long range weather forecasting is impossible), the long term residential demand equation is

$$RDEM = R_0 \times H \times (IPH)^{.3407} \times (SDPH)^{y} \times P^{-.3958} ,$$

where, now, y = .469 (for Ontario), .859 (for Manitoba), and 0 elsewhere. When this equation is combined with the EMR long term commercial energy demand equation and used in the present model, the energy demand and price variables are endogenous.

The EMR equation for commercial energy demand, in long term form, and incorporating the weather factor into the constant, is

$$CDEM = C_0 \times (POP) \times (IPC)^{.9060} \times (MDPH)^{.1565} \times P^{-.3823}$$

where, CDEM = demand for output energy in the commercial sector,

C_0 = a constant

POP = population

IPC = disposable income per capita

MDPH = number of multiple dwellings per household,

and, P = price of output energy. The commercial sector's estimated income and price elasticities were altered by EMR judgementally to the above more reasonable values, according to Sahi (1980).

In combining the residential and commercial sectors for the purpose of long-range forecasting, several simplifying assumptions can be made. The first is the elimination of the weather factor. Secondly, the MDPH variable may be dropped from the combined equation, since its positive elasticity suggests that it is more a measure of the amount of residential energy falling under the statistical class "commercial" than a measure of energy efficiency due to multiple dwellings. Thirdly, the SDPH variable may be dropped from the combined equation since it has a non-zero elasticity for only two provinces, indicating that its inclusion is primarily to explain the data classification problem associated with large multiple dwellings falling under the commercial classification. (This problem should disappear when the two sectors are combined.) Fourthly, the price elasticities for the residential and commercial sectors are very close, suggesting a price elasticity of -.39 for the combined demands would be a good choice. Lastly, although there has been a higher rate of growth of the number of households than that of population in recent decades (due to such factors as increasing divorce rate, the "baby boom" children growing to adulthood, and a lower birth rate), it is difficult to justify making a distinction between forecasts of these two growth rates over the long term of the present model (45 years). Therefore, output energy demand in the DFC sector is taken to be proportional to population, and to income per capita raised to some power:

$$DFC = A_0 \times (POP) \times (IPC)^z \times P^{-.39}$$

where DFC = demand for output energy in the DFC sector, and

A_0 = a constant.

The elasticity, z, is taken to be 0.9060 by EMR for the commercial sector. In the EMR equation for residential demand, the factor $H \times (IPH)^{.3407}$ corresponds to the factor $(POP) \times (IPC)^z$ in the above combined DFC equation. If z is chosen to make the average annual rates of growth of $H \times (IPH)^{.3407}$ and $(POP) \times (IPC)^z$ equal in the historical period 1960-1976, then, using the data for these growth rates presented by the National Energy Board (1979 , p.84), z = .58. Thus, if the above combined equation were to represent only the residential sector, the elasticity with respect to income per capita ought to be .58. The average of .58 and .906, weighted by the 1973 input energy to the residential and commercial sectors, respectively, is z = .71. Indices of population (pop) and of income per capita (ipc) are used, with a base year of 1973 in the DFC demand equations, giving

$$DFC = D_0 \text{ x } (pop) \text{ x } (ipc)^{.71} \text{ x } P^{-.39} ,$$

where D_0 = a constant, different for the east and west. The constant factors are chosen using data of 1970, which is assumed to be an equilibrium year.

One further adjustment is necessary to make the DFC demand equation appropriate for the model. In the DFC sector of the linear process model of energy supply, the non-fuel costs of space heating are taken into account, as well as the fuel costs. However, in the demand equation derived above, only the fuel cost is represented in the price variable. In section 8 of Appendix C, "Data for the Base Case", the output energy prices are derived for the base year, 1970. The weighted average of the western and eastern DFC output prices (weighted by output energy in the two DFC sectors), including non-fuel costs of heating, was 0.5074, in model units. The weighted average of the DFC output fuel prices, not including non-fuel heating costs, was 0.2431, in model units. An elasticity of 0.39 with respect to fuel price means that a 1% change in fuel price leads to a 0.39% change in output energy demand. However, a 1% change in fuel price alone implies a 0.48% (= .01 x .2431/.5074 x 100%) change in total output energy price, including non-fuel heating costs. Therefore, since a change of 0.48% in total output energy price leads to a 0.39% change in output energy demand, the elasticity of demand for output energy with respect to total price is -(0.39)/(0.48)= -.81. Therefore, the demand equation for the DFC sectors of the present model is

$$DFC = D_0 \text{x} (pop) \text{x} (ipc)^{.71} \text{x} P^{-.81}$$

The EMR industrial energy demand equation excludes the demands for coke, coke oven gas and non-energy use of oil, but includes the demand for natural gas as a petrochemical feedstock. The EMR variables and elasticities have been used in an equation which includes all of industry's demands for energy commodities, including for the above special uses. EMR makes separate projections for coke, coke oven gas and petrochemical use of oil, but here the approach adopted is that of Hedlin, Menzies and Associates (1976), of projecting the upper and lower limits of the fractions of industrial output energy (including the special uses) supplied by coal, oil, gas and electricity. The EMR equation uses industrial real domestic product as an explanatory variable, but since it is difficult to make a distinction between the growth rates of industrial RDP and total RDP over the long range of the present model, total real domestic product has been used here. Using indices (1973 = 1) of real domestic product and capital-output ratio, and combining the weather factor into the constant, the long term EMR equation is altered to the form used here:

$$\mathrm{IND} = I_0 \times (\mathrm{rdp}) \times (\mathrm{cor})^{.667} \times P^{-.48} ,$$

where, IND = output energy demand of industrial sector,

I_0 = constant, different for each region

rdp = index (1973 = 1) of real domestic product,

cor = index (1973 = 1) of the capital/output ratio (manufacturing capital stock divided by industrial output), and

P = price of output energy, industrial sector.

Again, the constant factors are chosen using the variables' values in 1970, an equilibrium year.

The EMR model of demand for motor gasoline, in Sahi (1979), has been estimated using as data the econometric-judgemental forecasts for 1976-1990 prepared by the National Energy Board (NEB) with the aid of the NEB's complex motor gasoline model. The interpretation of EMR's long-term income and price elasticities for use in the present model is complicated because EMR is estimating input energy requirements, and they use a lagged, new-car fuel economy standard as an explanatory variable. This model requires an equation of the demand for output energy requirements, where the average fuel economy of all cars is projected in the linear process supply model. Therefore, in the model discussed here, income and price elasticities are assumed to be in the ranges found by Dewees, Hyndman, and Waverman (1975), who estimated five different models of demand for gasoline (input energy) using Canadian data for 1956-1972. Although these researchers used an urbanization index and automobile price as explanatory variables (as well as gasoline price and income per capita), it has been assumed here that these two variables will be relatively constant over the time period covered by the model. In addition, it has been assumed that average fuel economy was constant over their estimation period, so that their elasticities are applicable to the estimation of demand for output energy. Since diesel fuel supplied only about 6% of the input energy to road transportation in 1973, it has been assumed here that the same income and price elasticities apply to the demands for both gasoline and road-diesel. The equation for the demand for output energy in the road transport sector is then:

$$RTR = R_0 \times (pop) \times (ipc)^{.8} \times P^{-.36}$$

where, RTR = demand for output energy in the road transport sector,

R_0 = a regional constant,

pop = an index of population (1973 = 1),

ipc = index of disposable income per capita (1973 = 1),

and, P = price of output energy in the road transport sector. The long term income and price elasticities, .8 and -.36, respectively, are the midpoints of the ranges reported by Dewees, Hyndman and Waverman (1975) for all of Canada --.69 to .91, and -.26 to -.45. The regional constants are derived from 1970 data.

The demands for input energy to the rail, aviation and marine subsectors of the transportation sector together accounted for 23% of the input energy demands of the whole transportation sector in 1973. It is therefore worthwhile to have a separate demand equation for the rail-aviation-marine sector, which is labelled "other tansportation" in this model. EMR has estimated demand equations, in Sahi (1979), for each of these three subsectors, using a 1976-1990 projection by the NEB. The long term price elasticities fall between -.067 and -.71, with an average (weighted by the 1973 input energy to the three subsectors) of -.36. The income variables are either real domestic product per capita (aviation) or real domestic product in industry and agriculture (the others). Population is also an explanatory variable in the aviation equation. Considering the average price elasticity above, and the similarity in the growth rate of real domestic product (RDP) and RDP in industry and agriculture, it is reasonable, upon examination of the three EMR equations, to adopt the following demand equation for other transportation:

$$OTR = O_0 \times (rdp) \times P^{-.36} ,$$

where, OTR = output energy demand in the sector of other transportation,

O_0 = a regional constant

rdp = an index of real domestic product (1973 = 1), and,

P = price of output energy, in the other transportation sector.

The regional constants are derived from 1970 data.

The following chart summarizes the four long term demand questions used in the present model.

Table 68. Demand Equations Used in the Model.

Sector	Equation
1. Domestic, Farm and Commercial	$DFC = D_0 \times (pop) \times (ipc)^{.71} \times P^{-.81}$
2. Industrial	$IND = I_0 \times (rdp) \times (cor)^{.667} \times P^{-.48}$
3. Road Transportation	$RTR = R_0 \times (pop) \times (ipc)^{.8} \times P^{-.36}$
4. Other Transportation	$OTR = O_0 \times (rdp) \times P^{-.36}$

Definitions of Symbols

DFC, IND, RTR, OTR = output energy demands in the various sectors

D_0, I_0, R_0, O_0 = regional (east or west) constants

pop = index of population in each region (1973 = 1)

ipc = index of disposable income per capita (1973 = 1)

rdp = index of real domestic product in each region (1973 = 1)

cor = index of capital/output ratio (1973 = 1) - i.e. manufacturing capital stock divided by industrial output.

Appendix B. Detailed Structure of the Model.

In this section, the detailed equations of the model are given. Endogenous variables are represented by upper case letters. Exogenous parameters are represented by lower case letters or by upper case letters with a bar above.

There are six time periods -- three five-year periods, three 10-year periods, all labelled by the last year. The periods are $T \equiv \{1980, 1985, 1990, 2000, 2010, 2020\}$. In listing the model contraints, the time index, t, appears in the inter-period constraints, and is otherwise suppressed, for the sake of clarity. Furthermore, because of the complications introduced into inter-period constraints by the unequal lengths of the time periods, the constraints are first presented as if the time periods are of equal length, i.e.

$$T' \equiv \{1980, 1985, 1990, 1995, 2005, 2000, 2010, 2015, 2020\}.$$

In a later section, alterations to inter-period constraints due to time period aggregation are discussed. The forms of intra-period constraints do not change when time periods are aggregated.

The names of variables generally obey the following pattern: the first letter indicates the region (W for west -- B.C., the prairie provinces, and northern territories -- E for east); the second letter indicates the type of energy commodity or the end-use sector (e.g., O for oil, G for gas, T for transportation, etc.); the letter X in the third place indicates a flow and capacity of an energy commodity; and the letter D in the third place indicates an addition to capacity. In addition, there are numerals appearing in some variable names, and in the computer implementation, there are 2 numerals prefixing the variable name to indicate the time period.

In addition to the parameters listed in the following sections, there are exogenously-assigned parameter values for pre-1980-period variables which occur in inter-period constraints.

Constraint names obey the following pattern:

(1) (2) (3) (4) (5) (6) (7)

(1) (2) - two numerals indicate the time period.

(3) - the letters W, E, or N stand for west, east, or non-regional.

(4) (5) - two letters indicate constraint type:

PR - production decline (oil or gas)
CP - capacity expansion and replacement
SB - supply-demand balance
SE - share equation
SL - share, lower bound
SU - share, upper bound
RL - reserves limit
M - miscellaneous

(7) - this may be a letter, numeral, or blank.

The constraint names appear to the left of the constraints in this appendix (without the first two numerals, indicating time period). Constraints which are upper or lower limits on single variables are not given names.

The letters "DFC" stand for the Domestic, Farm and Commercial end-use sector.

B.1. Coal

a) List of Variables

WCX1 = western production, low cost
WCX2 = western production, high cost
WCX3 = coal for liquefaction in west
WCX4 = coal for gasification in west
WCX5 = coal for electricity production in west
WCX6 = coal for industrial use in west
WCD1, WCD2 = capacity increases of low and high cost western production
WCE = western coal transported to eastern region

WCEX = coal exports
ECX1 = eastern production, low cost
ECX2 = eastern production, high cost
ECX3 = coal for electricity production in east
ECX4 = coal for industrial use in east
ECD1, ECD2 = capacity increases of low and high cost eastern production
ECIM = coal imports

b) List of Parameters

mciw, mcie = distribution margin for coal to industrial sector, liquefaction and gasification
cwc1, cwc2 = costs of corresponding western coal production
cec1, cec2 = costs of corresponding eastern coal production
pcex = price of coal exports
pcim = price of coal imports
cctr = cost of transporting coal from west to east
$\overline{\text{WCRi}}$, (i=1,2) = reserves of corresponding western production type remaining after 1975.
$\overline{\text{ECRi}}$, (i=1,2) = reserves of corresponding eastern production type remaining after 1975
$\overline{\text{WCE}}$ = maximum capacity of west-to east coal transportation system
bwc, bec = fraction of coal supply remaining after deduction of coal use by energy supply industries, in the west and east, respectively
$\overline{\text{ECX1}}$ = upper limit on production of low cost eastern coal

c) Constraints

(i) Capacity Expansion and Retirement

WCCPi: $\text{WCXi}(t) = \text{WCXi}(t-5) + \text{WCDi}(t) - \text{WCDi}(t-30), \; i = 1,2$

ECCPi: $\text{ECXi}(t) = \text{ECXi}(t-5) + \text{ECDi}(t) - \text{ECDi}(t-30), \; i = 1,2$

(ii) Reserve Limits

WCRLi: $\sum_{t \varepsilon T'} \text{WCXi}(t) \leq \overline{\text{WCRi}}, \quad i = 1,2$

ECRLi: $\sum_{t \varepsilon T'} \text{ECXi}(t) \leq \overline{\text{ECRi}}, \quad i = 1,2$

(iii) Supply-Demand Balances

WCSB: $\text{bwc} \cdot \sum_{i=1}^{2} \text{WCXi} = \sum_{i=3}^{6} \text{WCXi} + \text{WCEX} + \text{WCE}$

$$\text{ECSB:}\quad bec\cdot\left(\sum_{i=1}^{2} ECXi + ECIM + WCE\right) = \sum_{i=3}^{4} ECXi$$

(iv) Bounds

$WCE \leq \overline{WCE}$ -- west-to-east coal transport limits

$ECX1 \leq \overline{ECX1}$ -- limit on rate of production of eastern coal

B.2. Oil

a) List of Variables

("LHF" stands for "liquid hydrocarbon fuels")

WOX1 = conventional production, low cost, west
WOX2 = conventional production, high cost, west
WOX3 = northwest frontier production, low cost
WOX4 = northwest frontier production, high cost
WOX5 = tar sands production
WOX6 = western methanol production, from biomass
WODi,(i=1,..,6) = capacity expansions of above
WOEX = oil exports (to USA)
WOE = western oil transported to eastern region
WOG = oil to western refinery gate
EOX1 = eastern production, low cost (mostly southeast offshore)
EOX2 = eastern production, high cost (mostly northeast offshore)
EOX3 = eastern methanol production, from biomass
EODi,(i=1,2,3) = capacity expansions of above
EOIM = oil imports
EOG = oil to eastern refinery gate
WLX1,ELX1 = LHF for electricity production in west & east
WLX2,ELX2 = LHF for domestic, farm and commercial use in west & east
WLX3,ELX3 = LHF for industrial use in west & east
WLX4,ELX4 = LHF for transportation use in west & east
WLDC = capacity expansion of coal liquefaction, in west

b) List of Parameters

mltw,mlrw,mldw, mliw,mlte,mlre, mlde,mlie = oil distribution & refining margins to Transportation, Road Transportation, DFC and to Industrial sectors, respectively, west and east
cwoi,(i=1,...,6) = costs of corresponding western oil production
poex = price of oil exports
cotr = cost of transporting oil from west to east
WORi,(i=1,2,...5) = reserves of corresponding western production type remaining after 1975.

ao(s) = parameters for oil production decline curve
= fraction of capacity established s years ago which is still producing now
opipe = fraction of eastern crude market accessible to western oil production
$\overline{WOEX}$ = upper limit on oil exports
foim = maximum fraction of Canadian crude oil market served by net imports
ceoi, (i=1,2,3) = costs of corresponding eastern production
poim = price of oil imports
$\overline{EORi}$, (i=1,2) = reserves of corresponding eastern production type remaining after 1975
clc = cost per unit output of coal liquefaction, not including cost of the coal
bwl,bel = fraction of oil supply remaining after deduction of oil use by energy supply industries, west and east
acl = oil output per unit of coal input to coal liquefaction
$\overline{WLDC}$ = upper limit on capacity expansion of western coal liquefaction
$\overline{WOX6}$, $\overline{EOX3}$ = upper limits on production of methanol from biomass, in west and east
$\overline{WOX5}$ = exogenously fixed tar sands production
$\overline{EOX1}$, $\overline{EOX2}$ = upper limits on eastern oil production

c) Constraints

(i) Oil Production Decline Curves

$$\text{WOPRi:}\quad WOXi(t) = \sum_{s=0,5,\ldots}^{25} ao(s) \cdot WODi(t-s)\ ,\ i = 1,2,3,4$$

$$\text{EOPRi:}\quad EOXi(t) = \sum_{s=0,5,\ldots}^{25} ao(s) \cdot EODi(t-s)\ ,\ i = 1,2$$

(ii) Capacity Expansion and Retirement

$$\text{WOCPi:}\quad WOXi(t) = WOXi(t-5) + WODi(t) - WODi(t-30)\ ,\ i = 5,6$$

$$\text{EOCP3:}\quad EOX3(t) = EOX3(t-5) + EOD3(t) - EOD3(t-30)$$

$$\text{WOCPL:}\quad WCX3(t) = WCX3(t-5) + WLDC(t) - WLDC(t-30)$$

(iii) Reserves Limits

WORLi: $\sum_{t \varepsilon T'} \mathrm{WOXi(t)} \leq \overline{\mathrm{WORi}}, \quad i = 1, \ldots., 5$

EORLi: $\sum_{t \varepsilon T'} \mathrm{EOXi(t)} \leq \overline{\mathrm{EORi}}, \quad i = 1,2$

(iv) Supply-Demand Balances

WOSBO: $\sum_{i=1}^{5} \mathrm{WOXi} + \mathrm{acl} \cdot \mathrm{WCX3} = \mathrm{WOE} + \mathrm{WOG} + \mathrm{WOEX}$

EOSBO: $\mathrm{WOE} + \sum_{i=1}^{2} \mathrm{EOXi} + \mathrm{EOIM} = \mathrm{EOG}$

WOSBL: $\mathrm{bwl} \cdot (\mathrm{WOG} + \mathrm{WOX6}) = \sum_{i=1}^{4} \mathrm{WLXi}$

EOSBL: $\mathrm{bel} \cdot (\mathrm{EOG} + \mathrm{EOX3}) = \sum_{i=1}^{4} \mathrm{ELXi}$

(v) Other Constraints

NOMSS: $\mathrm{EOIM} - \mathrm{WOEX} \leq \mathrm{foim} \cdot (\mathrm{WOG} + \mathrm{EOG})$ -- target of net self-sufficiency for security of oil supply

NOMEM: $\mathrm{WOE} \leq \mathrm{opipe} \cdot \mathrm{EOG}$ -- all of eastern market is accessible to western oil when opipe = 1

(vi) Bounds

$\mathrm{WLDC} \leq \overline{\mathrm{WLDC}}$ -- Limits on introduction of coal liquefaction

$\mathrm{WOX6} \leq \overline{\mathrm{WOX6}}$ -- Limits on introduction of methanol from biomass, in west

$\mathrm{EOX3} \leq \overline{\mathrm{EOX3}}$ -- Limits on introduction of methanol from biomass, in east

$\mathrm{WOEX} \leq \overline{\mathrm{WOEX}}$ -- Export limits

$\mathrm{WOX5} = \overline{\mathrm{WOX5}}$ -- Fixing of tar sands production to 2000

$\left.\begin{array}{l} \mathrm{EOX1} \leq \overline{\mathrm{EOX1}} \\ \mathrm{EOX2} \leq \overline{\mathrm{EOX2}} \end{array}\right\}$ -- Limits on eastern oil production

B.3. Gas -- Natural and Synthetic

a) List of Variables

WGX1 = western natural gas production, conventional areas, low cost
WGX2 = western natural gas production, conventional areas, high cost
WGX3 = northwest frontier natural gas production, low cost
WGX4 = northwest frontier natural gas production, high cost
WGX5 = synthetic gas (from biomass) production, in west
WGDi, (i=1,2,...,5) = capacity expansions of above
WGD6 = capacity expansion of syn. gas production from coal, west
WGX7 = gas for electricity production in west
WGX8 = gas for domestic, farm and commercial use in west
WGX9 = gas for industrial use in west
WGE = western gas transported to western region
WGEX = gas exports (to USA)
EGX1 = eastern natural gas production, low cost
EGX2 = eastern natural gas production, high cost
EGX3 = synthetic gas (from biomass) production, in east
EGDi, (i=1,2,3) = capacity expansions of above
EGX4 = gas for electricity production in east
EGX5 = gas for domestic, farm and commercial use in east
EGX6 = gas for industrial use in east

b) List of Parameters

cwg1,cwg2,cwg3 } cwg4,cwg5 = costs of corresponding western gas sources
pgex = price of gas exports
cgc = cost per unit output of coal gasification, not including cost of the coal
cgtr = cost of transporting gas from west to east
WGRi, (i=1,...,4) = reserves of corresponding western production type remaining after 1975
acg = gas output per unit of coal input to gasification
bwg,beg = fraction of gas supply remaining after deduction of gas use by energy supply industries, in the west and east, respectively
$\overline{WGX5}$ = upper limit on production of synthetic gas from biomass in west
$\overline{WGD6}$ = upper limit on capacity expansion of western coal gas'n
$\overline{WGE}$ = maximum capacity of west-to-east gas pipeline
ceg1,ceg2,ceg3 = costs of corresponding eastern gas sources
ag(s) = parameters for natural gas production decline curve
= fraction of capacity established s years ago which is still producing now
$\overline{WGEX}$ = upper limit on gas exports
EGRi, (i=1,2) = reserves of corresponding eastern production type remaining after 1975
$\overline{EGX3}$ = upper limit on production of synthetic gas from biomass in east
mgdw, mgiw, } mgde, mdie = gas distribution margins, to DFC and to Industrial sectors, respectively, west and east
$\overline{EGX1}$, $\overline{EGX2}$ = upper limits on production of eastern gas

c) Constraints

(i) Gas Production Decline Curves

$$\text{WGPRi:}\quad \text{WGXi}(t) = \sum_{s=0,5,\ldots}^{30} \text{ag}(s)\cdot \text{WGDi}(t-s),\ i=1,\ldots,4$$

$$\text{EGPRi:}\quad \text{EGXi}(t) = \sum_{s=0,5,\ldots}^{30} \text{ag}(s)\cdot \text{EGDi}(t-s),\ i = 1,2$$

(ii) Capacity Expansion and Retirement

$$\text{WGCP6:}\quad \text{WCX4}(t) = \text{WCX4}(t-5) + \text{WGD6}(t) - \text{WGD6}(t-30)$$

$$\text{WGCP5:}\quad \text{WGX5}(t) = \text{WGX5}(t-5) + \text{WGD5}(t) - \text{WGD5}(t-30)$$

$$\text{EGCP3:}\quad \text{EGX3}(t) = \text{EGX3}(t-5) + \text{EGD3}(t) - \text{EGD3}(t-30)$$

(iii) Reserves Limits

$$\text{WGRLi:}\quad \sum_{t\varepsilon T'} \text{WGXi}(t) \le \overline{\text{WGRi}},\quad i = 1,\ldots,4$$

$$\text{EGRLi:}\quad \sum_{t\varepsilon T'} \text{EGXi}(t) \le \overline{\text{EGRi}},\quad i = 1,2$$

(iv) Supply-Demand Balances

$$\text{WGSB: bwg}\cdot\left(\sum_{i=1}^{5} \text{WGXi} + \text{acg}\cdot \text{WCX4}\right) = \sum_{i=7}^{9} \text{WGXi} + \text{WGE} + \text{WGEX}$$

$$\text{EGSB: beg}\cdot\left(\sum_{i=1}^{3} \text{EGXi} + \text{WGE}\right) = \sum_{i=4}^{6} \text{EGXi}$$

(v) Bounds

$\text{WGEX} \le \overline{\text{WGEX}}$ -- exports limit

$\text{WGE} \le \overline{\text{WGE}}$ -- capacity of west-to-east pipeline

$\text{WGD6} \le \overline{\text{WGD6}}$ -- limit on capacity expansion of coal gasification

$\text{WGX5} \le \overline{\text{WGX5}}$ -- limit on production of gas from biomass, west

$\text{EGX3} \le \overline{\text{EGX3}}$ -- limit on production of gas from biomass, east

$$\left.\begin{array}{l}\text{EGX1} \le \overline{\text{EGX1}}\\ \text{EGX2} \le \overline{\text{EGX2}}\end{array}\right\} \text{ -- limits on production from eastern sources}$$

B.4. Electricity

a) List of Variables

WEX4,EEX4 = electricity from nuclear, west and east
WEX5,EEX5 = hydroelectricity production, west and east
WEX6,EEX6 = electricity from biomass, wind, tidal, etc., west & east
WEDi,EEDi, (i=4,5,6) = capacity expansions of above
WED1,EED1 = capacity expansion of electricity from coal, west & east
WED2,EED2 = capacity expansion of electricity from oil, west & east
WED3,EED3 = capacity expansion of electricity from gas, west & east
WEX9,EEX9 = electricity for industrial use, west and east
WEX10,EEX10 = electricity for transportation (electric car), west & east
WEX11,EEX11 = electricity for DFC use, west and east
WEEX, EEEX = electricity exports from west and east

b) List of Parameters

ce4 = cost of electricity from nuclear
ce5 = cost of hydroelectricity
ce6 = cost of electricity from biomass, etc.
peex = price of electricity exports
cec = cost of electricity from coal, excluding coal cost
cel = cost of electricity from oil, excluding oil cost
ceg = cost of electricity from gas, excluding gas cost
bwe, bee = fraction of electricity supply remaining after deduction of electricity use by energy supply industries, west and east
ace = electricity output per unit of coal input
ale = electricity output per unit of oil input
age = electricity output per unit of gas input
medw,meiw, mede,meie = electricity distribution margins, to DFC and to Industrial sectors, respectively, west and east
met = electricity road tax for transportation
$\overline{\text{WEX5}}$,$\overline{\text{EEX5}}$ = maximum hydro electric capacities in west and east
$\overline{\text{WED4}}$,$\overline{\text{EED4}}$ = maximum rate of nuclear electric capacity expansion in west and east
hdw, hde = maximum fractions of total electric capacity expansion which can be filled by hydro, in west and east

c) Constraints

(i) Capacity Expansion and Retirement

$$\begin{array}{c} \text{WECPi:} \\ \& \\ \text{EECPi:} \\ (i=1,\ldots,6) \end{array} \left\{ \begin{aligned} &\text{WCX5}(t) = \text{WCX5}(t-5) + \text{WED1}(t) - \text{WED1}(t-30) \\ &\text{ECX3}(t) = \text{ECX3}(t-5) + \text{EED1}(t) - \text{EED1}(t-30) \\ &\text{WLX1}(t) = \text{WLX1}(t-5) + \text{WED2}(t) - \text{WED2}(t-30) \\ &\text{ELX1}(t) = \text{ELX1}(t-5) + \text{EED2}(t) - \text{EED2}(t-30) \\ & \\ & \end{aligned} \right.$$

$$\left\{\begin{array}{l}
\mathrm{WGX7}(t) = \mathrm{WGX7}(t-5) + \mathrm{WED3}(t) - \mathrm{WED3}(t-30) \\
\mathrm{EGX4}(t) = \mathrm{EGX4}(t-5) + \mathrm{EED3}(t) - \mathrm{EED3}(t-30) \\
\mathrm{WEXi}(t) = \mathrm{WEXi}(t-5) + \mathrm{WEDi}(t) - \mathrm{WEDi}(t-30) \;,\; i = 4,5,6 \\
\mathrm{EEXi}(t) = \mathrm{EEXi}(t-5) + \mathrm{EEDi}(t) - \mathrm{EEDi}(t-30) \;,\; i = 4,5,6
\end{array}\right.$$

(ii) Supply-Demand Balances

$$\mathrm{WESBE:}\quad \mathrm{bwe}\cdot(\mathrm{ace}\cdot\mathrm{WCX5} + \mathrm{ale}\cdot\mathrm{WLX1} + \mathrm{age}\cdot\mathrm{WGX7} + \sum_{i=4}^{6} \mathrm{WEXi}) = \sum_{i=9}^{11} \mathrm{WEXi} + \mathrm{WEEX}$$

$$\mathrm{EESBE:}\quad \mathrm{bee}\cdot(\mathrm{ace}\cdot\mathrm{ECX3} + \mathrm{ale}\cdot\mathrm{ELX1} + \mathrm{age}\cdot\mathrm{EGX4} + \sum_{i=4}^{6} \mathrm{EEXi}) = \sum_{i=9}^{11} \mathrm{EEXi} + \mathrm{EEEX}$$

(iii) Other Constraints

$$\mathrm{WEMH:}\quad \mathrm{WED5} \le \mathrm{hdw}\cdot(\mathrm{ace}\cdot\mathrm{WED1} + \mathrm{ale}\cdot\mathrm{WED2} + \mathrm{age}\cdot\mathrm{WED3} + \sum_{i=4}^{6} \mathrm{WEDi})$$

$$\mathrm{EEMH:}\quad \mathrm{EED5} \le \mathrm{hde}\cdot(\mathrm{ace}\cdot\mathrm{EED1} + \mathrm{ale}\cdot\mathrm{EED2} + \mathrm{age}\cdot\mathrm{EED3} + \sum_{i=4}^{6} \mathrm{EEDi})$$

(iv) Bounds

$$\left.\begin{array}{l}
\mathrm{WEX5} \le \overline{\mathrm{WEX5}} \\
\mathrm{EEX5} \le \overline{\mathrm{EEX5}}
\end{array}\right\} \text{maximum hydro capacities}$$

$$\left.\begin{array}{l}
\mathrm{WEEX} \le \overline{\mathrm{WEEX}} \\
\mathrm{EEEX} \le \overline{\mathrm{EEEX}}
\end{array}\right\} \text{export limits}$$

B.5. Transportation End Use Sectors

a) List of Variables

WLA, ELA = oil for automobiles, west and east
WTD1, ETD1 = capacity additions for electric autos, west and east
WTD2, ETD2 = capacity additions for conventional autos, west and east
WRTR, ERTR = total output energy, road transportation, west and east
WOTR, EOTR = output energy, other transportation, west and east

b) List of Parameters

aea = output energy per unit electricity input, for electric autos
ala = output energy per unit oil input, for conventional autos
alo = output energy per unit oil input, for other transportation
el = maximum fraction of new autos that can be electric
cea = differential cost of electric auto over conventional

c) Constraints

(i) Capacity Expansion and Retirement

WTCP1: $\mathrm{WEX10}(t) = \mathrm{WTD1}(t) + \mathrm{WTD1}(t-5)$

ETCP1: $\mathrm{EEX10}(t) = \mathrm{ETD1}(t) + \mathrm{ETD1}(t-5)$

WTCP2: $\mathrm{WLA}(t) = \mathrm{WTD2}(t) + \mathrm{WTD2}(t-5)$

ETCP2: $\mathrm{ELA}(t) = \mathrm{ETD2}(t) + \mathrm{ETD2}(t-5)$

(ii) Supply-Demand Balances

WTSBL: $\mathrm{WLA} + (1/\mathrm{alo})\cdot\mathrm{WOTR} = \mathrm{WLX4}$

ETSBL: $\mathrm{ELA} + (1/\mathrm{alo})\cdot\mathrm{EOTR} = \mathrm{ELX4}$

WTSBA: $\mathrm{aea}\cdot\mathrm{WEX10} + \mathrm{ala}\cdot\mathrm{WLA} = \mathrm{WRTR}$

ETSBA: $\mathrm{aea}\cdot\mathrm{EEX10} + \mathrm{ala}\cdot\mathrm{ELA} = \mathrm{ERTR}$

(iii) Electric Auto Constraints

WTMEA: $\mathrm{aea}\cdot\mathrm{WTD1} \leq \mathrm{el}\cdot(\mathrm{aea}\cdot\mathrm{WTD1} + \mathrm{ala}\cdot\mathrm{WTD2})$

ETMEA: $\mathrm{aea}\cdot\mathrm{ETD1} \leq \mathrm{el}\cdot(\mathrm{aea}\cdot\mathrm{ETD1} + \mathrm{ala}\cdot\mathrm{ETD2})$

B.6. Industrial End Use Sector

WIND, EIND = Total output energy, industrial sector, in west and east, respectively

b) List of Parameters

agi = output energy per unit gas input, in industry
ali = output energy per unit oil input, in industry
aci = output energy per unit coal input, in industry
aei = output energy per unit electricity input, in industry
lwg, leg = lower limit on fraction of total output energy from gas, west and east
lwl, lel = lower limit on fraction of total output energy from oil, west and east
lwc, lec = lower limit on fraction of total output energy from coal, west and east
lwe, lee = lower limit on fraction of total output energy from electricity, west and east
uwg, ueg = upper limit on fraction of total output energy from gas, west and east
uwl, uel = upper limit on fraction of total output energy from oil, west and east
uwc, uec = upper limit on fraction of total output energy from coal west and east
uwe, uee = upper limit on fraction of total output energy from electricity, west and east

c) Constraints

(i) Supply-Demand Balance

WISB: $agi \cdot WGX9 + ali \cdot WLX3 + aci \cdot WCX6 + aei \cdot WEX9 = WIND$

EISB: $agi \cdot EGX6 + ali \cdot ELX3 + aci \cdot ECX4 + aei \cdot EEX9 = EIND$

(ii) Market Share Bounds

WISLG, WISUG: $lwg \cdot WIND \leq agi \cdot WGX9 \leq uwg \cdot WIND$

WISLL, WISUL: $lwl \cdot WIND \leq ali \cdot WLX3 \leq uwl \cdot WIND$

WISLC, WISUC: $lwc \cdot WIND \leq aci \cdot WCX6 \leq uwc \cdot WIND$

WISLE, WISUE: $lwe \cdot WIND \leq aei \cdot WEX9 \leq uwe \cdot WIND$

EISLG, EISUG: $leg \cdot EIND \leq agi \cdot EGX6 \leq ueg \cdot EIND$

EISLL, EISUL: $lel \cdot EIND \leq ali \cdot ELX3 \leq uel \cdot EIND$

EISLC, EISUC: $lec \cdot EIND \leq aci \cdot ECX4 \leq uec \cdot EIND$

EISLE, EISUE: $lee \cdot EIND \leq aei \cdot EEX9 \leq uee \cdot EIND$

B.7. Domestic, Farm and Commercial (DFC) End Use Sector

a) List of Variables

WER, EER = electricity for DFC electric resistance heating, west & east
WEH, EEH = electricity for DFC heat pump, west and east
WEO, EEO = electricity for DFC non-heating uses, west and east
WDD1, EDD1 = capacity expansions of DFC gas heating, west & east
WDD2, EDD2 = capacity expansions of DFC oil heating, west & east
WDD3, EDD3 = capacity expansions of DFC electric resistance heating, west and east
WDD4, EDD4 = capacity expansions of DFC electric heat pump, west & east
WDX5, EDX5 = output energy of district heating by cogeneration, west & east
WDX6, EDX6 = output energy of solar heating, west and east
WDD5, EDD5 = capacity expansions of WDX5, EDX5
WDD6, EDD6 = capacity expansions of WDX6, EDX6
WDFC, EDFC = total output energy, DFC sector, west and east

b) List of Parameters

chp, crh, coh, cgh } = non-fuel costs of heating by heat pump, electric resistance, oil, gas, respectively
chs = cost of solar heat
cdh = cost of district heating by cogeneration
agh = output energy per unit gas input, for DFC heating
alh = output energy per unit oil input, for DFC heating
aeh = output energy per unit electricity input, for DFC heat pump
aer = output energy per unit electricity input, for DFC electric resistance heating
aeo = output energy per unit electricity input, for DFC non-heating uses
gwh, geh = fraction of total DFC output energy for heating, west & east
hpw, hpe = maximum fraction of heating due to heat pump, west & east
sw, se = maximum fraction of heating due to solar, west and east
gw, ge = maximum fraction of heating due to cogeneration, west & east
fc = fraction of new coal-electric capacity available for cogeneration
fn = fraction of new nuclear-electric capacity available for cogeneration

c) Constraints

(i) Capacity Expansion and Retirement

WDCP1: $WGX8(t) = WGX8(t-5) + WDD1(t) - WDD1(t-15)$

EDCP1: $EGX5(t) = EGX5(t-5) + EDD1(t) - EDD1(t-15)$

WDCP2: $WLX2(t) = WLX2(t-5) + WDD2(t) - WDD2(t-15)$

EDCP2: $ELX2(t) = ELX2(t-5) + EDD2(t) - EDD2(t-15)$

WDCP3: $WER(t) = WER(t-5) + WDD3(t) - WDD3(t-15)$

EDCP3: $EER(t) = EER(t-5) + EDD3(t) - EDD3(t-15)$

WDCP4: $WEH(t) = WEH(t-5) + WDD4(t) - WDD4(t-15)$

EDCP4: $EEH(t) = EEH(t-5) + EDD4(t) - EDD4(t-15)$

WDCP5: $WDX5(t) = WDX5(t-5) + WDD5(t) - WDD5(t-30)$

EDCP5: $EDX5(t) = EDX5(t-5) + EDD5(t) - EDD5(t-30)$

WDCP6: $WDX6(t) = WDX6(t-5) + WDD6(t) - WDD6(t-15)$

EDCP6: $EDX6(t) = EDX6(t-5) + EDD6(t) - EDD6(t-15)$

(ii) Supply-Demand Balances

WDSBE: $WEX11 = WEH + WEO + WER$

EDSBE: $EEX11 = EEH + EEO + EER$

WDSBH: $$aer \cdot WER + agh \cdot WGX8 + alh \cdot WLX2 + aeh \cdot WEH + \sum_{i=5}^{6} WDXi = gwh \cdot WDFC$$

EDSBH: $$aer \cdot EER + agh \cdot EGX5 + alh \cdot ELX2 + aeh \cdot EEH + \sum_{i=5}^{6} EDXi = geh \cdot EDFC$$

WDSEO: $aeo \cdot WEO = (1-gwh) \cdot WDFC$

EDSEO: $aeo \cdot EEO = (1-geh) \cdot EDFC$

(iii) Heat Pump Constraints

WDSUP: $aeh \cdot WEH \leq hpw \cdot gwh \cdot WDFC$

EDSUP: $aeh \cdot EEH \leq hpe \cdot geh \cdot EDFC$

(iv) Solar Heat Constraints

WDSUS: $WDX6 \leq sw \cdot gwh \cdot WDFC$

EDSUS: $EDX6 \leq se \cdot geh \cdot EDFC$

(v) District Heat by Cogeneration Constraints

WDSUC, EDSUC: $WDX5 \leq gw \cdot gwh \cdot WDFC$, $EDX5 \leq ge \cdot geh \cdot EDFC$

WDMCG: $WDD5 \leq fc \cdot WED1 + fn \cdot WED4$

EDMCG: $EDD5 \leq fc \cdot EED1 + fn \cdot EED4$

B.8. Objective Function

a) List of Variables

EC = energy cost

b) List of Parameters

d = social discount rate

ed, ei, er, eo = price elasticities of demand for output energy in the sectors DFC, industry, road transportation and other transportation, respectively

dwd, dwi, dwr, dwo, ded, dei, der, deo = parameters derived from demand equation parameters for the sectors DFC, industry, road transportation and other transportation, in west and east

c) Objective Function (Maximand)

$$\text{OBJECTIV:}\quad \sum_{t\,\varepsilon\,T'} [1/(1+d)]^{t-1975} \cdot (dwd_t \cdot WDFC_t^{(1-1/ed)} + ded_t \cdot EDFC_t^{(1-1/ed)}$$

$$+ dwi_t \cdot WIND_t^{(1-1/ei)} + dei_t \cdot EIND_t^{(1-1/ei)} + dwr_t \cdot WRTR_t^{(1-1/er)}$$

$$+ der_t \cdot ERTR_t^{(1-1/er)} + dwo_t \cdot WOTR_t^{(1-1/eo)} + deo_t \cdot EOTR_t^{(1-1/eo)}$$

$$- EC_t)$$

d) Constraint

$$\text{NMMEC:}\quad EC = \sum_{i=1}^{2} (cwci \cdot WCXi + ceci \cdot ECXi) + pcim \cdot ECIM - pcex \cdot WCEX$$

$$+ cctr \cdot WCE + mciw \cdot WCX6 + mcie \cdot ECX4 + \sum_{i=1}^{6} cwoi \cdot WOXi$$

$$+ \sum_{i=1}^{3} ceoi \cdot EOXi + (mciw + clc \cdot acl) \cdot WCX3 + poim \cdot EOIM$$

$$- poex \cdot WOEX + cotr \cdot WOE + (mldw + coh \cdot alh) \cdot WLX2$$

$$+ (mlde + coh \cdot alh) \cdot ELX2 + mliw \cdot WLX3 + mlie \cdot ELX3 + mltw \cdot WLX4$$

$$+ mlte \cdot ELX4 + mlrw \cdot WLA + mlre \cdot ELA + \sum_{i=1}^{5} cwgi \cdot WGXi + \sum_{i=1}^{3} cegi \cdot EGXi$$

$$+ (mciw + cgc \cdot acg) \cdot WCX4 - pgex \cdot WGEX + cgtr \cdot WGE$$

$$+ (mgdw + cgh \cdot agh) \cdot WGX8 + (mgde + cgh \cdot agh) \cdot EGX5$$

$$+ mgiw \cdot WGX9 + mgie \cdot EGX6 + cec \cdot ace \cdot (WCX5 + ECX3)$$

$$+ cel \cdot ale \cdot (WLX1 + ELX1) + ceg \cdot age \cdot (WGX7 + EGX4)$$

$$+ \sum_{i=1}^{2} cei \cdot (WEXi + EEXi) - peex \cdot (WEEX + EEEX) + meiw \cdot WEX9$$

$$+ meie \cdot EEX9 + (met + cea \cdot aea) \cdot (WEX10 + EEX10)$$

$$+ medw \cdot WEX11 + mede \cdot EEX11 + crh \cdot aer \cdot (WER + EER)$$

$$+ chp \cdot aeh \cdot (WEH + EEH) + cdh \cdot (WDX5 + EDX5) + chs \cdot (WDX6 + EDX6)$$

B.9. Time Period Aggregation

In the previous eight sections, it was assumed that there were nine 5-year time periods. To save computation time, and since there is greater uncertainty associated with later time periods, later time periods have been aggregated in the following way: three five-year periods, followed by three 10-year periods. The time index, t, which marks the last year in each period, takes on values in the set

$$T \equiv \{1980,1985,1990,2000,2010,2020\}, \text{ or alternatively,}$$

$$\{5,10,15,25,35,45\} \text{ for brevity in the computer coding.}$$

The forms of the intraperiod constraints described earlier do not change after aggregation. This section is concerned with changes to the inter-period constraints due to the aggregation.

a) Changes to Capacity Expansion and Retirement Constraints

Let $X(t)$ be the flow, or production, and $D(t)$ capacity expansion. For brevity, label the time periods $t=5,10,15,25,35$, or 45. The method followed is to consider what multiple of a capacity addition continues to produce in later periods of differing lengths.

In the following, a bar on top of a variable indicates that the value of the variable is a datum, fixed at its past value (i.e. before $t=5$).

(i) 30-Year Lifetime

$$X(t) = X(t-5) + D(t) - \overline{D(t-30)}, \text{ for } t=5,10,15$$

$$X(25) = D(25) + 2 \cdot D(15) + 2 \cdot D(10) + 2 \cdot D(5) + 2 \cdot \overline{D(0)} + \overline{D(-5)}$$

$$X(35) = D(35) + D(25) + 2 \cdot D(15) + 2 \cdot D(10) + D(5)$$

$$X(45) = D(45) + D(35) + D(25) + D(15)$$

(ii) 10-Year Lifetime (Automobiles)

$$X(t) = D(t) + D(t-5)\ ,\ \text{for } t=5,10,15$$

$$X(25) = D(25) + D(15)$$

$$X(t) = D(t)\ ,\ \text{for } t=35,45.$$

(iii) 15-Year Lifetime (Most Heating in DFC)

$$X(t) = D(t) + D(t-5) + D(t-10),\ \text{for } t=5,10,15$$

$$X(25) = D(25) + 2 \cdot D(15) + D(10)$$

$$X(t) = D(t) + (0.5) \cdot D(t-5),\ \text{for } t=35,45.$$

b) Changes in Production Decline Curves

(i) Crude Oil

Using the data assumptions presented in Appendix C, Section 2 - i.e. new capacity lasts 10 years, followed by a 15-year decline at 10% per year -- the following may be derived:

$$X(t) = D(t) + D(t-5) + (.59) \cdot D(t-10) + (.35) \cdot \overline{D(t-15)} + (.21) \cdot \overline{D(t-20)},\quad \text{for } t=5,10,15$$

$$X(25) = D(25) + (1.59) \cdot D(15) + (.94) \cdot D(10) + (.56) \cdot D(5) + (.21) \cdot \overline{D(0)}$$

$$X(35) = D(35) + (.47) \cdot D(25) + (.56) \cdot D(15) + (.21) \cdot D(10)$$

$$X(45) = D(45) + (.47) \cdot D(35) + (.10) \cdot D(25)$$

(ii) Natural Gas

Using the data assumptions presented in Appendix C, Section 3 -- i.e. new capacity lasts 15 years, followed by a 15-year decline at 10% per year -- the following may be derived:

$$X(t) = D(t) + D(t-5) + D(t-10) + (.59) \cdot \overline{D(t-15)} + (.35) \cdot \overline{D(t-20)}$$
$$+ (.21)\ \overline{D(t-25)} \quad \text{for } t=5,10,15$$

$$X(25) = D(25) + 2 \cdot D(15) + (1.68) \cdot D(10) + (.94) \cdot D(5)$$
$$+ (.56) \cdot \overline{D(0)} + (.21) \cdot \overline{D(-5)}$$

$$X(35) = D(35) + (.80) \cdot D(25) + (.98) \cdot D(15) + (.56) \cdot D(10)$$
$$+ (.21) \cdot D(5)$$

$$X(45) = D(45) + (.80) \cdot D(35) + (.28) \cdot D(25) + (.21) \cdot D(15)$$

$X(55) = D(55) + (.80) \cdot D(45) + (.28) \cdot D(35)$ (altered for end effects correction -- see next section).

c) Changes to Reserves Limits Constraints

There is no change in these constraints when time periods are aggregated.

B.10. Corrections for End Effects

End effects due to the finite time horizon are minimized by a procedure based on the dual equilibrium method of Grinold (1980). He assumes that prices are constant after the time horizon in his method for LP problems -- i.e. the dual variables are constant after the time horizon, if expressed in undiscounted dollars. This method has been extended slightly to the NLP problem here by assuming that the output energy prices, derived from the gradient of the objective function, are also constant (in undiscounted dollars) after the time horizon. This extension affects only the nonlinear variables in the objective function.

Presented below are the alterations to the linear constraints and the linear part of the objective function -- that is, of Grinold's dual equilibrium method applied to the LP problem associated with the NLP problem, obtained by fixing the nonlinear variables exogenously. Next the alterations to the nonlinear part of the objective function are shown.

The procedure involves the addition of an extra time period, with altered constraints. The vector of all exhaustible resource production levels in period t is represented by y_t, the vector of resource limits by $\overline{R}$, and all other variables by X_t. Period "0" below represents periods 5, 10 and 15 together. The matrix H_t defines the impact of X_o in period t. The matrix K_1 represents the impact of X_t on period (t+10); K_2 is the impact of X_t on period (t+20).

Below, A and B are matrices involving relations among variables in the same time period. If d is the social discount rate, let $a \equiv 1/(1+d)$. The right hand side vector is $b = (b_o, b_{25}, b_{35}, \ldots)$. Following Grinold, let

$$b_{55}(\tilde{a}) = \sum_{t=55,65,\ldots}^{\infty} a^{t-55} b_t \quad ,$$

$$X_{55}(a) = \sum_{t=55,65,\ldots}^{\infty} a^{t-55} X_t \quad ,$$

$$Y_{55}(a) = \sum_{t=55,65,\ldots}^{\infty} a^{t-55} \; Y_t \quad , \text{ and}$$

$$K_1(a) = K_1 + a \cdot K_2 \; .$$

Grinold shows that the (LP) problem of minimizing the discounted cost of meeting the specified energy demands (the nonlinear variables here), with the dual equilibrium method is:

$$\text{minimize} \sum_{t \in T} a^{t-1975} EC_t + a^{55} \cdot EC_{55}(a)$$

subject to:

$$A_o X_o + B_o Y_o = b_o$$

$$H_{25} X_o + A\,X_{25} + B\,Y_{25} = b_{25}$$

$$H_{35} X_o + K_1 X_{25} + A\,X_{35} + B\,Y_{35} = b_{35}$$

$$H_{45} X_o + K_2 X_{25} + K_1 X_{35} + A\,X_{45} + B\,Y_{45} = b_{45}$$

$$K_2 X_{35} + K_1(a) X_{45} + (A + K_1(a)) X_{55}(a) + B\,Y_{55}(a) = b_{55}(a)$$

$$Y_0 + Y_{25} + Y_{35} + Y_{45} + Y_{55}(a) \leq \bar{R} \; .$$

The procedure involves the addition of one variable to the objective function, EC_{55}, and an extra set of constraints almost identical in form to the constraints of period 45, but with some different coefficients and a right hand side which depend on the discount rate.

In the full NLP problem, these changes to the constraints and the linear part of the objective function are made, and extra nonlinear terms are added, related to the consumers' surplus in the new, additional period 55. Since it is assumed that the output energy prices (in undiscounted dollars) are constant after period 45, it follows that the output energy demands will increase from their period 45 levels at rates influenced only by the exogenous determinants of demand such as population, real domestic product, etc. Using the notation of chapter 4, for brevity, the objective function for the full infinite horizon problem would be:

$$\text{maximize} \sum_t a^t \cdot \left(\sum_{i=1}^{8} \left(\frac{ei}{ei-1}\right) \cdot A_{i,t}^{1/ei} \cdot E_{i,t}^{1-1/ei} - EC_t\right),$$

where $E_{i,t}$ = output energy demand in sector i, in period t,

ei = the price elasticity of demand in sector i,

$t = 5,10,15,25,35,\ldots$,

and $E_{i,t} = A_{i,t} \cdot P_{i,t}^{-ei}$,

where $P_{i,t}$ = the price of output energy in sector i and period t, and

$A_{i,t}$ = the product of the exogenous factors determining demand in sector i and period t.

The assumption of constant prices is :

$$P_{i,t} = P_{i,55}\ , \text{ for } t \geq 55.$$

Assuming that the exogenous variables determining demand each grow at certain rates per year after period 55 (it is assumed that these rates are the rates of growth between t=45 and t=55 -- see Appendix C for these rates), it follows that for some gi (i=1,...,8) which can easily be calculated from the rates of growth and the various elasticities with respect to income, etc.,

$$A_{i,t} = A_{i,55} \cdot (1+gi)^{t-55}\ , \text{ and}$$

$$E_{i,t} = E_{i,55} \cdot (1+gi)^{t-55}.$$

Therefore, the objective function, under the constant price and the growth assumptions, is

$$\text{maximize} \quad \sum_{t=5}^{45} a^{t} \cdot \left(\sum_{i=1}^{8} \left(\frac{ei}{ei-1}\right) \cdot A_{i,t}^{1/ei} \cdot E_{i,t}^{1-1/ei} - EC_{t}\right)$$

$$+ \sum_{t=55}^{\infty} a^{t} \cdot \left(\sum_{i=1}^{8} \left(\frac{ei}{ei-1}\right) \cdot A_{i,55}^{1/ei} (1+gi)^{t-55} \cdot E_{i,t}^{1-1/ei} - EC_{t}\right).$$

Finally, the infinite sum can be collapsed into a finite sum of nine terms involving the nonlinear variables E_i (provided $a \cdot (1+gi) \leq 1$), and $EC_{55}(a)$ (defined above), namely

$$\sum_{i=1}^{8} a^{55} \cdot (1/(1-a \cdot (1+gi))) \cdot \left(\frac{ei}{ei-1}\right) \cdot A_{i,55}^{1/ei} \cdot E_{i,55}^{1-1/ei}$$

$$- a^{55} \cdot EC_{55}(a).$$

Viewed from another perspective, this method corrects for end effects by adding another period representing the time beyond the planning horizon. The extra constraints' coefficients, bounds and right hand sides are given values which tend to make the variables larger than they would be if the extra period were an ordinary one. The extra period's consumers' surplus is also weighted more heavily than if it were an ordinary period, offsetting the larger energy cost (EC) associated with the larger values of the other variables. The net effect is to treat the post-horizon period as one (very long) period, with appropriate weights to account for the length of the infinite period, with discounting applied.

Appendix C. Data for the Base Case.

The following abbreviations are used for frequently mentioned organizations:

HMA	Hedlin, Menzies and Associates, Ltd.,
EMR	Energy, Mines and Resources, Canada,
NEB	National Energy Board of Canada,
CPA	Canadian Petroleum Association, and
SRI	Stanford Research Institute,
SC	Statistics Canada.

C.1.0 Data for the Coal Sector

Throughout this section, the thermal contents of various grades of coal are assumed to be those reported by Statistics Canada (cat. no. 57-207), i.e., in units of 10^6 BTU/short ton:

Anthracite	25.4
Imported Bituminous	25.8
Canadian Bituminous	25.2
Sub-bituminous	17.0
Lignite	13.2

C.1.1. Costs and Remaining Supplies

It is assumed that the current cost of producing coal (the "low cost" in the model) is the reported at-mine price in 1974 -- i.e. before the rapid rise in coal prices in 1975, to avoid inclusion of "windfall profits" or vastly increased royalties. For bituminous coal in the west, this was about $\$.60/10^6$ (1975\$), according to figures derived from EMR (1977f) and Statistics Canada (cat. no. 26-206). However, the at-mine price of Alberta sub-bituminous coal and Saskatchewan lignite were about \$.20/10^6 BTU, using figures derived from the same sources. Since coal is treated as one commodity in the model, we take the lower grade cost as the cost of coal at the low price - i.e. cwcl = .02. A distribution margin of \$.80/10^6BTU, i.e. mciw = .08, is added to coal used in western industry (including that for liquefaction or gasification), to account for the total costs of coal to western industry in 1970, \$ 1.00/10^6BTU in 1975 \$, derived from Statistics Canada (cat. no. 57-506). The price of exported coal in 1975 at the mine, using EMR (1977f) figures, was about \$1.43/10^6BTU, while the production cost for this bituminous coal was about \$ .60/10^6BTU , for an economic rent of about \$.83/10^6BTU. The logic of the model requires that the export price equal production cost plus economic rent. Since cwcl = .02 and rent (in 1975))= .083, the 1975 export price is taken to be .103. This price is escalated at the rate of 2 1/2 % per year until the year 2000.(The international oil price is assumed to increase at 4% per year until 2000.) The result is:

Period	05	10	15	25,35....
pcex	.117	.132	.149	.191

The situation in the east is simpler. The coal is all bituminous, as are imports, and there are virtually no exports. The import price in 1975 was $\$1.37/10^6$BTU, using EMR (1977f) figures, and is assumed to increase in real terms at 2 1/2 % per year, the same rate as export prices, until 2000. The result, in model units, is:

Period	05	10	15	25
pcim	.155	.175	.198	.254

The eastern cost of (bituminous) coal production is determined in Nova Scotia, where the largest production is. The 1974 at-mine price was $\$.80/10^6$BTU, using EMR (1977f) figures. Therefore,

$$\text{cecl} = .08 \ .$$

The 1975 coal costs to electric utilities reported by Ellison (1978. p.71), in the cases where the coal used is mined locally, are reasonably close to the above values for cwcl and cecl.

The distribution margin for coal to eastern industry is derived by subtracting the weighted average of the 1970 production and import costs from the cost of coal to eastern industry, as reported by Statistics Canada (cat. no. 57-506). The result is,

$$\text{mcie} = .04 \ .$$

The cost of transporting coal to the east from the west is arrived at by subtracting the production cost from the price paid by Ontario Hydro for western coal. According to Ellison (1978,p.65) Ontario Hydro imported 2.7×10^6 tons of bituminous coal from B.C. and Alberta, and 1×10^6 tons of lignite from Saskatchewan in 1975, at costs of $135.8¢/10^6$BTU and $55.2¢/10^6$BTU respectively. Calculating an average weighted by the total BTU contents of the two types gives a price of 122.8¢/10^6BTU paid by Ontario Hydro. Subtracting 20¢/10^6 BTU production cost leaves an average transport margin of 102.8¢/10^6 BTU -- i.e.

$$cctr = 0.103 \quad .$$

HMA (1976, p.241) present an estimate of remaining coal reserves of 660 x 10^{15} BTU at a cost of .055 (in model units), and a further 44 x 10^{15} BTU at a cost of 0.11 . The discussion concludes with the comment that the reserves figures are probably low. Therefore, the reserves data chosen for the model are midway between the above total amount, and the Latour-Christmas estimate mentioned in HMA (1976, p.241), with the same proportional split of reserves between cost levels. The proportional split of the reserves between east and west is the same as that in HMA (1976, p.240) for coal potential reserves, by region (i.e. west, 98.66%, east, 1.34%). Finally, the lower costs in each region are those established above, and the higher cost levels are double the lower. The results are (in model units):

$$cwc1 = .02 \qquad \overline{WCR1} = 1{,}587 \quad ,$$

$$cwc2 = .04 \qquad \overline{WCR2} = 106 \quad ,$$

$$cec1 = .08 \qquad \overline{ECR1} = 22 \quad ,$$

$$cec2 = .16 \qquad \overline{ECR2} = 1.4 \quad .$$

C.1.2 Energy Supply Industry Use

Let bwc,bec = fractions of western and eastern coal supplies not used by western and eastern energy supply industries. These parameters are equal in all periods to their 1971-1975 values of .9996 (west) and .9994 (east), using data from Statistics Canada (cat. no. 57-207).

C.1.3 Miscellaneous Limits

In an EMR document (1976d, pp.96-97), it is stated that the coal terminal at Thunder Bay is to open in 1979 at a capacity of 3.5 x 10^6 tons/year, of which 25 x 10^6 tons are bituminous coal, and 1 x 10^6 tons are lignite. The capacity can be expanded quickly to 6 x 10^6 tons, and eventually to 9 x 10^6 tons/year. Using this information, and adding the 1971-75 amount transported through existing facilities, expressed in model units and 5-year capacities puts upper limits on west-to-east coal transportation for the first three periods as shown below.

Period	05	10	15
$\overline{\text{WCE}}$	.215	.579	.879

Because of the costs chosen, the model has a tendency to expand eastern coal production unrealistically quickly. Therefore, the following upper limits have been placed on ECX1, corresponding to a doubling in production every 5 years (about 15% increase per year):

Period	05	10	15
$\overline{\text{ECX1}}$	.506	1.012	2.024

Because of the large size of the coal reserves, and because the international price of coal is so much higher than its cost of production, the model tends to export coal at an unrealistically high rate. Therefore, upper limits are placed on coal exports in all periods, allowing exports to increase at about 5% per year (assuming a levelling-off of the rapid growth in the early 1970's):

Period	05	10	15	25	35	45
$\overline{\text{WCEX}}$	1.7	2.2	2.8	9.2	14.8	24.2

C.2.0 Data for the Oil Sector

C.2.1 Primary Costs and Remaining Supplies

Until a study on long-run supply curves for oil and natural gas is completed by EMR, the cost and supply data must be based on various sources. The cost of the "low cost" conventional oil (cwol) of western Canada is taken to be the wellhead price before the rapid price rise after 1973, based on data presented by the CPA (1977) - i.e.

$$cwol = .4,$$

in model units, or \$4/bbl. Based on estimates by EMR (1977c, p.31) of the costs of Lloydminster heavy oil, using an 8% rate of return over a 15-year production time span, the higher cost of western "conventional" oil is taken to be

$$cwo2 = .8,$$

or \$8/bbl.

The total remaining reserves (after 1975) of conventional western oil, at both cost levels, are taken to be 12 x 10^9 bbl, which is the total of remaining reserves at the 100% probability, plus undiscovered resources at the 40% probability level reported by EMR (1977b) for western Canada. The amount of these reserves allocated to the lower cost level is taken to be sufficient to allow existing conventional western oil producing capacity to run the course of the oil production decline curve (i.e. to ensure model feasibility). The allocation $\overline{\text{WOR1}} = 6.0$, $\overline{\text{WOR2}} = 6.0$ works well.

The total remaining reserves of northern frontier oil (not including northeast offshore-Labrador oil, which is allocated to the east in the model) are taken to be 7.7 x 10^9 bbl, based on the 40% probability level in EMR (1977b). The low and high costs for these reserves (i.e. including transportation to southern Alberta) are based on various sources, namely an early draft of the EMR (1977d) study on long run supply curves, and figures in the report by HMA (1976). The costs chosen are \$10/bbl and \$14/bbl, or in model units

$$cwo3 = 1.0$$
$$cwo4 = 1.4$$

Based on the general shape of the tentative long-run supply curves in EMR (1977d), the following allocation of reserves between the two cost levels has been made:

$$\overline{WOR3} = 4.4$$
$$\overline{WOR4} = 3.3$$

Using cost estimates on tar sands mining, by EMR (1977c, p. 31), and a rate of return on capital of 8% over 30 years, the cost of syncrude is set at \$12/bbl, or in model units,

$$cwo5 = 1.2.$$

(This is the 1975 price of crude oil imported to eastern Canada, as well.) The remaining reserves of syncrude from the tar sands are taken to be 200 x 10^9 bbl, based on estimates in EMR (1978c), or in model units,

$$\overline{WOR5} = 200.0.$$

The "low cost" eastern oil is taken to be represented mostly by southeast offshore oil, and the "high cost" by northeast offshore oil. Based on the 40% probability level of potential resources in these two areas, reported by EMR (1977b), the reserves are taken to be

$$\overline{EOR1} = 3.0,$$
$$\overline{EOR2} = 2.0.$$

Based on various sources -- namely estimates by Millan (1980) of development and operating costs for the Hibernia discovery at an 8% rate of return, the EMR draft (1977d), and HMA (1976) -- the landed costs of these are set at \$7/bbl and \$10/bbl, respectively, i.e.

ceo1 = 0.7
ceo2 = 1.0.

Once again, limits are placed on the rate of expansion of these sources in the model (see the last section, on limits).

C.2.2 Import and Export Prices

The prices of imports and exports are taken to be the same except for the oil import subsidy in the first three periods. The 1975 price of imported oil, at North America, of \$12/bbl, is increased at the rate of 4% per year until the year 2000. Recall that all values are expressed in 1975\$ in the model, and that the 4% per year figure is therefore net of inflation. The figure of 4% has been chosen to reflect expectations of continuing rapid increases in the price of international oil, and because 4% per year is a rate which would be in the best interests of consuming and producing countries, according to Manne (1978). With a subsidized eastern domestic price of about \$10.80/bbl (calculated from Helliwell (1979)) in 1978, the mid-year of the first period, and assuming the subsidy reaches zero by the fourth period, the price series are:

Period	0.5	10	15	25,35,45..
poex	1.46	1.78	2.16	3.20
poim	1.08	1.48	1.93	3.20

C.2.3 Oil Production Decline Curves

The standard production time-profile presented by EMR (1973, p.80) is a two-year buildup to a peak lasting seven years, followed by a decline at the rate of 15% per year. This rate of decline appears to be too rapid when compared to the NEB (1978) projection of producibility from established light and heavy crude oil reserves. The latter suggests a decline rate of 10% per year, which is adopted in this model. In deriving the parameters ao(s), it is assumed as an approximation that new capacity established in one year lasts at the same level for ten years, then declines at 10% per year for the next 15 years. See Appendix B, section 9, "Time Period Aggregation" for the detailed results, taking into account the varying lengths of the time periods.

C.2.4. Coal Liquefaction

Let acl = 10^9 bbl of liquefied product per 10^{15} BTU of coal input; and clc = cost of liquefaction of coal, not including coal feed cost, in units of 10^{12}\$ per 10^9 bbl.

Using estimates by the SRI (1976, Vol. II, p.IV-7), and a real rate of return on capital of 8% per annum, the parameters are set at

$$\text{acl} = 0.1072 \text{ and clc} = .79,$$

in the model's units. The conversion efficiency corresponding to the above acl is 0.622.

The earliest date of introduction of coal liquefaction, according to SRI (1976), is 1987.

It is assumed in the model, therefore, that coal liquefaction can be introduced after 1985 -- i.e. WLDC = 0.0 for t = 0.5, 10.

C.2.5 Methanol from Biomass

Let cwo6, ceo3 = cost of producing methanol from biomass.

Using figures from Middleton Associates (1976, p. 316) \$30/bbl is the approximate cost. Since in the model methanol from biomass enters the oil stream, which is subject to refining charges, it is necessary to subtract a refining charge of \$4.20/bbl (from EMR (1977a, p. 53)).

from the cost of methanol, a finished product. The result, in model units of 10^{12}\$ per 10^9 bbl, is

$$cwo6 = ceo3 = 2.5.$$

It is assumed that this technology can be introduced after 1980, i.e.

$$\overline{WOX6} = \overline{EOX3} = 0.0 \text{ for } t = 05 .$$

C.2.6 West-to-East Oil Transportation

Let cotr = cost of transporting oil from west to east.

An EMR report (1978a, p.50) gives \$.60/bbl for this oil transportation margin in 1977, from Edmonton to Port Credit. In 1975\$ and model units, this is

$$cotr = .05.$$

Let opipe = fraction of eastern crude oil market accessible to western crude supply.

According to estimates in Oilweek (Feb. 12, 1979, p. 31, table entitled "Canadian Petroleum Consumption") the fraction of eastern crude oil supplied from western sources was 0.5355 in 1978 (i.e. after the extension of the pipeline to Montreal). In the model, the following gradual approach towards full accessibility of western oil to eastern markets is assumed:

Period, t =	0.5	10	15,25...
opipe	.54	.77	1.0

C.2.7 Distribution and Refining Margins

These costs have been estimated as the differences between the retail prices in the end use sectors and the refinery-gate price of crude oil, in a pre-"crisis" year, reduced by an amount to prevent double-counting of the cost of crude oil used by the energy supply industry (mostly the still gas used in the refining process).

Used in the DFC sector was the weighted average of the 1973 retail prices of light and heavy fuel oils for industry, as reported by Statistics Canada (cat. no. 57-506), adjusted downward by the difference between the 1970 and 1973 wellhead prices of oil, in 1975$, as reported by the CPA (1977). The margins are

$$mldw = 0.32, \quad mlde = 0.21.$$

Used in the industrial sector was the 1970 average retail price for all industrial fuel oils, as reported by Statistics Canada (cat. no. 57-506). The margins are

$$mliw = 0.04, \quad mlie = 0.01.$$

Used for the "other" transportation sector were the 1973 retail prices to industry for heavy fuel oil and disel oil, adjusted downward by the difference between the 1973 and 1970 western Canadian wellhead oil prices. An average price to "other" transportation was arrived at by weighting these prices by the 1970 consumption of heavy fuel oil, and diesel oil plus aviation turbine fuel. It was assumed that the price of aviation turbine fuel was the same as the diesel price, since the 1970 values per barrel shipped from refineries, derived from Statistics Canada (cat. no. 45-205, Table 6) for the two fuels, were almost equal (within 1% of each other). The margins are:

$$mltw = 0.77, \quad mlte = 0.69.$$

Used in the road transportation sector was the 1970 retail gasoline price reported by EMR (1977a, Appendix C). Since the "other" transportation margins, mltw and mlte, are applied to oil products going to both "other" and "road" transportation sectors -- i.e. to the variables WLX4 and ELX4 - it is necessary to deduct mltw and mlte from the margins for the road transportation sector. The net margins are

mlrw = 1.15, mlre = 1.36,

applied to the variables WLA and ELA.

C.2.8 Energy Supply Industry Use of Oil

Let bwl, bel = fractions of the western and eastern supplies of oil *not* used by the western energy supply industries (including refining).

These parameters are equal in all periods to their 1971-1975 values of .9272 (west) and .9262 (east), using data from Statistics Canada (cat. no. 57-207).

C.2.9. Miscellaneous Limits

Using the NEB (1978) figures for the "base case" expansion of tar sands capacity to 1995, the following values of tar sands production are imposed:

Period	05	10	15	25
WOX5	.181	.372	.767	2.756

Upper limits on oil exports (including net product exports) are taken from the NEB reports (1977, 1978), and, for 1976 and 1977, from EMR (1978c). The limits are assumed to be zero after 2000. The limits are

Period	05	10	15	25	35,45
WOEX	.597	.152	.073	.067	0.0

It is assumed that production from eastern onshore and southeast offshore sources is no higher than the 1971-75 level, in 1976-1980, and that it can increase to 50 million barrels per year in the 1986-1990 period, with a buildup in the 1981-1985 period:

Period	05	10	15
$\overline{\text{EOX1}}$	.004	.050	.250

It is assumed that production from northeast offshore sources cannot begin until after 1985, and that for t = 15, 25, it is no greater than southeast production is allowed to be one period earlier, i.e.:

Period	05	10	15	25
$\overline{\text{EOX2}}$	0.0	0.0	.050	.500

C.3.0 Data for the Gas Sector

C.3.1 Primary Costs and Supplies

Until a study by EMR on long-run supply curves is completed, the cost and supply data must be based on several sources. The cost of "low cost" conventional western gas is taken to be \$.30/Mcf. According to CPA (1977) data, the average wellhead price during 1971-1975 was \$.21/Mcf (1975\$). Thus \$.30/Mcf is a little farther along the long-run supply curve. In model units, this cost is:

$$cwg1 = .03$$

The higher cost western conventional gas is taken to be

$$cwg2 = .08,$$

somewhat arbitrarily.

The remaining reserve (after 1975) at the above cost levels are estimated roughly from the shape of the tentative long run supply curve of the EMR draft (1977d), and using the total of remaining known reserves plus undiscovered resources, at the 40% probability level, from EMR (1977b). They are:

$$\overline{WGR1} = 39.0$$
$$\overline{WGR2} = 59.0.$$

The total remaining reserves of northern frontier gas (not including northeast offshore gas, which is allocated to eastern production) are taken to be 137 x 10^{12} cu. ft., which is the figure for potential resources, at the 40% probability level, from EMR (1977b). The low and high cost levels (including transportation to southern Alberta) are based on various sources, namely an early draft of the EMR study (1977d) on long-run supply curves, and figures in the report by HMA (1976). The costs chosen are \$2.50/Mcf and \$3/Mcf, or, in model units:

$$\begin{aligned} cwg3 &= .25 \\ cwg4 &= .30. \end{aligned}$$

Based on the shapes of the tentative long-run supply curves of EMR (1977d), the following allocation of reserves between the two cost levels has been made:

$$\begin{aligned} \overline{WGR3} &= 44.4 \\ \overline{WGR4} &= 93.0. \end{aligned}$$

The low cost eastern gas is taken to be represented by southeast off-shore gas, and the high cost eastern gas by northeast offshore gas. Based on the 40% probability level of potential resources in these two areas, reported by EMR (1977b), the reserves are taken to be

$$\begin{aligned} \overline{EGR1} &= 16.0 \\ \overline{EGR2} &= 29.0. \end{aligned}$$

Based on the EMR draft (1977d) and HMA (1976), the landed costs of these are set at \$.60/Mcf and \$3.00/Mcf, respectively. In model units, these are

$$\begin{aligned} ceg1 &= .06 \\ ceg2 &= .30 \end{aligned}$$

Limits are placed on the rate of increase of production of the low cost eastern gas (see the section on miscellaneous limits).

C.3.2 Export Price

The 1976 EMR "Energy Strategy" report (1976a) lays out the policy that prices of gas exports should be competitive in the markets where they are sold. The 1978 (mid-year of first period) gas export price was \$1.92/Mcf, according to Helliwell (1979). Assuming gas export prices follow the same pattern assumed for oil prices, the real gas price is escalated at the rate of 4% per year until the year 2000. Since the logic of the model requires export prices to be equal to production cost plus economic rent, and since there is no provision in the model for gas transport charges from the wellhead to the border, the transport charge -- about \$.25/Mcf -- must be subtracted from the above. The result, in model units, is:

Period	05	10	15	25,35,45
pgex	.167	.209	.259	.396

C.3.3 Gas Production Decline Curves

The standard production time-profile presented by EMR (1973, p. 80) has the peak rate being achieved in the first year and maintained for 15 years, followed by a decline at the rate of 15% per year. This rate of decline appears to be too rapid. As with oil production, it is assumed that production declines at 10% per year. The detailed results for the values ag(s), based on the assumptions that capacity established in one year lasts 15 years, followed by a decline of 10% per year for another 15 years, are in Appendix B, section 9, "Time Period Aggregation".

C.3.4 Coal Gasification

Let acg = 10^{12} cu.ft. of gas output per 10^{15}BTU coal input; and cgc = cost of coal gasification, not including coal feed cost, in units of 10^{12} \$ per 10^{15}cu. ft.

Using estimates by the SRI (1976, Vol. II, pp. IV-4,5), the parameters are set at

$$acg = 0.567 \text{ and } cgc = 0.124.$$

These are arrived at by averaging the conversion efficiencies and costs for the Lurgi process, and an "Advanced" process, as estimated by SRI (1976), and converting to model units. The average conversion efficiency corresponding to the above acg is 0.587.

The earliest dates of introduction of coal gasification, according to SRI (1976), are 1984 for the Lurgi process, and 1987 for the "Advanced" process. The approximate date of 1985-86 is modeled by fixing capacity additions at the zero level for the periods ending 1980 and 1985, i.e.

$$\overline{WGDG} = \begin{cases} 0.0, & t = 05 \\ 0.0, & t = 10, \end{cases}$$

and setting initial capacity equal to zero.

C.3.5 Synthetic Gas from Biomass

Middleton Associates (1976, pp. 300-301) give a cost range for pyrolysis (gas and liquid output) of \$1.50-\$3.50 per million BTU(MMBTU). An average value of \$2.50 per MMBTU (or \$2.50 per MCF of gas) is taken for the model. In model units, this is $cwg5 = ceg3 = 0.25$. It is assumed that this technology is available after 1980. In order to model this, production is set equal to 0.0 in the first period. For later periods, low upper limits are placed on production from this source, as shown below:

Period	05	10	15	25,35,45
$\overline{WGX5}$	0.0	.0005	.001	.002
$\overline{EGX3}$	0.0	.001	.002	.004

C.3.6 West-to-East Gas Transportation

Let cgtr = cost of transporting gas from west to east.

Helliwell (1976, appendices) gives \$.44/mcf for this cost. In model units, this is

$$cgtr = .044.$$

It is assumed that the west-to-east transportation of gas can increase from the 1971-1975 level up to 3.5% per year until 1985, when the Quebec & Maritimes pipeline may be built. Since this pipeline will make the eastern market potentially 43% larger (based on population shares), an additional amount (above 3.5% growth) is added, equal to 1/2 the potential increase (i.e. 21.5% more), since it takes time to establish the new markets. There is no upper limit after 1990. The results are:

Period	05	10	15
$\overline{\text{WGE}}$	4.092	4.860	7.008

C.3.7 Distribution Margins

The margins for the two sectors industrial (mgiw, mgie) and DFC (mgdw, mgde), are taken to be the differences between the average revenues and wellhead price (Toronto city gate, for the east) in 1970, a pre-"crisis" year. The average revenues were derived from Statistics Canada (cat. no. 57-205), the wellhead price from the CPA (1977) and the Toronto city gate price from the sum of the wellhead price and the west-to-east gas transport charge. The margins are:

$$mgiw = 0.0155, \quad mgie = 0.0055, \text{ and}$$
$$mgdw = 0.0744, \quad mgde = 0.0851.$$

C.3.8 Energy Supply Industry Use of Gas

Let bwg, beg = fractions of the western and eastern supplies of gas <u>not</u> used by the western and eastern energy supply industries.

These parameters are equal in all periods to their 1971-1975 values of .8832 (west) and .958 (east), using data from Statistics Canada (cat. no. 57-207).

C.3.9 Miscellaneous Limits

Upper limits on future gas exports are set at the level of currently approved exports, according to the NEB (1979, Table G-12) -- i.e., in model units,

Period	05	10	15	25	35,45
$\overline{\text{WGEX}}$	5.4	8.4	3.7	0.3	0.0

Eastern production (mostly offshore) is assumed to be able to reach up to 0.8 Tcf per year in the year 1988, following comments by Walters (1979) on the availability of Sable Island gas, and assuming all eastern offshore gas is available, starting in 1988. It is assumed that the northeast offshore gas is available after 1990 (existing onshore production makes a small contribution in the first two periods).

The upper limits are:

Period	05	10	15	25	35,45
$\overline{\text{EGX1}}$	0.001	0.001	2.4	no limit	no limit
$\overline{\text{EGX2}}$	0.0	0.0	0.0	4.8	no limit

C.4.0 Data for the Electricity Sector

C.4.1 Capital and Non-fuel Operating Costs for Secondary Electricity Production

The source for the basic data is the report by HMA (1976, p. 250). The data given below, in model units, were derived using a real rate of return of 8% over 30 years. (Multiplication by 10 yields the costs in mills/kWh.).

Fuel	Gas	Coal	Oil
Cost	ceg = .54	cec = .76	cel = .66

C.4.2 Fuel-to-Electricity Conversion Coefficients

Let age = 10^{12}kWh electricity output per 10^{12} cu. ft. gas input,

ace = 10^{12}kWh electricity output per 10^{15}BTU coal input, and

ale = 10^{12}kWh electricity output per 10^{9} bbl oil input.

From data compiled by Statistics Canada (cat. no. 57-207) for 1971-1975, the above parameters can be estimated. The parameter values, with approximate corresponding conversion efficiencies are:

Parameter	age	ale	ace
Value in Model	.0788	.4621	.09396
Corresponding Conversion Efficiency	.2689	.2718	.32

For the base case, the conversion factors for gas, oil and coal are increased in the first three periods in approximately the same amount as assumed by EMR (1977a, p. 68). In addition, coal electric production is assumed to increase in efficiency to 38%, due to introduction of fluidized bed combustion (using estimates by Keairns, et al. (1975, p. 10)), by the period 2000. The results are:

Parameter \ Period	05	10	15	25,35,...
age	.0850	.0879	.0879	.0879
ale	.4942	.5746	.5900	.5900
ace	.0954	.0998	.1028	.1113

C.4.3 Nuclear Power

The cost of electricity from nuclear power is taken to be 10 mills/kwh, or ce4 = 1.0, in model units. This figure is based on capital and non-fuel operating costs of 8.9 mills/kwh, derived from estimates by HMA (1976), with a real rate of return of 8% over 30 years, and fuelling costs of 1.1 mills/kwh, converted to 1975$ from a 1976 estimate by Kee and Woodhead (1977). Since Canada has abundant reserves of uranium, no cost increase over time is assumed for nuclear electricity. In later time periods, this technology may be thought of as the thorium near-breeder, or a fusion system.

Because of the long lead times in establishing nuclear capacity, and because there is no nuclear power yet in the west, the following restriction is specified:

$$\overline{WED4} = 0.0 \ , \quad t = 05,10 \ .$$

C.4.4 Cost of Hydroelectricity

Protti (1978, p.56) gives the capital cost of a recent, large hydro installation in Manitoba. Using this information, in 1975 dollars, and a rate of return on capital of 8% over 30 years, together with the non-fuel operating costs assumed for coal-electric production by HMA (1976, p. 250), the cost of hydro-electricity is taken to be 7.7 mills/kwh, or in model units,

$$ce5 = .77 \ .$$

C.4.5 Limitations on Hydroelectricity

Using estimates in the report by HMA (1976, p.242), the maximum hydroelectric production, per 5-year period, that can be realized in the future is about 1.27×10^{12} kwh in the west, and 2.21×10^{12} kwh in the east. From Statistics Canada (cat. no. 57-207), the 1971-1975 hydro productions were 0.24×10^{12} kwh for the west and 0.71×10^{12} kwh for the east. Assuming that the future potential can be reached no sooner than the period ending 2000, and allowing a linear increase in capacity until then, the values for the parameters in the model are (recall that the first

3 periods are 5 years long, and the rest are 10):

Period	05	10	15	25,35,...
WEX5	0.45	0.65	0.86	2.54
EEX5	1.01	1.31	1.61	4.42 .

To account for the relative lack of hydro potential in some provinces of each region, it is assumed that the proportion of electric capacity expansion due to hydro cannot exceed the 1971-1975 fraction of total electricity production coming from hydro -- i.e., using figures from Statistics Canada (cat. no. 57-207, and 57-204),

$$hdw = .753, \quad hde = .779.$$

C.4.6 Cost of Electricity from Biomass

According to Middleton Associates (1976, p. 287), the cost of wood chip input is approximately \$1.50/MMBTU, if we reduce Middleton's figures somewhat to account for the higher capital cost (10%) than is assumed in this model (8%). The thermal efficiency of generation is 34%. Therefore, the fuel cost is $\frac{\$1.50}{.34} \cong \$4.50$ per MMBTU of output. Converting to units of mills/kWh, the fuel cost is 15.3. Assuming the capital and non-fuel operating costs are the same as for coal (7.6 mills/kWh), the total cost, expressed in model units is

$$ce6 = 2.29.$$

C.4.7 Electricity Exports

Manne (1976) presents a projection of U.S. electricity prices, which can be approximated by 18 mills/kWh in the period 1975-1990, and 23 mills/kWh in the period 2000-2025, expressed in 1970\$. The CPA (1977, Section XI, Table 3), presents statistics on quantity and value of electricity exports. The 1975 average export price is 14.5 mills/kWh. Appling a factor of 14.5/18.0 to the Manne (1976) projection produces the projection used in the model (model units are presented in the table):

Period	05	10	15	25,35,45
peex	1.45	1.45	1.45	1.86

Electricity exports are allowed to be no greater than the level in 1971-75, increased at a rate of 1% per year, i.e.

Period	05	10	15	25	35	45
$\overline{\text{WEEX}}$	.0161	.0169	.0178	.0393	.0434	.0480
$\overline{\text{EEEX}}$	.0333	.0350	.0368	.0814	.0898	.0992

C.4.8 Electricity Distribution Margins

The margins for the two sectors industrial (meiw, meie) and DFC (medw, mede) are taken to be the differences between the average revenues and average generation costs in 1971, a pre-"crisis" year. The average revenues were derived from Statistics Canada (cat. no. 57-202), and the average generation costs from Statistics Canada (cat. no. 57-207), using the unit generation costs and fuel costs derived above.

The margin for electricity used in road transportation (met) -- i.e. for electric automobiles -- is based on two assumptions: first, that there would be a road tax equivalent to the road tax on gasoline, and second that the recharging of electric autos would receive off-peak price discounts. Specifically, the road tax of approximately 13 cents per gallon across the country (according to Statistics Canada (cat. no. 68-201)) is converted to dollars per output BTU, and then converted to dollars per kWh of electricity used for electric autos. It is assumed that revenue from electricity sales to the road transportation sector covers only generation costs and the road tax -- i.e. there is no distribution margin.

The margins are:

meiw = 0.18, meie = -0.10,
medw = 1.55, mede = 1.00, and
met = 1.03

C.4.9 Energy Supply Industry Use of Electricity

Let bw, bee = fractions of the western and eastern supplies of electricity *not* used by the western and eastern energy supply industries (including transmission losses).

These parameters are equal in the period 1971-1975 to .8938 (west) and .9096 (east), using data from Statistics Canada (cat. no. 57-207). They are altered in the first three periods roughly in accordance with the assumptions of EMR (1977a, p. 71). The results are:

Period Parameter	05	10	15, 25, 35 ...
bwe	.8984	.9034	.9083
bee	.9143	.9193	.9244

C.5.0 Data for Transportation End Use Sector

C.5.1 Conversion Factors

Let ala = 10^{15} BTU output per 10^{9} bbl input, conventional autos,
aea = 10^{15} BTU output per 10^{12} kWh input, electric autos, and
alo = 10^{15} BTU output per 10^{9} bbl input, non-auto transportation.

EMR (1977a, p. 28) estimates the utilization efficiency for gasoline to be 20%. Using the factor for conversion of gasoline units to BTU's,

$$ala = .2 \times 5.222 = 1.0444.$$

Assuming an improvement in fuel economy bringing average mileage from the present 17.5 miles per gallon to 33 miles per gallon after 1985 as projected by EMR (1976b, p. 2), and increasing to 50 m.p.g. by 2020, the values are:

Period	05	10	15	25	35	45
ala	1.3527	1.6611	1.9694	2.3076	2.6457	2.9839

The comparable conversion efficiency for electric autos is the basic operating efficiency of 70%, given by Swinton (1976, p. 29). Multiplying by the factor for conversion of electrical units to BTUs,

$$aea = .7 \times 3.412 = 2.388.$$

For non-auto transportation, a weighted average of utilization efficiencies given by EMR (1977a, p. 28) for rail, air and marine transport, using liquid fuels, yields a conversion efficiency of 24%. (Coal, already in little use by 1975 in transportation, is assumed not to be used in transportation.) With an approximate average factor for conversion of liquid fuel units to BTUs,

$$alo = .24 \times 5.8 = 1.41.$$

Air, truck and bus energy efficiency measures discussed in EMR (1977e, p. 28) are expected to amount to 18%-20% fuel savings in 1990. Assuming the fuel savings will actually be 15%, by 2000, and more modest improvements after 2000, the conversion factor, alo, takes the following values:

Period	05	10	15	25	35, 45
alo	1.46	1.51	1.66	1.71	1.71

C.5.2 Electric Auto Growth Restrictions

Let el = maximum fraction of new autos that can be electric, in west and east. From the discussion by Hedley, et al. (1976, p. 13) on the "free market" penetration of electric autos, it is assumed that

$$el = \begin{cases} 0, & t = 05, 10 \\ .15, & t = 15 \end{cases}$$

but that a 60% penetration can be achieved by 2010, i.e.

$$el = \begin{cases} .375, & t = 25 \\ .6, & t = 35, 45. \end{cases}$$

C.5.3 Differential Cost of Electric Auto over Conventional Auto

The latest information on the U.S. electric test vehicle, ETV-1, suggests an initial cost difference of approximately $1500 extra for the electric auto, in Canadian 1975$, according to Wayne (1979, p. 13). Lower maintenance costs for the electric car would be offset by battery replacement charges. Amortized over 10 years, at a rate of return on capital of 8%, the annual extra cost is $224. Assuming the vehicle travels 10,000 miles in a year, this is $0.0224 per mile extra for the electric car.

Since ala = 1.0444 corresponds to 17.5 miles per gallon, the quantity of output energy per mile driven is

$$(1.0444/(35 \times 10^{9} \times 17.5) = (1.705 \times 10^{-12}) \times 10^{15}\text{BTU per mile.}$$

(Dividing by aea = 2.388 gives the number of kwh per mile, 0.714 kwh per mile.

This falls within the range given by Wayne (1979, p. 10), of 0.5 - 1.5 kwh per mile.)

Therefore, the differential cost of electric auto output energy is $.0224/1.705 = $.0132 per 10^{3}BTU, or in model units, cea = 1.32.

C.6.0 Data for Industrial End-Use Sector

C.6.1 Conversion Factors

Let

agi = 10^{15}BTU per 10^{12} cu. ft. gas used in industrial sector,

ali = 10^{15}BTU per 10^{9}bbl liquid hydrocarbon (oil) used in industrial sector,

aci = 10^{15}BTU per 10^{15}BTU coal used in industrial sector, and

aei = 10^{15}BTU per 10^{12}kWh electricity used in industrial sector.

EMR (1977a, p. 28) has estimated average utilization efficiencies for the different fuels in the industrial sector. The above parameters are set at EMR estimates, expressed in model units, for all time periods. Since EMR deals separately with different liquid fuels, it is necessary to take a weighted average of the liquid fuel conversion efficiencies, for the model.

The parameter values, and associated conversion efficiencies, are:

Parameter	agi	ali	aci	aei
Value in Model	.85	4.13	.87	3.412
Corresponding Conversion Efficiency	.85	.70	.87	1.00

C.6.2 Upper and Lower Limits on Fractions of Total Industrial Output Energy Available from the Different Fuels

HMA (1976, p. 148) present estimates of these upper and lower limits for the year 2000. It is assumed that these parameters change linearly from their 1971-1975 values (when upper limit = lower limit = actual fraction), estimated from Statistics Canada (cat. no. 57-207), to the HMA (1976) values for 2000, and remain constant after this. The results are presented in Table 69. Non-energy uses of oil and gas (e.g. for petrochemicals, asphalt, etc.) are included in industrial uses.

Table 69. Bounds on Industrial Fuel Shares

Fuel	Limit	Period Base	05	10	15	25,35,...
Coal	lwc	.030	.044	.058	.072	.10
	lec	.172	.158	.143	.129	.10
	uwc	.030	.084	.138	.192	.30
	uec	.172	.198	.223	.249	.30
Oil	lwl	.279	.243	.207	.172	.10
	lel	.348	.298	.249	.199	.10
	uwl	.279	.343	.407	.472	.60
	uel	.348	.398	.449	.499	.60
Gas	lwg	.455	.384	.313	.242	.10
	leg	.242	.214	.185	.157	.10
	uwg	.455	.484	.513	.542	.60
	ueg	.242	.314	.385	.457	.60
Electricity	lwe	.236	.229	.222	.214	.20
	lee	.238	.230	.223	.215	.20
	uwe	.236	.289	.342	.394	.50
	uee	.238	.290	.343	.395	.50

C.7.0 Data for Domestic, Farm and Commercial (DFC) Sector

C.7.1 Conversion Factors

The conversion efficiencies for fuels in the DFC sector are presented below, along with the corresponding values for the conversion factors. The efficiencies are taken from EMR (1977a, p. 28), except in the case of the heat pump, for which the SRI (1976, Vol. II, pp. IX-14,15) figure is used. There is close agreement between the EMR and SRI efficiency values for electric resistance heating, oil heat, and gas heat.

Process	Thermal Efficiency	Conversion Factor
Electrical, non-heating	1.0	aeo = 3.412
Electric-heat pump	2.0	aeh = 6.824
Electric-resistance heating	1.0	aer = 3.412
Gas heat	0.76	agh = 0.76
Oil heat	0.65	alh = 3.835

C.7.2 Heating Costs

Except for district heating by cogeneration, the following costs are taken from SRI (1976, Vol. II, pp. IX-14,15). The heat pump cost is reduced to 5/6 of the SRI value, under the assumptions that 1/2 of the users would have air conditioning even without a heat pump, and that the air conditioning function of the heat pump would be used 1/3 of the time, for a total credit of 1/6 of the non-fuel cost. The district heat cost is taken from estimates by Berthin (1980) of capital costs for plant equipment changes, piping, and in-home heat exchangers, amortized over 30 years at an 8% rate of return, plus system maintenance costs of \$25/yr./house, plus in-home maintenance costs of \$37/yr./home (the maintenance cost for gas heat assumed by SRI (1976)), with the same annual heating load of 94.7×10^6 BTU/yr. as assumed by SRI (1976).

Process	Non-Fuel Cost (\$/10^3BTU)
Electric Resistance Heating	crh = .105
Gas Heat	cgh = .251
Oil Heat	coh = .336
Heat Pump	chp = .466
Solar Heat	chs = .706
District Heat by Cogeneration	cdh = .662

C.7.3 Heat Pump Limits

It is assumed that the heat pump is commercially available only after 1980, and that the upper limit on the fraction of heating done by heat pump rises linearly from 0 in 1980 to 1 in 2000 -- i.e.

$$
\begin{aligned}
hpw = hpe = {} & 0, && t = 05 \\
& .25, && t = 10 \\
& .50, && t = 15 \\
& 1, && t = 25, 35, \ldots .
\end{aligned}
$$

C.7.4 Solar Heating Limits

Berkowitz (1977, p. 7) deals with a partial solar system providing 70% of a structure's heating and hot water demands. He further assumes (p. 119) a 15% penetration of solar home heating by 2000. Using the 70% and the latter criteria puts an upper limit on the fraction of heating that can be done by solar. It is assumed that this level is achievable by 2000, that a further doubling can take place by 2010, another doubling by 2020, that solar heating is at virtually zero level until after 1980, and that the solar potential increases linearly between 1980 and 2000 - i.e.

Period	05	10	15	25	35	45
sw = se	0	.0263	.0525	.105	.21	.42

C.7.5 Limits on District Heating by Cogeneration

According to Berthin (1980) the total combined efficiency of coal-steam-electric plus district heat is 72%, with 27% for electricity and 45% for heating. To simplify matters, it is assumed that 32% is used for electricity (as with no district heating), and that 40% (= 72% - 32%) of the input energy is available for district heating. Therefore, the coefficient relating new coal-electric capacity to the maximum new capacity of district heating is

$$fc = .40.$$

Assuming that heat from waste heat of nuclear power generation would be publically unacceptable, the coefficient relating new nuclear electricity capacity to the maximum new capacity of district heating is zero in the base case:

$$fn = 0.0.$$

It is assumed that district heating by cogeneration is not possible in Newfoundland, Quebec, Manitoba or B.C., where electricity is produced mainly by hydro. If these areas are elminated in proportion to their populations, as given by Statistics Canada, (1978, p. 186), and the resulting upper limits are taken to be achievable by 2000, with linear increase from 0 in 1980 then the maximum fractions of total heating due to district heat by cogeneration are:

Period	05	10	15	25,35, ...
gw	0	.1125	.225	.45
ge	0	.15	.3	.6

C.7.6 Proportion of DFC Output Energy for Heating

The values for 1974 of energy used by end-use function, presented by EMR (1977a, pp. 20-21), adjusted for end use efficiencies using EMR (1977a, p. 28) data gives

$$gwh = geh = .8661.$$

This value is taken to be constant in all time periods.

C.8.0 Data for the Objective Function

C.8.1 Social Discount Rate

The real social discount rate is taken to be 10%, that is

$$d = 0.10.$$

This is the figure derived by Jenkins (1977, p. 140) for the social opportunity cost of government funds. A real discount rate of 10% is also the rate preferred by the NEB (1979) in the calculations of costs and benefits of proposed exports of natural gas.

C.8.2 Price Elasticities of Demand

The derivation of the price elasticities of demand is discussed in Appendix A. For completeness of this section, they are presented here:

ed = 0.81, for DFC,
ei = 0.48, for industry,
er = 0.36, for road transportation, and
eo = 0.36, for other transportation.

C.8.3 Base Year Prices and Quantities

For the calculation of the parameters dwd, dwi, etc., it is necessary to have estimates of the prices and quantities of output energy used in a base year. The base year chosen is 1970, since this year was before the rapid escalation of petroleum prices and was thus likely an equilibrium year in energy markets.

The base year quantities of output energy were calculated from Statistics Canada (cat. no. 57-207), which gives the input energy to the end use sectors, and from the end use conversion efficiencies specified in sections 5, 6 and 7 above, which were adapted mostly from EMR (1977a, p. 28).

The base year prices were calculated in two stages. First, the base year prices of the fuels, in natural units and in 1975\$, were calculated for each end use sector. Secondly, the total energy costs in each end use sector were calculated, using the base year fuel prices and input energy quantities, then divided by the total output energy quantities for each sector. In the DFC sectors, the non-fuel costs of heating, as presented in section 7 above, are also incorporated into the price.

The base year natural gas prices in the DFC and industrial sectors of the west and east were estimated by calculating the average revenues, from data in Statistics Canada (cat. no. 57-205). The residential and commercial categories were combined for the DFC calculation.

The base year electricity prices in the DFC and industrial sectors of the west and east were estimated by calculating the average revenues, from data in Statistics Canada (cat. no. 57-202). The residential, commercial and street lighting categories were combined for the DFC calculation. The 1971 data were used to calculate electricity prices. This should not introduce much error since, as is well known, real energy prices were quite stable between 1970 and 1971.

The base year coal prices for industry in the west and east were estimated by calculating the average cost to industry of coal and coke, from data in Statistics Canada (cat. no. 57-506).

Weighted averages of the gasoline prices in five regions, from EMR (1977a, Appendix C), were used for the base year fuel prices in the road transportation sectors of the west and east.

The base year prices of oil used in the western and eastern industrial sectors were estimated by calculating the average cost to industry of all oil products consumed, from data in Statistics Canada (cat. no. 57-506).

There are no readily available statistics for the base year prices of oil in the DFC sector. The prices of light fuel oil and heavy fuel oil to western and eastern industry were calculated from Statistics

Canada (cat. no. 57-506). Since light and heavy fuel oils are the predominant oil fuels used in the DFC sector, averages of these two prices were calculated for the west and the east, weighted by the proportions of the 1970 consumption of the two fuels in each region. Since Statistics Canada (cat. no. 57-506) does not distinguish between light and heavy fuel oils until 1973, the 1973 prices were used, but adjusted downward by the difference between the 1973 and 1970 western Canadian wellhead oil prices, in 1975$, as reported by the CPA (1977).

The base year prices of oil products in "other" transportation are weighted averages of the prices to industry of heavy fuel oil, diesel oil and aviation turbo fuel. The prices of heavy fuel oil and diesel oil were calculated from Statistics Canada (cat. no. 57-506) for 1973, when these products were first distinguished separately, but adjusted downward by the difference between the 1973 and 1970 western Canadian wellhead oil prices, as reported by the CPA (1977). The price of aviation turbine fuel was taken to be the same as the price of diesel fuel oil, since the values per barrel shipped from refineries in 1970 of the two commodities were very nearly equal, according to data in Statistics Canada (cat. no. 45-205, Table 6).

A summary of the calculations for the output energy prices is presented in the tables below. The input fuel prices are expressed in familiar units, but all other quantities and monetary values are expressed in model units.

Sector	Fuel	Input Price	Output Energy	Total Cost
Road Transportation, West	oil	\$.67/gallon	.056951	.1281
			Output Price =	2.2501
Road Transportation, East	oil	\$.70/gallon	.127151	.2995
			Output Price =	2.3554
Other Transportation, West	oil	\$.33/gallon	.019503	.0161
			Output Price =	.8261
Other Transportation, East	oil	\$.32/gallon	.049652	.0400
			Output Price =	.8046
Industry, West	coal	\$1,00/10^{6}BTU	.0110254	.00127
	gas	\$.386/mcf	.131535	.00597
	oil	\$.13/gallon	.09044	.01007
	electricity	1.17¢/kwh	.0806339	.02765
		Totals:	.3136343	.04496
			Output Price =	.14335
Industry, East	coal	\$.88/10^{6}BTU	.2170946	.02196
	gas	\$.774/mcf	.2076631	.01891
	oil	\$.12/gallon	.42497	.04219
	electricity	1.06¢/kwh	.2503984	.07779
		Totals:	1.1001261	.16085
			Output Price =	.14621
DFC, West (Note: Total Cost	gas	\$.975/mcf	.175376	.379
	oil	\$.21/gallon	.103850	.512
	electricity	2.54¢/kwh	.073094	.782
		Total:	.352320	---
			Output Price =	.5018
DFC, East (Note: Total Cost is per unit of output energy, including non-fuel cost)	gas	\$1.57/mcf	.154927	.458
	oil	\$.17/gallon	.940832	.482
	electricity	2.16¢/kwh	.225452	.656
		Total:	1.321211	---
			Output Price =	.5089

C.8.4 Base Year Values of Exogenous Parameters

For the calculation of the objective function parameters dwd, dwi, etc., it is necessary to have base year (1970) estimates of the indices (1973 = 1) of population, income per capita, real domestic product and capital output ratio. It is assumed that the 1970 indices of population and real domestic product are the same in the west and the east -- i.e. that there was not much difference between west and east in the percentage changes of these quantities from 1970 to 1973. Income per capita is personal disposable income, divided by population. The indices and data sources are shown below.

Index	Value	Source
population	.9662	Statistics Canada (cat. no. 91-201)
income per capita	.8217	Statistics Canada (cat. no. 13-531, and cat. no. 91-201)
real domestic product	.8249	Statistics Canada (cat. no. 13-531)
Capital output ratio	1.0343	EMR (1977a, Appendix C)

C.8.5 Projections of Exogeneous Parameters

For the calculation of the parameters dwd, dwi, etc., projections are needed for the indices of western and eastern population, income per capita, western and eastern real domestic product, and capital output ratio.

The population indices for the base case are arrived at by taking slightly lower values than the NEB's base case projections for all of Canada, in Douglas and Nichols (1979), until the year 2000, and applying the regional population proportions in EMR (1977a, Appendix C) to derive separate indices for the west and east. The NEB's base case projections have been lowered slightly because they are deliberately a little on the high side. Population growth after 2000 is taken to be at the same rate in both regions, using the midpoint of the four main projections in Statistics Canada (cat. no. 91-520). The projections, expressed in per cent change per year, are shown below.

Period	1980	1985	1990	2000	2010	2020	2030
Population, West, %/yr.	1.5	1.2	1.1	0.9	0.6	0.5	0.3
Population, East, %/yr,	1.2	0.9	0.8	0.7	0.6	0.5	0.3

The projection of income per capita until 2000 is slightly lower than the base case NEB projections, in Douglas and Nichols (1979), which are a little on the high side. (Because the NEB is evaluating proposed new gas exports, any errors in domestic demand projection should be on the high side). After 2000, the rate of growth of income per capita is 2.3% per year, under the assumptions that the proportion of the population in the work force will have stabilized by that time, and that the main source of the increase in income per capita will be the increase in output per worker due to technological change, which has typically been about 2% per year. The projection is:

Period	1980	1985	1990	2000	2010	2020	2030
Income per Capita, %/yr.	3.7	1.9	2.3	2.5	2.3	2.3	2.3

The projections of the western and eastern real domestic product until 2000 are slightly lower than the NEB projections for all of Canada, in Douglas and Nichols (1979), with the split between west and east chosen to make the real domestic product per capita increase at the same rate in each region. After 2000, the rates of growth in the two regions are taken to be equal to the rate of growth of population plus that of income per capita. The projections are:

Period	1980	1985	1990	2000	2010	2020	2030
Real Domestic Product, West, %/yr.	3.5	4.0	3.7	3.8	2.9	2.8	2.6
Real Domestic Product, East, %/yr.	3.2	3.7	3.4	3.6	2.9	2.8	2.6

The projection of the capital output ratio (i.e. capital stock divided by output) is based on the projections by EMR (1977a, Appendix C) of industrial capital stock and industrial real domestic product, until 1990. After 1990, the rate of growth of the capital output ratio is assumed to gradually slow to zero -- i.e. that industrial capital stock and output eventually grow at the same rate. The projection is:

Period	1980	1985	1990	2000	2010	2020	2030
Capital Output Ratio, %/yr.	2.0	2.1	2.8	1.0	0.5	0.0	0.0

In all of the above projections, the rate of growth in the period ending 2030 is used in the end effects modifications as the rate of growth in every period after the time horizon, 2020.

C.9.0 Right-Hand Side Values (Initial Conditions)

The interperiod constraints of the first few time periods relate the values of variables to historical (pre-1976) values. These historical values combine in various ways to form the non-zero right hand sides of the model's constraints. (The values of various bounds on variables have been outlined in earlier sections).

These right hand sides involve combinations of production levels and capacity additions in historical periods. Since statistics for production levels are easy to obtain, but statistics for capacity additions are not, estimates of the capacity additions are made by a simple procedure from the data on production levels. The annual growth rate of a production level in historical periods is estimated using two years separated by several years. It is then assumed that the growth rate of capacity additions is the same as that estimated for the production level, and a simple expression relating the capacity additions to the production level in the period 1971-1975 is derived. It is then a simple matter to evaluate the right hand side.

In the following, let $X(t)$ represent a production level, and $D(t)$ represent a capacity addition.

C.9.1 Capacity Expansion and Retirement -- 30 Year Lifetime

The equations with non-zero right hand sides, separated into unknowns on the left and historical values on the right hand side, are

$$X(5) - D(5) = X(0) - D(-25) ,$$

$$X(10) - X(5) - D(10) = - D(-20) ,$$

$$X(15) - X(10) - D(15) = - D(-15) , \text{ and}$$

$$X(25) - D(25) - 2 \cdot D(15) - 2 \cdot D(10) - 2 \cdot D(5)$$
$$= 2 \cdot D(0) + D(-5) .$$

Assuming an annual growth rate r in both X and D ,

$$\begin{aligned} X(0) &= D(0) + D(-5) + D(-10) + D(-15) + D(-20) + D(-25) \\ &= D(0) \cdot [1 + (1+r)^{-5} + (1+r)^{-10} + (1+r)^{-15} + (1+r)^{-20} + (1+r)^{-25}] \\ &= D(0) \cdot [1-(1+r)^{-30}] / [1 - (1+r)^{-5}] . \end{aligned}$$

Therefore,

$$D(0) = X(0) \cdot [1 - (1+r)^{-5}] / [1 - (1+r)^{-30}], \text{ and}$$

$$D(t) = D(0) \cdot (1+r)^{t} , \text{ for } t = -5,-10,-15,-20,-25 .$$

The calculations for each of the technologies having 30-year lifetimes and existing in the past are

Production of	r	X(0)	D(0)	Right Hand Side, for t =			
				5	10	15	25
coal, west	.121	2.159	.971	2.103	-.099	-.175	2.491
coal, east	-.057	.253	.018	.175	-.058	-.043	.060
electricity, hydro, west	.049	.239	.067	.219	-.026	-.033	.187
electricity, hydro, east	.049	.708	.169	.657	-.065	-.083	.471
coal for electricity, west	.099	.562	.225	.541	-.034	-.055	.590
coal for electricity, east	.099	1.240	.496	1.193	-.075	-.120	1.301
gas for electricity, west	.099	.449	.180	.432	-.027	-.044	.472
gas for electricity, east	.099	.317	.127	.305	-.019	-.031	.333
oil for electricity, west	.099	.014	.006	.013	-.001	-.002	.016
oil for electricity. east	.099	.076	.030	.073	-.005	-.007	.079
electricity, wood, west	.099	.004	.0016	.004	0	0	.004
electricity, nuclear, east(*)	---	.051	.046	.051	0	0	.096
oil from tar sands(*)	---	.088	.059	.088	0	0	.147

(*) - right hand side take directly from data sources.

The estimates for r and X(0) are based upon statistics in SC(26-206) for coal, CPA (1977) for oil from the tar sands, and SC(57-207) for the rest.

C.9.2 Capacity Expansion and Retirement - 10 Year Lifetime

These are conventional and electric automobiles. The only relevant equation is

$$X(5) - D(5) = D(0) \ ,$$

with a non-zero right hand side only for conventional autos in each region, since there have been virtually no electric autos in recent history. Since

$$\begin{aligned} X(0) &= D(0) + D(-5) \\ &= D(0) \cdot [1 + (1+r)^{-5}], \end{aligned}$$

it follows that

$$D(0) = X(0) \,/\, [1 + (1+r)^{-5}] \ .$$

From SC(57-207) , $r = 0.057$,

$WLA(0) = .426$, and

$ELA(0) = .909$.

Therefore,

$$WTD2(0) = 0.2423, \text{ and}$$

$$ETD2(0) = 0.5171\ ,$$

which are the right hand sides.

C.9.3 Capacity Expansion and Retirement - 15 Year Lifetime

These technologies are all of the DFC heating, except district heat by cogeneration. The relevant equations are

$$X(5) - D(5) = D(0) + D(-5)\ , \text{ and}$$

$$X(10) - D(10) - D(5) = D(0).$$

It is easy to show that

$$D(0) = X(0) \ / \ [1 + (1+r)^{-5} + (1+r)^{-10}]\ , \text{ and}$$

$$D(-5) = D(0) \cdot (1+r)^{-5}\ .$$

The chart below shows the estimates for r and X(0), taken from SC(57-207), and the calculated right hand sides for the three historical heating fuels - gas, oil and electric resistance. In the calculations for electric resistance, it is necessary first to estimate the proportion of DFC electricity use which is for heating purposes, since the statistics in SC(57-207) are for all electricity used in the DFC sector. This is done by estimating the quantities of total output energy used in the western and eastern DFC sectors during the period 1971 - 1975, subtracting non-heating output energy according to the proportion derived in section 7.6 above, subtracting the output energy supplied by gas and oil to arrive at a residual which is presumed to be heating output energy supplied by electricity. This quantity is converted to secondary energy in the form of input kilowatt-hours of electricity using the end-use conversion coefficient listed in section 7.1 above. The results are

			Right Hand Side, for t =	
Heating by	r	X(0)	5	10
gas, west	.045	1.534	1.13	.627
gas, east	.073	1.329	1.03	.605
oil, west	-.006	.155	.102	.05
oil, east	-.047	.664	.388	.171
elec. resistance, west	.091	.088	.07	.043
elec. resistance, east	.081	.293	.23	.137

C.9.4 Oil Production Decline Curves

The relevant equations are

$$X(5) - D(5) = D(0) + (0.59) \cdot D(-5) + (0.35) \cdot D(-10) + (0.21) \cdot D(-15),$$

$$X(10) - D(10) - D(5) = (0.59) \cdot D(0) + (0.35) \cdot D(-5) + (0.21) \cdot D(-10),$$

$$X(15) - D(15) - \ldots = (0.35) \cdot D(0) + (0.21) \cdot D(-5),$$

$$X(25) - \ldots = (0.21) \cdot D(0) .$$

The relationship between X(0) and D(0) is

$$D(0) = X(0) \,/\, [1 + (1+r)^{-5} + (0.59)\ (1+r)^{-10} + (0.35)(1+r)^{-15} + (0.21)(1+r)^{-20}] .$$

As above,

$$D(t) = D(0) \cdot (1+r)^{t}, \text{ for } t = -5,-10,-15 .$$

The values of r are estimated from data in CPA (1977), and X(0) from SC(57-207). The chart below shows the results for the low cost conventional oil of each region, which is assumed to be the only historically existing oil production (oil from the tar sands is covered in section 9.1 above).

Oil from	r	X(0)	Right Hand Side, for t = 5	10	15	25
west, low cost	.082	3.121	2.417	1.374	.733	.3131
east, low cost	-.021	.004	.0026	.0014	.0006	.0002

C.9.5 Natural Gas Production Decline Curves

The relevant equations are

$$X(5) - D(5) = D(0) + D(-5) + (0.59)D(-10) + (0.35)D(-15) + (0.21)D(-20),$$

$$X(10) - \ldots = D(0) + (0.59)D(-5) + (0.35)D(-10) + (0.21)D(-15) ,$$

$$X(15) - \ldots = (0.59)D(0) + (0.35)D(-5) + (0.21)D(-10) ,$$

$$X(25) - \ldots = (0.56)D(0) + (0.21)D(-5) .$$

It is easy to show that

$$D(0) = X(0) / [1 + (1+r)^{-5} + (1+r)^{-10} + (0.59)(1+r)^{-15} + (0.35)(1+r)^{-20} + (0.21)(1+r)^{-25}]$$

and

$$D(t) = D(0) \cdot (1+r)^{t}, \text{ for } t = -5,-10,-15,-20.$$

The value of r is estimated from CPA (1977), and X(0) from SC(57-207). The chart below shows the results for the low cost conventional gas production in the two regions.

Gas from	r	X(0)	Right Hand Side, for t = 5	10	15	25
west, low cost	.138	12.77	11.665	9.557	5.533	4.461
east, low cost	-.023	.00078	.0006	.0004	.0002	.0001 .

Appendix D. DETAILED OUTPUT FOR THE BASE CASE.

The following table gives the optimal values of the base case variables, and sixteen prices, in undiscounted, 1975$. The first eight rows in the table are prices, whose names begin with "P", followed by the name of the constraint from which the dual activity was taken for the price calculation. The next eight rows are the variables which enter nonlinearly into the objective function, expressed as average annual flows in each period. The next eight rows in the table are prices calculated from the objective function gradient; the name of each begins with "P", followed by the name of the associated nonlinear variable.

The remaining rows in the table are all the other variables, expressed as average values for each period.

BASE CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
PWCSB	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
PECSB	0.1551	0.1751	0.1697	0.1231	0.1231	0.1231	0.1231
PWOSBL	0.5557	0.8843	0.9305	0.9141	1.1397	1.2942	1.2942
PEOSBL	0.8659	1.0907	0.9855	0.9691	1.1949	1.3496	1.3496
PWGSB	0.1041	0.1093	0.1158	0.1669	0.2560	0.2831	0.2831
PEGSB	0.2243	0.2615	0.1994	0.2201	0.3132	0.3132	0.3132
PWESBE	0.9123	0.9075	0.9060	0.9180	0.8755	0.8572	0.8572
PEESBE	0.9014	0.9524	0.9224	0.9088	1.0818	1.0818	1.0818
WDFC	0.5013	0.5639	0.6379	0.7156	0.7837	0.9514	1.9146
EDFC	1.5635	1.6543	2.0748	2.3592	2.7751	3.4348	6.9249
WIND	0.4223	0.5287	0.6964	0.9409	1.2019	1.5498	2.7902
EIND	1.3072	1.5744	2.1365	3.0259	3.8367	5.0235	9.0439
WRTR	0.0926	0.1091	0.1334	0.1756	0.2285	0.2831	0.4417
ERTR	0.1952	0.2308	0.2831	0.3670	0.4783	0.5930	0.9254
WOTR	0.0271	0.0309	0.0371	0.0503	0.0647	0.0829	0.1374
EOTR	0.0637	0.0737	0.0901	0.1205	0.1549	0.1984	0.3288
PWDFC	0.5172	0.5228	0.5307	0.5886	0.6913	0.7064	0.7080
PEDFC	0.6466	0.6922	0.6074	0.6503	0.6994	0.6977	0.6977
PWIND	0.1805	0.1965	0.1958	0.2078	0.2426	0.2539	0.2539
PEIND	0.2317	0.2653	0.2410	0.2250	0.2668	0.2705	0.2705
PWRTR	1.8302	1.6882	1.4474	1.2282	1.1565	1.2149	1.2149
PERTR	2.1557	1.8908	1.5413	1.3083	1.2265	1.2850	1.2850
PWOTR	0.9080	1.0956	1.0900	1.0145	1.1168	1.2072	1.2072
PEOTR	1.0657	1.1794	1.0740	0.9994	1.1023	1.1928	1.1928
WCX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCX6	0.0408	0.0839	0.1537	0.3245	0.4144	0.5344	0.9621
WCD1	0.1351	0.2511	0.3035	0.9668	1.2091	2.6140	4.9594
WCD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCE	0.0430	0.1158	0.1758	0.4491	0.6378	1.2986	3.1205
WCEX	0.3400	0.4400	0.5600	0.9200	1.4800	2.4200	10.7068
ECX4	0.2374	0.4035	0.3807	1.0434	1.3230	1.7322	3.1186
ECD1	0.0662	0.1128	0.2110	0.3291	0.0000	0.0000	0.0000
ECD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ECIM	0.3321	0.3093	0.0000	0.0000	0.0000	0.0000	0.0000
WOX6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOD1	0.0733	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000
WOD2	0.0000	0.1470	0.1635	0.0000	0.0706	0.0000	0.0000
WOD3	0.0000	0.0000	0.0000	0.0000	0.0635	0.2256	0.0000
WOD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOD5	0.0186	0.0382	0.0790	0.1251	0.0000	0.1796	0.3234
WOD6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOEX	0.1194	0.0304	0.0146	0.0067	0.0000	0.0000	0.0000
WOE	0.3280	0.4048	0.5076	0.3790	0.1875	0.4247	0.8090
WOG	0.1455	0.1349	0.1321	0.1411	0.2595	0.2082	0.3396

BASE CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
EOX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOD1	0.0003	0.0094	0.0403	0.1406	0.0000	0.0000	0.0000
EOD2	0.0000	0.0000	0.0000	0.0000	0.1274	0.0000	0.0000
EOD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOIM	0.2786	0.1109	0.0000	0.0000	0.0000	0.0000	0.0000
EOG	0.6075	0.5257	0.5576	0.5562	0.3933	0.4986	0.8217
WLX1	0.0026	0.0024	0.0020	0.0016	0.0000	0.0000	0.0000
WLX2	0.0204	0.0100	0.0000	0.0000	0.0000	0.0000	0.0000
WLX3	0.0248	0.0265	0.0290	0.0228	0.1164	0.0375	0.0676
WLX4	0.0871	0.0861	0.0915	0.1064	0.1242	0.1555	0.2473
WLDC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ELX1	0.0146	0.0136	0.0122	0.0079	0.0000	0.0000	0.0000
ELX2	0.2341	0.1907	0.1565	0.0000	0.0000	0.0000	0.0000
ELX3	0.1260	0.0949	0.1463	0.2756	0.0929	0.1216	0.2190
ELX4	0.1880	0.1877	0.2015	0.2316	0.2713	0.3402	0.5421
WGX5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD1	0.3751	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD2	0.2480	1.4916	0.4998	0.6025	0.0000	0.0000	0.0000
WGD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.3428	0.2000
WGD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGX7	0.0864	0.0810	0.0722	0.0472	0.0000	0.0000	0.0000
WGX8	0.4055	0.5536	0.7270	0.8155	0.8278	0.3158	0.2837
WGX9	0.2206	0.2693	0.3457	0.4428	0.1414	0.1823	0.3283
WGE	0.8184	0.9720	1.4016	1.3381	0.0907	0.0000	0.0000
WGEX	1.0800	1.6800	0.7400	0.0300	0.0000	0.0000	0.0000
EGX3	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004	0.0006
EGD1	0.0001	0.0000	0.4798	0.2904	0.0000	0.0000	0.0000
EGD2	0.0000	0.0000	0.0000	0.0000	0.2476	0.2867	0.4090
EGD3	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0001
EGX4	0.0610	0.0572	0.0510	0.0333	0.0000	0.0000	0.0000
EGX5	0.3941	0.5315	1.3064	1.6305	0.3117	0.0000	0.0000
EGX6	0.3291	0.3427	0.4452	0.3560	0.4514	0.5910	1.0640
WEX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEX4	0.0201	0.0509	0.0726	0.1216	0.8277	1.0650	2.1433
WEX5	0.0506	0.0522	0.0548	0.0677	0.0877	0.2224	0.3392
WEX6	0.0008	0.0008	0.0008	0.0004	0.0000	0.0000	0.0000
WED5	0.0068	0.0067	0.0093	0.0262	0.0421	0.1495	0.0377
WED6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED1	0.0235	0.0221	0.0296	0.0771	0.1241	0.4706	0.4566
WED2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEX9	0.0283	0.0344	0.0437	0.0552	0.0705	0.2271	0.4089

BASE CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
WEX10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEX11	0.0337	0.0307	0.0250	0.0281	0.0308	0.0373	0.0751
WEEX	0.0032	0.0034	0.0036	0.0039	0.0043	0.0048	0.0093
WCX5	0.1317	0.1470	0.1656	0.2113	0.2647	0.6866	1.8653
EEX5	0.1666	0.2620	0.3220	0.4420	0.4420	0.4420	0.7193
EEX6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED5	0.0352	0.1084	0.0766	0.1747	0.0647	0.1643	0.1790
EED6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED4	0.0100	0.0307	0.0217	0.0496	0.7207	0.2839	0.4315
EEX9	0.0881	0.1583	0.2412	0.1985	0.5622	0.7361	1.3253
EEX10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEX11	0.1074	0.1521	0.1412	0.3282	0.5959	0.6405	1.2912
EEEX	0.0067	0.0070	0.0074	0.0081	0.0090	0.0099	0.0191
ECX3	0.2386	0.2236	0.1996	0.1301	0.0000	0.0000	0.0000
WLA	0.0685	0.0657	0.0678	0.0761	0.0864	0.1070	0.1670
WTD1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WTD2	0.0201	0.0456	0.0221	0.0650	0.0864	0.1070	0.1670
ELA	0.1443	0.1389	0.1437	0.1590	0.1808	0.2241	0.3498
ETD1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ETD2	0.0409	0.0980	0.0457	0.1361	0.1808	0.2241	0.3498
WER	0.0140	0.0086	0.0000	0.0000	0.0000	0.0000	0.0000
WEH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEO	0.0197	0.0221	0.0250	0.0281	0.0308	0.0373	0.0751
WDD1	0.1795	0.2487	0.2988	0.3924	0.6316	0.0000	0.1891
WDD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDX5	0.0000	0.0000	0.0000	0.0000	0.0497	0.2379	0.7461
WDX6	0.0000	0.0000	0.0000	0.0000	0.0000	0.3461	0.6965
WDD5	0.0000	0.0000	0.0000	0.0000	0.0497	0.1882	0.1826
WDD6	0.0000	0.0000	0.0000	0.0000	0.0000	0.3461	0.3490
EER	0.0460	0.0872	0.0598	0.2357	0.4870	0.5057	1.0195
EEH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEO	0.0614	0.0649	0.0814	0.0926	0.1089	0.1348	0.2718
EDD1	0.1881	0.2224	0.8959	0.6234	0.0000	0.0000	0.0000
EDD2	0.1565	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDD3	0.0000	0.0598	0.0000	0.2058	0.3842	0.3136	0.5751
EDD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDX5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDX6	0.0000	0.0000	0.0000	0.0000	0.5048	1.2496	2.5193
EDD5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDD6	0.0000	0.0000	0.0000	0.0000	0.5048	0.9972	1.3471

BASE CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
WCX1	0.5557	0.7870	1.0555	1.9057	2.7981	4.9417	16.6613
WCX2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ECX1	0.1012	0.2024	0.4048	0.7251	0.6860	0.4346	0.0000
ECX2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOX1	0.5567	0.3486	0.1904	0.0521	0.0001	0.0000	0.0000
WOX2	0.0000	0.1470	0.3106	0.1991	0.1318	0.0332	0.0071
WOX3	0.0000	0.0000	0.0000	0.0000	0.0635	0.2554	0.1211
WOX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOX5	0.0362	0.0744	0.1534	0.2756	0.2516	0.3442	1.0204
EOX1	0.0008	0.0100	0.0500	0.1772	0.0784	0.0141	0.0000
EOX2	0.0000	0.0000	0.0000	0.0000	0.1274	0.0599	0.0127
WGX1	2.7081	2.2865	1.4817	0.6224	0.0394	0.0000	0.0000
WGX2	0.2480	1.7396	2.2394	2.4047	1.1606	0.2212	0.0000
WGX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.3428	0.6928
WGX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EGX1	0.0002	0.0002	0.4800	0.7703	0.4578	0.1317	0.0000
EGX2	0.0000	0.0000	0.0000	0.0000	0.2476	0.4848	1.1100
EC	1.9109	2.0743	2.5462	3.1702	4.1829	5.5728	9.5867

Appendix E. Detailed Output for the High and Low Cases

The following two tables list the values of the variables, and sixteen prices for the high and low demand cases. The prices, prefixed by "P", are derived in the same manner as for the Base Case detailed output listing, in Appendix D.

HIGH CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
PWCSB	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
PECSB	0.1551	0.1751	0.1715	0.1231	0.1231	0.1231	0.1231
PWOSBL	0.5817	0.9202	0.9389	1.0802	1.2165	1.2942	1.2942
PEOSBL	0.8800	1.1184	0.9939	1.1353	1.2718	1.3496	1.3496
PWGSB	0.1081	0.1135	0.1173	0.1964	0.2693	0.2831	0.2831
PEGSB	0.2193	0.2691	0.2177	0.2509	0.3173	0.3240	0.3414
PWESBE	0.9110	0.9083	0.9071	0.9223	0.8580	0.9223	0.9223
PEESBE	0.9014	1.0323	0.9294	1.0509	1.0818	1.0818	1.0818
WDFC	0.4978	0.5703	0.6651	0.7504	0.9113	1.1973	2.5997
EDFC	1.5743	1.6623	2.1124	2.4435	3.2583	4.2717	9.2929
WIND	0.4184	0.5466	0.7461	1.0501	1.6114	2.3613	4.9302
EIND	1.3069	1.6035	2.2625	3.3081	5.1790	7.7377	16.0981
WRTR	0.0923	0.1109	0.1400	0.1902	0.2718	0.3611	0.5990
ERTR	0.1949	0.2348	0.2970	0.3950	0.5651	0.7511	1.2458
WOTR	0.0269	0.0320	0.0398	0.0538	0.0800	0.1145	0.2174
EOTR	0.0635	0.0762	0.0962	0.1282	0.1906	0.2729	0.5178
PWDFC	0.5217	0.5277	0.5326	0.6223	0.7060	0.7024	0.7041
PEDFC	0.6412	0.7043	0.6277	0.6920	0.6994	0.6977	0.6977
PWIND	0.1840	0.2005	0.1970	0.2259	0.2505	0.2634	0.2634
PEIND	0.2318	0.2767	0.2462	0.2531	0.2691	0.2718	0.2738
PWRTR	1.8494	1.7099	1.4517	1.3001	1.1855	1.2149	1.2149
PERTR	2.1661	1.9074	1.5456	1.3804	1.2555	1.2850	1.2850
PWOTR	0.9258	1.1194	1.0954	1.1145	1.1617	1.2072	1.2072
PEOTR	1.0753	1.1977	1.0794	1.0996	1.1472	1.1928	1.1928
WCX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCX6	0.0404	0.0867	0.1647	0.3621	0.5556	0.8142	1.7001
WCD1	0.1336	0.2593	0.3190	1.0995	1.7621	3.7217	5.6943
WCD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCE	0.0430	0.1158	0.1758	0.5464	1.1009	2.2352	5.5544
WCEX	0.3400	0.4400	0.5600	0.9200	1.4800	2.4200	10.7068
ECX4	0.2373	0.4110	0.3807	1.1407	1.7859	2.6682	5.5511
ECD1	0.0662	0.1128	0.2110	0.3291	0.0000	0.0000	0.0000
ECD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ECIM	0.3320	0.3168	0.0000	0.0000	0.0000	0.0000	0.0000
WOX6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOD1	0.0738	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOD2	0.0000	0.1595	0.2143	0.0071	0.0000	0.0000	0.0000
WOD3	0.0000	0.0000	0.0000	0.0000	0.2803	0.0000	0.0000
WOD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOD5	0.0186	0.0382	0.0790	0.1251	0.0000	0.6372	0.4313
WOD6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOEX	0.1194	0.0304	0.0146	0.0067	0.0000	0.0000	0.0000
WOE	0.3292	0.4144	0.5630	0.4204	0.2939	0.6164	1.2460
WOG	0.1448	0.1378	0.1398	0.1530	0.3181	0.3178	0.6939

HIGH CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
EOX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOD1	0.0003	0.0094	0.0403	0.1406	0.0000	0.0000	0.0000
EOD2	0.0000	0.0000	0.0000	0.0251	0.1022	0.0000	0.0000
EOD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOIM	0.2796	0.1138	0.0000	0.0000	0.0000	0.0000	0.0000
EOG	0.6096	0.5382	0.6130	0.6227	0.4863	0.6811	1.2562
WLX1	0.0026	0.0024	0.0020	0.0016	0.0000	0.0000	0.0000
WLX2	0.0204	0.0100	0.0000	0.0000	0.0000	0.0000	0.0000
WLX3	0.0246	0.0274	0.0311	0.0254	0.1454	0.0912	0.2899
WLX4	0.0867	0.0879	0.0966	0.1148	0.1495	0.2035	0.3535
WLDC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ELX1	0.0146	0.0136	0.0122	0.0079	0.0000	0.0000	0.0000
ELX2	0.2365	0.1931	0.1589	0.0000	0.0000	0.0000	0.0000
ELX3	0.1259	0.1000	0.1842	0.3204	0.1254	0.1874	0.3898
ELX4	0.1876	0.1918	0.2125	0.2484	0.3250	0.4435	0.7737
WGX5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD1	0.3751	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD2	0.2412	1.5170	0.5442	0.5397	0.0000	0.0000	0.0000
WGD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.4734	0.5363
WGD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGX7	0.0864	0.0810	0.0722	0.0472	0.0000	0.0000	0.0000
WGX8	0.4015	0.5609	0.7579	0.8552	0.8499	0.3243	0.3852
WGX9	0.2186	0.2784	0.3704	0.4942	0.1896	0.2778	0.5800
WGE	0.8184	0.9720	1.4016	1.2457	0.0000	0.0000	0.3182
WGEX	1.0800	1.6800	0.7400	0.0300	0.0000	0.0000	0.0000
EGX3	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004	0.0006
EGD1	0.0001	0.0000	0.4798	0.2904	0.0000	0.0000	0.0000
EGD2	0.0000	0.0000	0.0000	0.0000	0.4238	0.4791	0.5788
EGD3	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0001
EGX4	0.0610	0.0572	0.0510	0.0333	0.0000	0.0000	0.0000
EGX5	0.3942	0.5252	1.3337	1.5088	0.2357	0.0000	0.0000
EGX6	0.3290	0.3490	0.4179	0.3892	0.6093	0.9103	1.8939
WEX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEX4	0.0202	0.0509	0.0726	0.1216	1.1841	1.6641	3.7393
WEX5	0.0503	0.0533	0.0583	0.0741	0.1227	0.2540	0.4134
WEX6	0.0008	0.0008	0.0008	0.0004	0.0000	0.0000	0.0000
WED5	0.0065	0.0083	0.0116	0.0291	0.0705	0.1486	0.0574
WED6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED1	0.0223	0.0271	0.0369	0.0858	0.2078	0.9587	0.4178
WED2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEX9	0.0281	0.0356	0.0468	0.0616	0.1074	0.3049	0.5161

HIGH CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
WEX10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEX11	0.0335	0.0310	0.0261	0.0294	0.0358	0.0470	0.1020
WEEX	0.0032	0.0034	0.0036	0.0039	0.0043	0.0048	0.0093
WCX5	0.1305	0.1509	0.1768	0.2312	0.3688	1.2707	2.5327
EEX5	0.1670	0.2620	0.3220	0.4420	0.4420	0.4420	0.7193
EEX6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED5	0.0356	0.1080	0.0766	0.1747	0.0649	0.1641	0.1790
EED6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED4	0.0101	0.0306	0.0217	0.0496	1.0772	0.5265	0.8102
EEX9	0.0881	0.1572	0.2390	0.1939	0.7589	1.1339	2.3590
EEX10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEX11	0.1078	0.1532	0.1434	0.3328	0.7288	0.7965	1.7328
EEEX	0.0067	0.0070	0.0074	0.0081	0.0090	0.0099	0.0191
ECX3	0.2386	0.2236	0.1996	0.1301	0.0000	0.0000	0.0000
WLA	0.0682	0.0668	0.0711	0.0824	0.1027	0.1365	0.2264
WTD1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WTD2	0.0198	0.0469	0.0241	0.0704	0.1027	0.1365	0.2264
ELA	0.1441	0.1414	0.1508	0.1712	0.2136	0.2839	0.4709
ETD1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ETD2	0.0407	0.1007	0.0501	0.1461	0.2136	0.2839	0.4709
WER	0.0140	0.0086	0.0000	0.0000	0.0000	0.0000	0.0000
WEH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEO	0.0195	0.0224	0.0261	0.0294	0.0358	0.0470	0.1020
WDD1	0.1755	0.2600	0.3224	0.4028	0.6486	0.0000	0.2568
WDD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDX5	0.0000	0.0000	0.0000	0.0000	0.0831	0.4666	1.0131
WDX6	0.0000	0.0000	0.0000	0.0000	0.0602	0.3240	0.9458
WDD5	0.0000	0.0000	0.0000	0.0000	0.0831	0.3835	0.1671
WDD6	0.0000	0.0000	0.0000	0.0000	0.0602	0.2939	0.5326
EER	0.0460	0.0879	0.0605	0.2369	0.6009	0.6289	1.3681
EEH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEO	0.0618	0.0652	0.0829	0.0959	0.1279	0.1676	0.3647
EDD1	0.1882	0.2160	0.9295	0.4713	0.0000	0.0000	0.0000
EDD2	0.1589	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDD3	0.0000	0.0605	0.0000	0.2067	0.4976	0.3801	0.7853
EDD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDX5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDX6	0.0000	0.0000	0.0000	0.1612	0.5927	1.5540	3.3808
EDD5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDD6	0.0000	0.0000	0.0000	0.1612	0.5121	1.2980	1.8212

HIGH CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
WCX1	0.5542	0.7937	1.0777	2.0606	3.5068	6.7428	20.5022
WCX2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ECX1	0.1012	0.2024	0.4048	0.7251	0.6860	0.4346	0.0000
ECX2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOX1	0.5572	0.3486	0.1902	0.0520	0.0000	0.0000	0.0000
WOX2	0.0000	0.1595	0.3739	0.2525	0.0801	0.0007	0.0000
WOX3	0.0000	0.0000	0.0000	0.0000	0.2803	0.1317	0.0280
WOX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOX5	0.0362	0.0744	0.1534	0.2756	0.2516	0.8018	1.9118
EOX1	0.0008	0.0100	0.0500	0.1772	0.0784	0.0141	0.0000
EOX2	0.0000	0.0000	0.0000	0.0251	0.1141	0.0506	0.0102
WGX1	2.7081	2.2865	1.4817	0.6224	0.0394	0.0000	0.0000
WGX2	0.2412	1.7582	2.3024	2.4032	1.1376	0.2083	0.0000
WGX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.4734	1.4531
WGX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EGX1	0.0002	0.0002	0.4800	0.7703	0.4578	0.1317	0.0000
EGX2	0.0000	0.0000	0.0000	0.0000	0.4238	0.8181	1.6581
EC	1.9134	2.1088	2.6596	3.4055	5.2842	7.7410	15.1445

LOW CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
PWCSB	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
PECSB	0.1551	0.1751	0.1707	0.1231	0.1231	0.1231	0.1231
PWOSBL	0.5554	0.8813	0.9351	0.9024	1.1232	1.2942	1.2942
PEOSBL	0.8657	1.0884	0.9901	0.9573	1.1784	1.3496	1.3496
PWGSB	0.1039	0.1090	0.1158	0.1648	0.2560	0.2831	0.2831
PEGSB	0.2256	0.2589	0.2003	0.2180	0.3132	0.3132	0.3132
PWESBE	0.9123	0.9075	0.9060	0.9180	0.8755	0.8572	0.8572
PEESBE	0.9014	0.9576	0.8992	0.8992	1.0818	1.0818	1.0818
WDFC	0.5015	0.5536	0.6100	0.6541	0.6855	0.7910	1.4618
EDFC	1.5606	1.6286	1.9836	2.1730	2.4454	2.8770	5.3266
WIND	0.4225	0.5164	0.6462	0.8147	0.9915	1.2020	1.9875
EIND	1.3063	1.5373	1.9912	2.6227	3.1564	3.8949	6.4402
WRTR	0.0926	0.1069	0.1270	0.1590	0.1982	0.2323	0.3380
ERTR	0.1952	0.2261	0.2694	0.3347	0.4179	0.4903	0.7133
WOTR	0.0271	0.0301	0.0353	0.0447	0.0548	0.0660	0.1011
EOTR	0.0637	0.0720	0.0858	0.1071	0.1311	0.1579	0.2419
PWDFC	0.5169	0.5225	0.5307	0.5862	0.6913	0.7064	0.7080
PEDFC	0.6481	0.6894	0.6075	0.6475	0.6994	0.6977	0.6977
PWIND	0.1804	0.1962	0.1960	0.2065	0.2410	0.2539	0.2539
PEIND	0.2320	0.2651	0.2390	0.2231	0.2664	0.2705	0.2705
PWRTR	1.8299	1.6864	1.4497	1.2231	1.1502	1.2149	1.2149
PERTR	2.1555	1.8894	1.5437	1.3032	1.2202	1.2850	1.2850
PWOTR	0.9077	1.0937	1.0930	1.0074	1.1071	1.2072	1.2072
PEOTR	1.0655	1.1779	1.0769	0.9924	1.0926	1.1928	1.1928
WCX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCX6	0.0408	0.0819	0.1426	0.2809	0.3419	0.4145	0.6853
WCD1	0.1351	0.2458	0.2863	0.7817	1.0687	2.2972	4.5244
WCD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WCE	0.0430	0.1158	0.1758	0.3100	0.4030	0.9092	2.2221
WCEX	0.3400	0.4400	0.5600	0.9200	1.4800	2.4200	10.7068
ECX4	0.2372	0.3941	0.3807	0.9044	1.0884	1.3431	2.2208
ECD1	0.0662	0.1128	0.2110	0.3291	0.0000	0.0000	0.0000
ECD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ECIM	0.3319	0.2998	0.0000	0.0000	0.0000	0.0000	0.0000
WOX6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOD1	0.0665	0.0073	0.0000	0.0000	0.0000	0.0000	0.0000
WOD2	0.0000	0.1335	0.1163	0.0000	0.1316	0.0000	0.0000
WOD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.2917	0.0000
WOD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOD5	0.0186	0.0344	0.0674	0.0854	0.0000	0.0228	0.2766
WOD6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOEX	0.1194	0.0304	0.0146	0.0067	0.0000	0.0000	0.0000
WOE	0.3212	0.3900	0.4412	0.2960	0.1565	0.3277	0.5995
WOG	0.1455	0.1323	0.1251	0.1264	0.2189	0.1677	0.2535

LOW CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
EOX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOD1	0.0003	0.0094	0.0403	0.1406	0.0000	0.0000	0.0000
EOD2	0.0000	0.0000	0.0000	0.0000	0.1274	0.0000	0.0000
EOD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EOIM	0.2728	0.1065	0.0000	0.0000	0.0000	0.0000	0.0000
EOG	0.5949	0.5065	0.4912	0.4732	0.3623	0.4016	0.6122
WLX1	0.0026	0.0024	0.0020	0.0016	0.0000	0.0000	0.0000
WLX2	0.0204	0.0100	0.0000	0.0000	0.0000	0.0000	0.0000
WLX3	0.0249	0.0259	0.0269	0.0197	0.0960	0.0291	0.0481
WLX4	0.0871	0.0843	0.0871	0.0958	0.1069	0.1264	0.1869
WLDC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ELX1	0.0146	0.0136	0.0122	0.0079	0.0000	0.0000	0.0000
ELX2	0.2225	0.1791	0.1449	0.0000	0.0000	0.0000	0.0000
ELX3	0.1259	0.0927	0.1062	0.2208	0.1009	0.0943	0.1559
ELX4	0.1880	0.1838	0.1917	0.2095	0.2346	0.2777	0.4111
WGX5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD1	0.3751	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD2	0.2484	1.4708	0.4559	0.6666	0.0000	0.0000	0.0000
WGD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.2369	0.1545
WGD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGD6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WGX7	0.0864	0.0810	0.0722	0.0472	0.0000	0.0000	0.0000
WGX8	0.4057	0.5418	0.6951	0.7454	0.7241	0.2750	0.2166
WGX9	0.2207	0.2631	0.3208	0.3834	0.1166	0.1414	0.2338
WGE	0.8184	0.9720	1.4016	1.4710	0.2410	0.0000	0.0000
WGEX	1.0800	1.6800	0.7400	0.0300	0.0000	0.0000	0.0000
EGX3	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004	0.0006
EGD1	0.0001	0.0000	0.4798	0.2904	0.0000	0.0000	0.0000
EGD2	0.0000	0.0000	0.0000	0.0000	0.1419	0.2327	0.2826
EGD3	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0001
EGX4	0.0610	0.0572	0.0510	0.0333	0.0000	0.0000	0.0000
EGX5	0.3943	0.5396	1.2397	1.8053	0.4345	0.0000	0.0000
EGX6	0.3289	0.3346	0.5119	0.3086	0.3713	0.4582	0.7577
WEX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEX4	0.0231	0.0509	0.0703	0.0979	0.5727	0.7736	1.4082
WEX5	0.0506	0.0512	0.0513	0.0596	0.0743	0.1746	0.2381
WEX6	0.0008	0.0008	0.0008	0.0004	0.0000	0.0000	0.0000
WED5	0.0068	0.0057	0.0067	0.0216	0.0368	0.1129	0.0188
WED6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED1	0.0235	0.0188	0.0215	0.0636	0.1084	0.3624	0.3411
WED2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WED4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEX9	0.0284	0.0336	0.0405	0.0478	0.0581	0.1761	0.2912

LOW CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
WEX10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEX11	0.0337	0.0303	0.0239	0.0257	0.0269	0.0310	0.0574
WEEX	0.0032	0.0034	0.0036	0.0039	0.0043	0.0048	0.0093
WCX5	0.1317	0.1437	0.1542	0.1865	0.2241	0.5452	1.4242
EEX5	0.1770	0.2620	0.3139	0.3583	0.4420	0.4420	0.7193
EEX6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED5	0.0456	0.0980	0.0685	0.0991	0.1536	0.1551	0.1471
EED6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EED4	0.0129	0.0278	0.0194	0.0281	0.4908	0.2449	0.2423
EEX9	0.0881	0.1545	0.2305	0.1939	0.4329	0.5708	0.9438
EEX10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEX11	0.1195	0.1559	0.1424	0.2348	0.4895	0.5364	0.9932
EEEX	0.0067	0.0070	0.0074	0.0081	0.0090	0.0099	0.0191
ECX3	0.2386	0.2236	0.1996	0.1301	0.0000	0.0000	0.0000
WLA	0.0685	0.0644	0.0645	0.0689	0.0749	0.0878	0.1277
WTD1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WTD2	0.0201	0.0443	0.0202	0.0588	0.0749	0.0878	0.1277
ELA	0.1443	0.1361	0.1368	0.1450	0.1579	0.1853	0.2696
ETD1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ETD2	0.0409	0.0952	0.0416	0.1242	0.1579	0.1853	0.2696
WER	0.0140	0.0086	0.0000	0.0000	0.0000	0.0000	0.0000
WEH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WEO	0.0197	0.0217	0.0239	0.0257	0.0269	0.0310	0.0574
WDD1	0.1797	0.2367	0.2787	0.3483	0.5500	0.0000	0.1444
WDD2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDD3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WDX5	0.0000	0.0000	0.0000	0.0000	0.0434	0.1883	0.5697
WDX6	0.0000	0.0000	0.0000	0.0000	0.0000	0.2878	0.5318
WDD5	0.0000	0.0000	0.0000	0.0000	0.0434	0.1450	0.1364
WDD6	0.0000	0.0000	0.0000	0.0000	0.0000	0.2878	0.2586
EER	0.0582	0.0919	0.0645	0.1495	0.3936	0.4235	0.7842
EEH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EEO	0.0612	0.0639	0.0778	0.0853	0.0960	0.1129	0.2090
EDD1	0.1883	0.2302	0.8211	0.8691	0.0000	0.0000	0.0000
EDD2	0.1449	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDD3	0.0122	0.0523	0.0000	0.1233	0.3319	0.2576	0.4369
EDD4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDX5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDX6	0.0000	0.0000	0.0000	0.0000	0.4448	1.0466	1.9378
EDD5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EDD6	0.0000	0.0000	0.0000	0.0000	0.4448	0.8242	1.0171

LOW CASE

Period Ending:	1980	1985	1990	2000	2010	2020	end effects
WCX1	0.5557	0.7817	1.0330	1.6980	2.4500	4.2907	15.0444
WCX2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ECX1	0.1012	0.2024	0.4048	0.7251	0.6860	0.4346	0.0000
ECX2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOX1	0.5499	0.3486	0.1932	0.0534	0.0008	0.0000	0.0000
WOX2	0.0000	0.1335	0.2498	0.1552	0.1782	0.0618	0.0132
WOX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.2917	0.1483
WOX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WOX5	0.0362	0.0706	0.1380	0.2205	0.1965	0.1419	0.6914
EOX1	0.0008	0.0100	0.0500	0.1772	0.0784	0.0141	0.0000
EOX2	0.0000	0.0000	0.0000	0.0000	0.1274	0.0599	0.0127
WGX1	2.7081	2.2865	1.4817	0.6224	0.0394	0.0000	0.0000
WGX2	0.2484	1.7192	2.1752	2.4086	1.1855	0.2345	0.0000
WGX3	0.0000	0.0000	0.0000	0.0000	0.0000	0.2369	0.5100
WGX4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EGX1	0.0002	0.0002	0.4800	0.7703	0.4578	0.1317	0.0000
EGX2	0.0000	0.0000	0.0000	0.0000	0.1419	0.3462	0.7902
EC	1.9106	2.0226	2.3906	2.7956	3.4912	4.3925	6.6890

Appendix F. Computer Programs and Data Listings for the Base Case.

This appendix briefly describes the computing procedure for running the model and obtaining printed and graphical output. The base case is used as the example.

The steps in running the model are:

1. make any changes to the matrix (the file LPDC DATA), the right hand side (rare) or bounds (both in the file RBI DATA) for the linear process model of supply;
2. if demand data (in the file DEMAND DATA) are to be changed, then produce a new subroutine CALCFG (using the FORTRAN program CRCALC), then compile it to produce the new CALCFG object file which MINOS uses to evaluate the objective function and its gradient;
3. if the discount rate is to be altered (in the file DEMAND DATA), it is necessary to run the FORTRAN program ENDPROG which alters the matrix, right hand side and bounds in accordance with the procedure to mitigate and effects;
4. solve the problem using MINOS;
5. re-arrange the format of the raw output of variables and some prices from MINOS, using the REFORM FORTRAN program which also expresses all variables in annual terms (dividing by 5 or 10 as required), and expresses all prices in undiscounted dollars (the output from REFORM for the base case is in Appendix D);
6. produce a plot file (up to 27 plots may be chosen by inserting "1" beside the desired plot names in the file CHPLT DATA) and their printed tables of values, using the FORTRAN program GPLT; and
7. send the plot file to the Calcomp plotter, if desired.

In practice, steps 4,5, and 6 are done together, in Batch mode.

The following is the file DEMAND DATA (base case data is entered here):

```
LAYOUT:        DFC        IND        RTR        OTR
PRELAST:     0.81       0.48       0.36       0.36
OTHELAS:     0.71       0.667      0.8
BASYPRW:     0.5018     0.1434     2.2501     0.8261
BASYPRE:     0.5089     0.1462     2.3554     0.8046
BASYQTW:     0.3523     0.3136     0.0570     0.0195
BASYQUE:     1.3212     1.1001     0.1272     0.0497
BASE YEAR VALUES OF EXOGENOUS PARAMETERS
POP:    0.9662
IPC:    0.8217
RDP:    0.8249
COR:    1.0343
ANNUAL GROWTH RATE PROJECTIONS, PER CENT
POPW:     1.5    1.2    1.1    0.9    0.6    0.5    0.3
POPE:     1.2    0.9    0.8    0.7    0.6    0.5    0.3
IPC:      3.7    1.9    2.3    2.5    2.3    2.3    2.3
RDPW:     3.5    4.0    3.7    3.8    2.9    2.8    2.6
RDPE:     3.2    3.7    3.4    3.6    2.9    2.8    2.6
COR:      2.0    2.1    2.8    1.0    0.5    0.0    0.0
DISCOUNT RATE:    10.0   PER CENT PER YEAR
```

The following is the FORTRAN program CRCALC for producing the subroutine CALCFG, needed by MINOS to evaluate the objective function and its gradient.

```
$JOB
      DIMENSION XPOPW(7),XPOPE(7),XIPC(7),XRDPW(7),XRDPE(7),XCOR(7)
      DIMENSION A(8,7),E(8),BP(8),BQ(8),DF(7),TF(7),EX(7)
      READ(1,110)
      READ(1,110)  E(1),E(3),E(5),E(7)
      READ(1,110)  ELDI,ELIC,ELRI
      READ(1,110)  BPWD,BPWI,BPWR,BPWO
      READ(1,110)  BPED,BPEI,BPER,BPEO
      READ(1,110)  BQWD,BQWI,BQWR,BQWO
      READ(1,110)  BQED,BQEI,BQER,BQEO
      READ(1,110)
      READ(1,120)  BPOP
      READ(1,120)  BIPC
      READ(1,120)  BRDP
      READ(1,120)  BCOR
      READ(1,110)
      READ(1,130)  XPOPW
      READ(1,130)  XPOPE
      READ(1,130)  XIPC
      READ(1,130)  XRDPW
      READ(1,130)  XRDPE
      READ(1,130)  XCOR
      READ(1,140)  D
  110 FORMAT(9X,4(3X,F7.4))
  120 FORMAT(8X,F6.4)
  130 FORMAT(6X,7(3X,F3.1))
  140 FORMAT(18X,F4.1)
      GPOPW=(1+XPOPW(7)/100.)**10
      GPOPE=(1+XPOPE(7)/100.)**10
      GIPC=(1+XIPC(7)/100.)**10
      GRDPW=(1+XRDPW(7)/100.)**10
      GRDPE=(1+XRDPE(7)/100.)**10
      GCOR=(1+XCOR(7)/100.)**10
      XPOPW(1)=(1.+XPOPW(1)/100.)**5
      XPOPE(1)=(1.+XPOPE(1)/100.)**5
      XIPC(1)=(1.+XIPC(1)/100.)**5
      XRDPW(1)=(1.+XRDPW(1)/100.)**5
      XRDPE(1)=(1.+XRDPE(1)/100.)**5
      XCOR(1)=(1.+XCOR(1)/100.)**5
      DO 3 J=1,7
      IF(J.LT.4)  EX(J)=5.
      IF(J.EQ.4)  EX(J)=7.5
      IF(J.GT.4)  EX(J)=10.
    3 CONTINUE
      DO 5 J=2,7
      XPOPW(J)=XPOPW(J-1)*(1.+XPOPW(J)/100.)**EX(J)
      XPOPE(J)=XPOPE(J-1)*(1.+XPOPE(J)/100.)**EX(J)
      XIPC(J)=XIPC(J-1)*(1.+XIPC(J)/100.)**EX(J)
      XRDPW(J)=XRDPW(J-1)*(1.+XRDPW(J)/100.)**EX(J)
      XRDPE(J)=XRDPE(J-1)*(1.+XRDPE(J)/100.)**EX(J)
    5 XCOR(J)=XCOR(J-1)*(1.+XCOR(J)/100.)**EX(J)
      DO 10 I=1,7,2
   10 E(I+1)=E(I)
C     CALCULATION OF UNKNOWN CONSTANTS IN DEMAND EQUATIONS
      AWD=BQWD/(BPOP*BIPC**ELDI*BPWD**(-E(1)))
```

```
      AED=BQED/(BPOP*BIPC**ELDI*BPED**(-E(2)))
      AWI=BQWI/(BRDP*BCOR**ELIC*BPWI**(-E(3)))
      AEI=BQEI/(BRDP*BCOR**ELIC*BPEI**(-E(4)))
      AWR=BQWR/(BPOP*BIPC**ELRI*BPWR**(-E(5)))
      AER=BQER/(BPOP*BIPC**ELRI*BPER**(-E(6)))
      AWO=BQWO/(BRDP*BPWO**(-E(7)))
      AEO=BQEO/(BRDP*BPEO**(-E(8)))
      DO 12 J=1,7
      IF(J.LE.3) TF(J)=5.
      IF(J.GT.3) TF(J)=10.
   12 CONTINUE
C  CALCULATION OF PROJECTED A'S IN DEMAND EQUATIONS
      DO 15 J=1,7
      A(1,J)=AWD*XPOPW(J)*XIPC(J)**ELDI*TF(J)
      A(2,J)=AED*XPOPE(J)*XIPC(J)**ELDI*TF(J)
      A(3,J)=AWI*XRDPW(J)*XCOR(J)**ELIC*TF(J)
      A(4,J)=AEI*XRDPE(J)*XCOR(J)**ELIC*TF(J)
      A(5,J)=AWR*XPOPW(J)*XIPC(J)**ELRI*TF(J)
      A(6,J)=AER*XPOPE(J)*XIPC(J)**ELRI*TF(J)
      A(7,J)=AWO*XRDPW(J)*TF(J)
   15 A(8,J)=AEO*XRDPE(J)*TF(J)
C  CALCULATION OF EXPONENTS FOR BENEFITS EQUATION
      DO 20 I=1,8
   20 E(I)=(E(I)-1.)/E(I)
      D=D/100.
      DF(1)=1./(1+D)**5
      DO 22 J=2,7
   22 DF(J)=DF(J-1)/(1+D)**EX(J)
C  CALCULATION OF PROJECTED A'S IN BENEFITS EQUATION
      DO 30 J=1,7
      DO 25 I=1,8
   25 A(I,J)=-A(I,J)**(1-E(I))*DF(J)/E(I)
   30 CONTINUE
C ALTERATION FOR END EFFECTS
      A(1,7)=A(1,7)/(1.-GPOPW*GIPC**ELDI/(1.+D)**10)
      A(2,7)=A(2,7)/(1.-GPOPE*GIPC**ELDI/(1.+D)**10)
      A(3,7)=A(3,7)/(1.-GRDPW*GCOR**ELIC/(1.+D)**10)
      A(4,7)=A(4,7)/(1.-GRDPE*GCOR**ELIC/(1.+D)**10)
      A(5,7)=A(5,7)/(1.-GPOPW*GIPC**ELRI/(1.+D)**10)
      A(6,7)=A(6,7)/(1.-GPOPE*GIPC**ELRI/(1.+D)**10)
      A(7,7)=A(7,7)/(1.-GRDPW/(1.+D)**10)
      A(8,7)=A(8,7)/(1.-GRDPE/(1.+D)**10)
C  OUTPUT OF FORTRAN PROGRAM TO CALCFG FORTRAN A
      WRITE(2,201)
  201 FORMAT(6X,'SUBROUTINE CALCFG(MODE,N,X,F,G,NSTATE,NPROB)')
      WRITE(2,202)
  202 FORMAT(6X,'IMPLICIT INTEGER(I-N),REAL*8(A-H,O-Z)')
      WRITE(2,203)
  203 FORMAT(6X,'DIMENSION X(N),G(N)')
      WRITE(2,204)
  204 FORMAT(6X,'DIMENSION A(8,7),E(8)')
      DO 60 J=1,7
      DO 50 I=1,8
   50 WRITE(2,210) I,J,A(I,J)
   60 CONTINUE
```

```
  210 FORMAT(6X,'A(',I1,',',I1,')=',E14.7)
      DO 70 I=1,8
   70 WRITE(2,220) I,E(I)
  220 FORMAT(6X,'E(',I1,')=',E14.7)
      WRITE(2,231)
  231 FORMAT(6X,'F=0.D0')
      WRITE(2,232)
  232 FORMAT(6X,'DO 200 J=1,7')
      WRITE(2,233)
  233 FORMAT(6X,'DO 100 I=1,8')
      WRITE(2,234)
  234 FORMAT(6X,'K=8*(J-1)+I')
      WRITE(2,235)
  235 FORMAT(6X,'F=F+A(I,J)*X(K)**E(I)')
      WRITE(2,236)
  236 FORMAT(2X,'100 G(K)=E(I)*A(I,J)*X(K)**(E(I)-1.D0)')
      WRITE(2,237)
  237 FORMAT(2X,'200 CONTINUE')
      WRITE(2,238)
  238 FORMAT(6X,'RETURN')
      WRITE(2,239)
  239 FORMAT(6X,'END')
C  PRODUCE EC DATA FILE, CORRECTLY DISCOUNTED
      K=5
      WRITE(3,301) K,K,DF(1)
      DO 82 L=2,3
      K=5*L
   82 WRITE(3,302) K,K,DF(L)
      DO 84 L=4,7
      K=10*L-15
   84 WRITE(3,302) K,K,DF(L)
  301 FORMAT(4X,'0',I1,'EC',6X,'0',I1,'NMMEC',5X,'-1.0',9X,'OBJECTIV',4X
     C,F8.5)
  302 FORMAT(4X,I2,'EC',6X,I2,'NMMEC',5X,'-1.0',9X,'OBJECTIV',4X,F8.5)
      STOP
      END
$ENTRY
```

The following is the FORTRAN program ENDPROG, which corrects the input files to MINOS for end effects.

```
$JOB WATFIV
C INPUT LOGICAL UNITS:  1=DEMAND DATA A 2=LPDC DATA A 3=RBI DATA A
C OUTPUT LOGICAL UNITS:  4=LPDC DATA B 7=RBI DATA B
      REAL*8 SS,TT,UU,YY,END/'ENDATA  '/
      REAL D/'D   '/,H
      DIMENSION M(265),X(300),E(300),F(265)
C READ DISCOUNT RATE
      DO 1 I=1,19
    1 READ(1,402)SS
      READ(1,101) DISC
  101 FORMAT(18X,F4.1)
      ALF=1/(1+DISC/100.)**10
C READ AND WRITE LPDC UP TO T=35
      READ(2,201) SS
      WRITE(4,201) SS
  201 FORMAT(A8)
      DO 5 I=1,1475
      READ(2,205) SS,TT,XX,UU,YY
    5 WRITE(4,205) SS,TT,XX,UU,YY
  205 FORMAT(4X,A8,2X,A8,4X,F7.4,6X,A8,4X,A8)
      DO 9 I=1,264
C READ FROM NON-EXHAUSTIBLE RESOURCE VARIABLES, T=35
      READ(2,100) SS,M(I),TT,X(I),UU,YY
    9 WRITE(4,100) SS,M(I),TT,X(I),UU,YY
  100 FORMAT(4X,A8,2X,I1,A8,3X,F7.4,6X,A8,4X,A8)
      M(265)=3
      I=1
      K=0
      J=0
   10 IF(I.GT.264)GO TO 40
      IF(M(I+1).NE.4)GO TO 20
      IF(M(I+2).NE.5)GO TO 30
      K=K+1
      J=J+1
C E'S ARE 'A' AND 'K1+AK2' MATRICES; F IS 'A+K1+AK2' MATRIX
      E(K)=X(I)
      F(J)=X(I)+X(I+1)+ALF*X(I+2)
      K=K+1
      E(K)=X(I+1)+ALF*X(I+2)
      I=I+3
      GO TO 10
   20 K=K+1
      J=J+1
      E(K)=X(I)
      F(J)=X(I)
      I=I+1
      GO TO 10
   30 K=K+1
      J=J+1
      E(K)=X(I)
      F(J)=X(I)+X(I+1)
      K=K+1
      E(K)=X(I+1)
      I=I+2
      GO TO 10
```

```
   40 CONTINUE
C READ AND WRITE REMAINING T=35
      DO 43 I=1,34
      READ(2,205) SS,TT,XX,UU,YY
   43 WRITE(4,205) SS,TT,XX,UU,YY
C WRITE LPDC, T=45
      DO 50 I=1,K
      READ(2,100) SS,MM,TT,XX,UU,YY
      IF(MM.EQ.5) XX=E(I)
   50 WRITE(4,100) SS,MM,TT,XX,UU,YY
C READ AND WRITE REMAINING, T=45
      DO 53 I=1,34
      READ(2,205) SS,TT,XX,UU,YY
   53 WRITE(4,205) SS,TT,XX,UU,YY
C WRITE LPDC, T=55
      DO 60 I=1,J
      READ(2,300) SS,H,VV,TT,XX,UU,YY
      IF(H.EQ.D) XX=F(I)
   60 WRITE(4,300) SS,H,VV,TT,XX,UU,YY
  300 FORMAT(4X,A4,A1,A2,3X,A8,4X,F7.4,6X,A8,4X,A8)
C READ AND WRITE REMAINING, T=55
      DO 63 I=1,34
      READ(2,205) SS,TT,XX,UU,YY
   63 WRITE(4,205) SS,TT,XX,UU,YY
C READ AND WRITE RHS TO BOUNDS
      READ(3,400) VV
      WRITE(7,400) VV
  400 FORMAT(A4)
      DO 70 I=1,47
      READ(3,401) SS,TT,XX,UU,YY
   70 WRITE(7,401) SS,TT,XX,UU,YY
  401 FORMAT(4X,A8,2X,A8,2X,F9.4,6X,A8,3X,A8)
      READ(3,402) SS
      WRITE(7,402) SS
  402 FORMAT(A8)
C READ, CHANGE AND WRITE BOUNDS
      DO 80 I=1,300
      READ(3,500) SS,MM,TT,X(I)
      IF(SS.EQ.END) GO TO 90
      IF(MM.NE.5) GO TO 79
      IF(X(I-1).NE.0.) GO TO 78
      X(I)=0.
      GO TO 79
   78 X(I)=X(I-1)*(X(I-1)/X(I-2))/(1.-ALP*X(I-1)/X(I-2))
   79 CONTINUE
   80 WRITE(7,500) SS,MM,TT,X(I)
  500 FORMAT(A8,6X,I1,A8,1X,F9.4)
   90 WRITE(7,402) SS
      STOP
      END
$ENTRY
```

The following files represent the input files (other than the CALCFG object file) to MINOS. The file NLPSPEC DATA gives specifications such as tolerances, iteration limit, etc. to MINOS. The file LPDR DATA lists the rows of the linear constraints (since it repeats after the first period, changing only the time index, this listing is truncated after the end of the first period, for brevity). The file LPDC DATA gives the non-zero elements of the constraint matrix, by column, beginning with the nonlinear variables (again, when the largely repetitive part begins, the listing is truncated after the first period). The file RBI DATA contains the right hand side, the bounds, and the special bounds called INITIAL, which are used by MINOS as a first approximation to the nonlinear variables if no starting basis is specified.

```
FILE: NLPSPEC  DATA     A   05/10/80  22:25:00  UNIVERSITY OF WATERLOO

BEGIN
     MINIMIZE
     OBJECTIVE = OBJECTIV
     RHS = FIRSTTRY
     BOUNDS = B
     ROWS    800
     COLUMNS   1000
     ELEMENTS (COEFFICIENTS) 5200
     ITERATIONS   2000
     LOG FREQ  10
     INSERT FILE  11
     PUNCH FILE 12
     SOLUTION     FILE 13
     NONLINEAR VARIABLES  56
     SUPERBASICS LIMIT 57
     HESSIAN DIMENSION 57
     ERROR MESSAGE LIMIT 100
     DEBUG LEVEL  2
END
```

```
FILE: LPDR      DATA      A     04/19/80  09:11:00  UNIVERSITY OF WATERLOO

NAME          ENEBSEC
RCWS
 N  OBJECTIV
 E  05WCCP1
 E  05WCCP2
 E  05ECCP1
 E  05ECCP2
 E  05WOPR1
 E  05WOPR2
 E  05WOPR3
 E  05WOPR4
 E  05WOCP5
 E  05WOCP6
 E  05WOCPL
 E  05EOPR1
 E  05EOPR2
 E  05EOCP3
 E  05WGPR1
 E  05WGPR2
 E  05WGPR3
 E  05WGPR4
 E  05WGCP5
 E  05WGCP6
 E  05EGPR1
 E  05EGPR2
 E  05EGCP3
 E  05WECP1
 E  05WECP2
 E  05WECP3
 E  05WECP4
 E  05WECP5
 E  05WECP6
 E  05EECP1
 E  05EECP2
 E  05EECP3
 E  05EECP4
 E  05EECP5
 E  05EECP6
 E  05WTCP1
 E  05WTCP2
 E  05ETCP1
 E  05ETCP2
 E  05WDCP1
 E  05WDCP2
 E  05WDCP3
 E  05WDCP4
 E  05WDCP5
 E  05WDCP6
 E  05EDCP1
 E  05EDCP2
 E  05EDCP3
 E  05EDCP4
 E  05EDCP5
 E  05EDCP6
 E  05WCSB
```

```
FILE: LPDR     DATA     A     04/19/80  09:11:00  UNIVERSITY OF WATERLOO

 E  05ECSB
 E  05WOSBO
 E  05WCSBL
 E  05EOSBO
 E  05ECSBL
 L  05NOMSS
 L  05NCMEM
 E  05WGSB
 E  05EGSB
 E  05WESBE
 L  05WEMH
 E  05EESBE
 L  05EEMH
 E  05WTSBL
 E  05WTSBA
 L  05WTMEA
 E  05ETSBL
 E  05ETSBA
 L  05ETMEA
 E  05WISB
 L  05WISLG
 L  05WISLL
 L  05WISLC
 L  05WISLE
 G  05WISUG
 G  05WISUL
 G  05WISUC
 G  05WISUE
 E  05EISB
 L  05EISLG
 L  05EISLL
 L  05EISLC
 L  05EISLE
 G  05EISUG
 G  05EISUL
 G  05EISUC
 G  05EISUE
 E  05WDSBE
 E  05WDSBH
 E  05WDSEO
 L  05WDSUP
 L  05WDSUS
 L  05WDSUC
 L  05WDMCG
 E  05EDSBE
 E  05EDSBH
 E  05EDSEO
 L  05EDSUP
 L  05EDSUS
 L  05EDSUC
 L  05EDMCG
 L  05NMMEC
 E  10WCCP1
 E  10WCCP2
 E  10ECCP1
```

```
FILE: LPDC      DATA      A    04/19/80  09:11:00  UNIVERSITY OF WATERLOO

COLUMNS
    05WDFC      05WDSBH      -0.8661      05WDSEO      -0.1339
    05WDFC      05WDSUP       0.0000      05WDSUS      -0.0
    05WDFC      05WDSUC       0.0000
    05EDFC      05EDSBH      -0.8661      05EDSEO      -0.1339
    05EDFC      05EDSUP       0.0000      05EDSUS      -0.0
    05EDFC      05EDSUC       0.0000
    05WIND      05WISB       -1.0000      05WISLG      +0.384
    05WIND      05WISUG       0.4840      05WISLL      +0.243
    05WIND      05WISUL       0.3430      05WISLC      +0.044
    05WIND      05WISUC       0.0840      05WISLE      +0.229
    05WIND      05WISUE       0.2890
    05EIND      05EISB       -1.0000      05EISLG      +0.214
    05EIND      05EISUG       0.3140      05EISLL      +0.298
    05EIND      05EISUL       0.3980      05EISLC      +0.158
    05EIND      05EISUC       0.1980      05EISLE      +0.230
    05EIND      05EISUE       0.2900
    05WRTR      05WTSBA      -1.0000
    05ERTR      05ETSBA      -1.0000
    05WOTR      05WISBL       0.6849
    05ECTR      05EISBL       0.6849
    10WDFC      10WDSBH      -0.8661      10WDSEO      -0.1339
    10WDFC      10WDSUP      -0.2165      10WDSUS      -0.0228
    10WDFC      10WDSUC      -0.0974
    10EDFC      10EDSBH      -0.8661      10EDSEO      -0.1339
    10EDFC      10EDSUP      -0.2165      10EDSUS      -0.0228
    10EDFC      10EDSUC      -0.1299
    10WIND      10WISB       -1.0000      10WISLG      +0.313
    10WIND      10WISUG       0.5130      10WISLL      +0.207
    10WIND      10WISUL       0.4070      10WISLC      +0.058
    10WIND      10WISUC       0.1380      10WISLE      +0.222
    10WIND      10WISUE       0.3420
    10EIND      10EISB       -1.0000      10EISLG      +0.185
    10EIND      10EISUG       0.3850      10EISLL      +0.249
    10EIND      10EISUL       0.4490      10EISLC      +0.143
    10EIND      10EISUC       0.2230      10EISLE      +0.223
    10EIND      10EISUE       0.3430
    10WRTR      10WTSBA      -1.0000
    10ERTR      10ETSBA      -1.0000
    10WOTR      10WTSBL       0.6623
    10ECTR      10ETSBL       0.6623
    15WDFC      15WDSBH      -0.8661      15WDSEO      -0.1339
    15WDFC      15WDSUP      -0.4331      15WDSUS      -0.0455
    15WDFC      15WDSUC      -0.1949
    15EDFC      15EDSBH      -0.8661      15EDSEO      -0.1339
    15EDFC      15EDSUP      -0.4331      15EDSUS      -0.0455
    15EDFC      15EDSUC      -0.2598
    15WIND      15WISB       -1.0000      15WISLG      +0.242
    15WIND      15WISUG       0.5420      15WISLL      +0.172
    15WIND      15WISUL       0.4720      15WISLC      +0.072
    15WIND      15WISUC       0.1920      15WISLE      +0.214
    15WIND      15WISUE       0.3940
    15EIND      15EISB       -1.0000      15EISLG      +0.157
    15EIND      15EISUG       0.4570      15EISLL      +0.199
    15EIND      15EISUL       0.4990      15EISLC      +0.129
```

```
15EIND    15EISUC     0.2490    15EISLE     +0.215
15EIND    15EISUE     0.3950
15WRTR    15WTSBA    -1.0000
15ERTR    15ETSBA    -1.0000
15WOTR    15WTSBL     0.6410
15EOTR    15ETSBL     0.6410
25WDFC    25WDSBH    -0.8661    25WDSEO     -0.1339
25WDFC    25WDSUP    -0.8661    25WDSUS     -0.0909
25WDFC    25WDSUC    -0.3897
25EDFC    25EDSBH    -0.8661    25EDSEO     -0.1339
25EDFC    25EDSUP    -0.8661    25EDSUS     -0.0909
25EDFC    25EDSUC    -0.5197
25WIND    25WISB     -1.0000    25WISLG     +0.1
25WIND    25WISUG     0.6000    25WISLL     +0.1
25WIND    25WISUL     0.6000    25WISLC     +0.1
25WIND    25WISUC     0.3000    25WISLE     +0.2
25WIND    25WISUE     0.5000
25EIND    25EISB     -1.0000    25EISLG     +0.1
25EIND    25EISUG     0.6000    25EISLL     +0.1
25EIND    25EISUL     0.6000    25EISLC     +0.1
25EIND    25EISUC     0.3000    25EISLE     +0.2
25EIND    25EISUE     0.5000
25WRTR    25WTSBA    -1.0000
25ERTR    25ETSBA    -1.0000
25WOTR    25WTSBL     0.6024
25EOTR    25ETSBL     0.6024
35WDFC    35WDSBH    -0.8661    35WDSEO     -0.1339
35WDFC    35WDSUP    -0.8661    35WDSUS     -0.1819
35WDFC    35WDSUC    -0.3897
35EDFC    35EDSBH    -0.8661    35EDSEO     -0.1339
35EDFC    35EDSUP    -0.8661    35EDSUS     -0.1819
35EDFC    35EDSUC    -0.5197
35WIND    35WISB     -1.0000    35WISLG     +0.1
35WIND    35WISUG     0.6000    35WISLL     +0.1
35WIND    35WISUL     0.6000    35WISLC     +0.1
35WIND    35WISUC     0.3000    35WISLE     +0.2
35WIND    35WISUE     0.5000
35EIND    35EISB     -1.0000    35EISLG     +0.1
35EIND    35EISUG     0.6000    35EISLL     +0.1
35EIND    35EISUL     0.6000    35EISLC     +0.1
35EIND    35EISUC     0.3000    35EISLE     +0.2
35EIND    35EISUE     0.5000
35WRTR    35WTSBA    -1.0000
35ERTR    35ETSBA    -1.0000
35WOTR    35WTSBL     0.5848
35EOTR    35ETSBL     0.5848
45WDFC    45WDSBH    -0.8661    45WDSEO     -0.1339
45WDFC    45WDSUP    -0.8661    45WDSUS     -0.3638
45WDFC    45WDSUC    -0.3897
45EDFC    45EDSBH    -0.8661    45EDSEO     -0.1339
45EDFC    45EDSUP    -0.8661    45EDSUS     -0.3638
45EDFC    45EDSUC    -0.5197
45WIND    45WISB     -1.0000    45WISLG     +0.1
45WIND    45WISUG     0.6000    45WISLL     +0.1
45WIND    45WISUL     0.6000    45WISLC     +0.1
```

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FILE: LPDC      DATA       A    04/19/80  09:11:00  UNIVERSITY OF WATERLOO

      45WIND      45WISUC         0.3000        45WISLE        +0.2
      45WIND      45WISUE         0.5000
      45EIND      45EISB         -1.0000        45EISLG        +0.1
      45EIND      45EISUG         0.6000        45EISLL        +0.1
      45EIND      45EISUL         0.6000        45EISLC        +0.1
      45EIND      45EISUC         0.3000        45EISLE        +0.2
      45EIND      45EISUE         0.5000
      45WRTR      45WTSBA        -1.0000
      45ERTR      45ETSBA        -1.0000
      45WOTR      45WTSBL         0.5848
      45EOTR      45ETSBL         0.5848
      55WDFC      55WDSBH        -0.8661        55WDSEO        -0.1339
      55WDFC      55WDSUP        -0.8661        55WDSUS        -0.3638
      55WDFC      55WDSUC        -0.3897
      55EDFC      55EDSBH        -0.8661        55EDSEO        -0.1339
      55EDFC      55EDSUP        -0.8661        55EDSUS        -0.3638
      55EDFC      55EDSUC        -0.5197
      55WIND      55WISB         -1.0000        55WISLG        +0.1
      55WIND      55WISUG         0.6000        55WISLL        +0.1
      55WIND      55WISUL         0.6000        55WISLC        +0.1
      55WIND      55WISUC         0.3000        55WISLE        +0.2
      55WIND      55WISUE         0.5000
      55EIND      55EISB         -1.0000        55EISLG        +0.1
      55EIND      55EISUG         0.6000        55EISLL        +0.1
      55EIND      55EISUL         0.6000        55EISLC        +0.1
      55EIND      55EISUC         0.3000        55EISLE        +0.2
      55EIND      55EISUE         0.5000
      55WRTR      55WISBA        -1.0000
      55ERTR      55ETSBA        -1.0000
      55WOTR      55WTSBL         0.5848
      55EOTR      55ETSBL         0.5848
      05WCX3      05WCSB         -1.0000        05WOCPL          1.0
      05WCX3      05WOSBO         0.1072        05NMMEC           .1647
      05WCX3      10WOCPL        -1.0000
      05WCX4      05WCSB         -1.0000        05WGCP6          1.0
      05WCX4      05WGSB          0.5670        05NMMEC           .1503
      05WCX4      10WGCP6        -1.0000
      05WCX6      05WCSB         -1.0000        05WISE            .87
      05WCX6      05WISLC        -0.8700        05WISUC          -.87
      05WCX6      05NMMEC         0.0800
      05WCD1      05WCCP1        -1.0000
      05WCD1      25WCCP1        -2.0000
      05WCD1      35WCCP1        -1.0000
      05WCD2      05WCCP2        -1.0000
      05WCD2      25WCCP2        -2.0000
      05WCD2      35WCCP2        -1.0000
      05WCE       05WCSB         -1.0000        05ECSB            .9994
      05WCE       05NMMEC         0.1030
      05WCEX      05WCSB         -1.0000        05NMMEC          -.117
      05ECX4      05ECSB         -1.0000        05EISB            .87
      05ECX4      05EISLC        -0.8700        05EISUC          -.87
      05ECX4      05NMMEC         0.0400
      05ECD1      05ECCP1        -1.0000
      05ECD1      25ECCP1        -2.0000
      05ECD1      35ECCP1        -1.0000
```

```
FILE: LPDC      DATA      A     04/19/80   09:11:00   UNIVERSITY OF WATERLOO

     05ECD2     05ECCP2      -1.0000
     05ECD2     25ECCP2      -2.0000
     05ECD2     35ECCP2      -1.0000
     05ECIM     05ECSB        0.9994       05NMMEC      +0.155
     05WOX6     05WOCP6       1.0000       05WOSBL       0.9272
     05WOX6     05NMMEC       2.5000
     05WOX6     10WOCP6      -1.0000
     05WOD1     05WOPR1      -1.0000
     05WOD1     10WOPR1      -1.0000
     05WOD1     15WOPR1      -0.5900
     05WOD1     25WOPR1      -0.5600
     05WOD2     05WOPR2      -1.0000
     05WOD2     10WOPR2      -1.0000
     05WOD2     15WOPR2      -0.5900
     05WOD2     25WOPR2      -0.5600
     05WOD3     05WOPR3      -1.0000
     05WOD3     10WOPR3      -1.0000
     05WOD3     15WOPR3      -0.5900
     05WOD3     25WOPR3      -0.5600
     05WOD4     05WOPR4      -1.0000
     05WOD4     10WOPR4      -1.0000
     05WOD4     15WOPR4      -0.5900
     05WOD4     25WOPR4      -0.5600
     05WOD5     05WOCP5      -1.0000
     05WOD5     25WOCP5      -2.0000
     05WOD5     35WOCP5      -1.0000
     05WOD6     05WOCP6      -1.0000
     05WOD6     25WOCP6      -2.0000
     05WOD6     35WOCP6      -1.0000
     05WOEX     05WOSBO      -1.0000       05NOMSS      -1.0
     05WOEX     05NMMEC      -1.4600
     05WOE      05WOSBO      -1.0000       05EOSBO       1.0
     05WOE      05NOMEM       1.0000       05NMMEC        .05
     05WOG      05WOSBO      -1.0000       05WOSBL      +0.9272
     05WOG      05NOMSS      -1.0000
     05EOX3     05EOCP3       1.0000       05EOSBL      +0.9262
     05EOX3     05NMMEC       2.5000
     05EOX3     10EOCP3      -1.0000
     05EOD1     05EOPR1      -1.0000
     05EOD1     10EOPR1      -1.0000
     05EOD1     15EOPR1      -0.5900
     05EOD1     25EOPR1      -0.5600
     05EOD2     05EOPR2      -1.0000
     05EOD2     10EOPR2      -1.0000
     05EOD2     15EOPR2      -0.5900
     05EOD2     25EOPR2      -0.5600
     05EOD3     05EOCP3      -1.0000
     05EOD3     25EOCP3      -2.0000
     05EOD3     35ECCP3      -1.0000
     05EOIM     05EOSBO       1.0000       05NOMSS      +1.0
     05EOIM     05NMMEC       1.0800
     05EOG      05EOSBO      -1.0000       05EOSBL      +0.9262
     05EOG      05NOMSS      -1.0000       05NOMEM      -0.54
     05WLX1     05WOSBL      -1.0000       05WECP2      +1.0
     05WLX1     05WESBE       0.4440       05NMMEC      +0.326
```

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FILE: LPDC      DATA      A    04/19/80   09:11:00   UNIVERSITY OF WATERLOO

     05WLX1     10WECP2     -1.0000
     05WLX2     05WOSBL     -1.0000       05WDCP2       +1.0
     05WLX2     05WDSBH      3.8350       05NMMEC       +1.71
     05WLX3     05WOSBL     -1.0000       05WISLL       -4.13
     05WLX3     05WISUL     -4.1300       05NMMEC       +0.04
     05WLX3     05WISB       4.1300
     05WLX4     05WOSBL     -1.0000       05WTSBL       -1.0
     05WLX4     05NMMEC      0.7700
     05WLDC     05WOCPL     -1.0000
     05WLDC     25WOCPL     -2.0000
     05WLDC     35WOCPL     -1.0000
     05ELX1     05EOSBL     -1.0000       05EECP2       +1.0
     05ELX1     05EESBE      0.4518       05NMMEC       +0.326
     05ELX1     10EECP2     -1.0000
     05ELX2     05EOSBL     -1.0000       05EDCP2       +1.0
     05ELX2     05EDSBH      3.8350       05NMMEC       +1.60
     05ELX3     05EOSBL     -1.0000       05EISLL       -4.13
     05ELX3     05EISUL     -4.1300       05NMMEC       +0.01
     05ELX3     05EISB       4.1300
     05ELX4     05EOSBL     -1.0000       05ETSBL       -1.0
     05ELX4     05NMMEC      0.6900
     05WGX5     05WGCP5      1.0000       05WGSE        +0.8832
     05WGX5     05NMMEC      0.2500
     05WGX5     10WGCP5     -1.0000
     05WGD1     05WGPR1     -1.0000
     05WGD1     10WGPR1     -1.0000
     05WGD1     15WGPR1     -1.0000
     05WGD1     25WGPR1     -0.9400
     05WGD1     35WGPR1     -0.2100
     05WGD2     05WGPR2     -1.0000
     05WGD2     10WGPR2     -1.0000
     05WGD2     15WGPR2     -1.0000
     05WGD2     25WGPR2     -0.9400
     05WGD2     35WGPR2     -0.2100
     05WGD3     05WGPR3     -1.0000
     05WGD3     10WGPR3     -1.0000
     05WGD3     15WGPR3     -1.0000
     05WGD3     25WGPR3     -0.9400
     05WGD3     35WGPR3     -0.2100
     05WGD4     05WGPR4     -1.0000
     05WGD4     10WGPR4     -1.0000
     05WGD4     15WGPR4     -1.0000
     05WGD4     25WGPR4     -0.9400
     05WGD4     35WGPR4     -0.2100
     05WGD5     05WGCP5     -1.0000
     05WGD5     25WGCP5     -2.0000
     05WGD5     35WGCP5     -1.0000
     05WGD6     05WGCP6     -1.0000
     05WGD6     25WGCP6     -2.0000
     05WGD6     35WGCP6     -1.0000
     05WGX7     05WGSB      -1.0000       05WECP3       +1.0
     05WGX7     05WESBE      0.0764       05NMMEC       +0.046
     05WGX7     10WECP3     -1.0000
     05WGX8     05WGSB      -1.0000       05WDCP1       +1.0
     05WGX8     05WDSBH      0.7600       05NMMEC       +0.265
```

```
FILE: LPDC      DATA      A    04/19/80   09:11:00  UNIVERSITY OF WATERLOO

     05WGX9     05WGSB       -1.0000      05WISB        +0.85
     05WGX9     05WISLG      -0.8500      05WISUG       -0.85
     05WGX9     05NMMEC       0.0155
     05WGE      05WGSB       -1.0000      05EGSB        +0.958
     05WGE      05NMMEC       0.0440
     05WGEX     05WGSB       -1.0000      05NMMEC       -0.167
     05EGX3     05EGCP3       1.0000      05EGSB        +0.958
     05EGX3     05NMMEC       0.2500
     05EGX3     10EGCP3      -1.0000
     05EGD1     05EGPR1      -1.0000
     05EGD1     10EGPR1      -1.0000
     05EGD1     15EGPR1      -1.0000
     05EGD1     25EGPR1      -0.9400
     05EGD1     35EGPR1      -0.2100
     05EGD2     05EGPR2      -1.0000
     05EGD2     10EGPR2      -1.0000
     05EGD2     15EGPR2      -1.0000
     05EGD2     25EGPR2      -0.9400
     05EGD2     35EGPR2      -0.2100
     05EGD3     05EGCP3      -1.0000
     05EGD3     25EGCP3      -2.0000
     05EGD3     35EGCP3      -1.0000
     05EGX4     05EGSB       -1.0000      05EECP3       +1.0
     05EGX4     05EESBE       0.0777      05NMMEC       +0.046
     05EGX4     10EECP3      -1.0000
     05EGX5     05EGSB       -1.0000      05EDCP1       +1.0
     05EGX5     05EDSBH       0.7600      05NMMEC       +0.276
     05EGX6     05EGSB       -1.0000      05EISB        +0.85
     05EGX6     05EISLG      -0.8500      05EISUG       -0.85
     05EGX6     05NMMEC       0.0055
     05WEX4     05WESBE       0.8984      05NMMEC       +1.00
     05WEX4     05WECP4       1.0000
     05WEX4     10WECP4      -1.0000
     05EEX4     05EESBE       0.9143      05NMMEC       +1.00
     05EEX4     05EECP4       1.0000
     05EEX4     10EECP4      -1.0000
     05WEX5     05WECP5       1.0000      05WESBE       +0.8983
     05WEX5     05NMMEC       0.7700
     05WEX5     10WECP5      -1.0000
     05WEX6     05WECP6       1.0000      05WESBE       +0.8983
     05WEX6     05NMMEC       2.2900
     05WEX6     10WECP6      -1.0000
     05WED5     05WECP5      -1.0000      05WEMH        +0.247
     05WED5     25WECP5      -2.0000
     05WED5     35WECP5      -1.0000
     05WED6     05WECP6      -1.0000      05WEMH        -0.753
     05WED6     25WECP6      -2.0000
     05WED6     35WECP6      -1.0000
     05WED1     05WDMCG      -0.4000
     05WED1     05WECP1      -1.0000      05WEMH        -0.07180
     05WED1     25WECP1      -2.0000
     05WED1     35WECP1      -1.0000
     05WED2     05WECP2      -1.0000      05WEMH        -0.37210
     05WED2     25WECP2      -2.0000
     05WED2     35WECP2      -1.0000
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FILE: LPDC      DATA      A     04/19/80   09:11:00   UNIVERSITY OF WATERLOO

     05WED3     05WECP3      -1.0000      05WEMH        -0.06400
     05WED3     25WECP3      -2.0000
     05WED3     35WECP3      -1.0000
     05WED4     05WDMCG       0.0000
     05WED4     05WECP4      -1.0000      05WEMH        -0.753
     05WED4     25WECP4      -2.0000
     05WED4     35WECP4      -1.0000
     05WEX9     05WESBE      -1.0000      05WISB        +3.412
     05WEX9     05WISLE      -3.4120      05WISUE       -3.412
     05WEX9     05NMMEC       0.1800
     05WEX10    05WESBE      -1.0000      05WTCP1       +1.0
     05WEX10    05WISBA       2.3880      05NMMEC       +4.18
     05WEX11    05WESBE      -1.0000      05WDSEE       +1.0
     05WEX11    05NMMEC       1.5500
     05WEEX     05WESBE      -1.0000      05NMMEC       -1.45
     05WCX5     05WCSB       -1.0000
     05WCX5     05WECP1       1.0000
     05WCX5     05WESBE       0.0857      05NMMEC       +0.0725
     05WCX5     10WECP1      -1.0000
     05EEX5     05EECP5       1.0000      05EESBE       +0.9096
     05EEX5     05NMMEC       0.7700
     05EEX5     10EECP5      -1.0000
     05EEX6     05EECP6       1.0000      05EESBE       +0.9096
     05EEX6     05NMMEC       2.2900
     05EEX6     10EECP6      -1.0000
     05EED5     05EECP5      -1.0000      05EEMH        +0.221
     05EED5     25EECP5      -2.0000
     05EED5     35EECP5      -1.0000
     05EED6     05EECP6      -1.0000      05EEMH        -0.779
     05EED6     25EECP6      -2.0000
     05EED6     35EECP6      -1.0000
     05EED1     05EDMCG      -0.4000
     05EED1     05EECP1      -1.0000      05EEMH        -0.07430
     05EED1     25EECP1      -2.0000
     05EED1     35EECP1      -1.0000
     05EED2     05EECP2      -1.0000      05EEMH        -0.38500
     05EED2     25EECP2      -2.0000
     05EED2     35EECP2      -1.0000
     05EED3     05EECP3      -1.0000      05EEMH        -0.06620
     05EED3     25EECP3      -2.0000
     05EED3     35EECP3      -1.0000
     05EED4     05EDMCG       0.0000
     05EED4     05EECP4      -1.0000      05EEMH        -0.779
     05EED4     25EECP4      -2.0000
     05EED4     35EECP4      -1.0000
     05EEX9     05EESBE      -1.0000      05EISB        +3.412
     05EEX9     05EISLE      -3.4120      05EISUE       -3.412
     05EEX9     05NMMEC      -0.1000
     05EEX10    05EESBE      -1.0000      05ETCP1       +1.0
     05EEX10    05ETSBA       2.3880      05NMMEC       +4.18
     05EEX11    05EESBE      -1.0000      05EDSBE       +1.0
     05EEX11    05NMMEC       1.0000
     05EEEX     05EESBE      -1.0000      05NMMEC       -1.45
     05ECX3     05ECSB       -1.0000
     05ECX3     05EECP1       1.0000
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05ECX3    05EESBE    0.0872    05NMMEC    +0.0725
05ECX3    10EECP1   -1.0000
05WLA     05WTCP2    1.0000    05WTSEL    +1.0
05WLA     05WTSBA    1.3527    05NMMEC     1.15
05WTD1    05WTCP1   -1.0000    05WTMEA    +2.388
05WTD1    10WTCP1   -1.0000
05WTD2    05WTCP2   -1.0000    05WTMEA     0.0
05WTD2    10WTCP2   -1.0000
05ELA     05ETCP2    1.0000    05ETSBL    +1.0
05ELA     05ETSBA    1.3527    05NMMEC     1.36
05ETD1    05ETCP1   -1.0000    05ETMEA    +2.388
05ETD1    10ETCP1   -1.0000
05ETD2    05ETCP2   -1.0000    05ETMEA     0.0
05ETD2    10ETCP2   -1.0000
05WER     05WDCP3    1.0000    05WDSBE    -1.0
05WER     05WDSBH    3.4120    05NMMEC    +0.358
05WEH     05WDCP4    1.0000    05WDSBE    -1.0
05WEH     05WDSBH    6.8240    05WDSUP    +6.824
05WEH     05NMMEC    3.1800
05WEO     05WDSBE   -1.0000    05WDSEO    +3.412
05WDD1    05WDCP1   -1.0000
05WDD1    10WDCP1   -1.0000
05WDD1    15WDCP1   -1.0000
05WDD2    05WDCP2   -1.0000
05WDD2    10WDCP2   -1.0000
05WDD2    15WDCP2   -1.0000
05WDD3    05WDCP3   -1.0000
05WDD3    10WDCP3   -1.0000
05WDD3    15WDCP3   -1.0000
05WDD4    05WDCP4   -1.0000
05WDD4    10WDCP4   -1.0000
05WDD4    15WDCP4   -1.0000
05WDX5    05WDCP5    1.0000    05WDSBH    +1.0
05WDX5    05NMMEC    0.6620    05WDSUC    +1.0
05WDX5    10WDCP5   -1.0000
05WDX6    05WDCP6    1.0000    05WDSBH    +1.0
05WDX6    05NMMEC    0.7060    05WDSUS    +1.0
05WDD5    05WDCP5   -1.0000    05WDMCG    +1.0
05WDD5    25WDCP5   -2.0000
05WDD5    35WDCP5   -1.0000
05WDD6    05WDCP6   -1.0000
05WDD6    10WDCP6   -1.0000
05WDD6    15WDCP6   -1.0000
05EER     05EDCP3    1.0000    05EDSBE    -1.0
05EER     05EDSBH    3.4120    05NMMEC    +0.358
05EEH     05EDCP4    1.0000    05EDSBE    -1.0
05EEH     05EDSBH    6.8240    05EDSUP    +6.824
05EEH     05NMMEC    3.1800
05EEO     05EDSBE   -1.0000    05EDSEO    +3.412
05EDD1    05EDCP1   -1.0000
05EDD1    10EDCP1   -1.0000
05EDD1    15EDCP1   -1.0000
05EDD2    05EDCP2   -1.0000
05EDD2    10EDCP2   -1.0000
05EDD2    15EDCP2   -1.0000
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05EDD3    05EDCP3    -1.0000
05EDD3    10EDCP3    -1.0000
05EDD3    15EDCP3    -1.0000
05EDD4    05EDCP4    -1.0000
05EDD4    10EDCP4    -1.0000
05EDD4    15EDCP4    -1.0000
05EDX5    05EDCP5     1.0000     05EDSBH      +1.0
05EDX5    05NMMEC     0.6620     05EDSUC      +1.0
05EDX5    10EDCP5    -1.0000
05EDX6    05EDCP6     1.0000     05EDSBH      +1.0
05EDX6    05NMMEC     0.7060     05EDSUS      +1.0
05EDD5    05EDCP5    -1.0000     05EDMCG      +1.0
05EDD5    25EDCP5    -2.0000
05EDD5    35EDCP5    -1.0000
05EDD6    05EDCP6    -1.0000
05EDD6    10EDCP6    -1.0000
05EDD6    15EDCP6    -1.0000
05WCX1    05WCCP1     1.0000     05WCSB          .9996
05WCX1    00WCRL1     1.0000     05NMMEC         .02
05WCX1    10WCCP1    -1.0000
05WCX2    05WCCP2     1.0000     05WCSB          .9996
05WCX2    00WCRL2     1.0000     05NMMEC         .04
05WCX2    10WCCP2    -1.0000
05ECX1    05ECCP1     1.0000     05ECSB          .9994
05ECX1    00ECRL1     1.0000     05NMMEC         .08
05ECX1    10ECCP1    -1.0000
05ECX2    05ECCP2     1.0000     05ECSB          .9994
05ECX2    00ECRL2     1.0000     05NMMEC         .16
05ECX2    10ECCP2    -1.0000
05WOX1    05WOPR1     1.0000     05WOSBO       1.0
05WOX1    05NMMEC     0.4000     00WORL1       1.0
05WOX2    05WOPR2     1.0000     05WOSBO       1.0
05WOX2    05NMMEC     0.8000     00WORL2       1.0
05WOX3    05WOPR3     1.0000     05WOSBO       1.0
05WOX3    05NMMEC     1.0000     00WORL3       1.0
05WOX4    05WOPR4     1.0000     05WOSBO       1.0
05WOX4    05NMMEC     1.4000     00WORL4       1.0
05WOX5    05WOCP5     1.0000     05WOSBO       1.0
05WOX5    05NMMEC     1.2000     00WORL5       1.0
05WOX5    10WOCP5    -1.0000
05EOX1    05EOPR1     1.0000     05EOSBO       1.0
05EOX1    05NMMEC     0.7000     00EORL1       1.0
05EOX2    05EOPR2     1.0000     05EOSBO       1.0
05EOX2    05NMMEC     1.0000     00EORL2       1.0
05WGX1    05WGPR1     1.0000     05WGSB          .8832
05WGX1    05NMMEC     0.0300     00WGRL1       1.0
05WGX2    05WGPR2     1.0000     05WGSB          .8832
05WGX2    05NMMEC     0.0800     00WGRL2       1.0
05WGX3    05WGPR3     1.0000     05WGSB          .8832
05WGX3    05NMMEC     0.2500     00WGRL3       1.0
05WGX4    05WGPR4     1.0000     05WGSB          .8832
05WGX4    05NMMEC     0.3000     00WGRL4       1.0
05EGX1    05EGPR1     1.0000     05EGSB          .958
05EGX1    05NMMEC     0.0600     00EGRL1       1.0
05EGX2    05EGPR2     1.0000     05EGSB          .958
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FILE: LPDC      DATA     A    04/19/80   09:11:00   UNIVERSITY OF WATERLOO

     05EGX2     05NMMEC       0.3000       00EGBL2       1.0
     10WCX3     10WCSB       -1.0000       10WOCPL       1.0
     10WCX3     10WOSBO       0.1072       10NMMEC        .1647
     10WCX3     15WOCPL      -1.0000
     10WCX4     10WCSB       -1.0000       10WGCP6       1.0
     10WCX4     10WGSB        0.5670       10NMMEC        .1503
     10WCX4     15WGCP6      -1.0000
     10WCX6     10WCSB       -1.0000       10WISB         .87
     10WCX6     10WISLC      -0.8700       10WISUC       -.87
     10WCX6     10NMMEC       0.0800
     10WCD1     10WCCP1      -1.0000
     10WCD1     25WCCP1      -2.0000
     10WCD1     35WCCP1      -2.0000
     10WCD2     10WCCP2      -1.0000
     10WCD2     25WCCP2      -2.0000
     10WCD2     35WCCP2      -2.0000
     10WCE      10WCSB       -1.0000       10ECSB         .9994
     10WCE      10NMMEC       0.1030
     10WCEX     10WCSB       -1.0000       10NMMEC       -.132
     10ECX4     10ECSB       -1.0000       10EISB         .87
     10ECX4     10EISLC      -0.8700       10EISUC       -.87
     10ECX4     10NMMEC       0.0400
     10ECD1     10ECCP1      -1.0000
     10ECD1     25ECCP1      -2.0000
     10ECD1     35ECCP1      -2.0000
     10ECD2     10ECCP2      -1.0000
     10ECD2     25ECCP2      -2.0000
     10ECD2     35ECCP2      -2.0000
     10ECIM     10ECSB        0.9994       10NMMEC      +0.175
     10WOX6     10WOCP6       1.0000       10WOSBL       0.9272
     10WOX6     10NMMEC       2.5000
     10WOX6     15WOCP6      -1.0000
     10WOD1     10WOPR1      -1.0000
     10WOD1     15WOPR1      -1.0000
     10WOD1     25WOPR1      -0.9400
     10WOD1     35WOPR1      -0.2100
     10WOD2     10WOPR2      -1.0000
     10WOD2     15WOPR2      -1.0000
     10WOD2     25WOPR2      -0.9400
     10WOD2     35WOPR2      -0.2100
     10WOD3     10WOPR3      -1.0000
     10WOD3     15WOPR3      -1.0000
     10WOD3     25WOPR3      -0.9400
     10WOD3     35WOPR3      -0.2100
     10WOD4     10WOPR4      -1.0000
     10WOD4     15WOPR4      -1.0000
     10WOD4     25WOPR4      -0.9400
     10WOD4     35WOPR4      -0.2100
     10WOD5     10WOCP5      -1.0000
     10WOD5     25WOCP5      -2.0000
     10WOD5     35WOCP5      -2.0000
     10WOD6     10WOCP6      -1.0000
     10WOD6     25WOCP6      -2.0000
     10WOD6     35WOCP6      -2.0000
     10WOEX     10WOSBO      -1.0000       10NOMSS      -1.0
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FILE: RBI       DATA      A    04/17/80  22:34:00  UNIVERSITY OF WATERLOO

RHS
    FIRSTTRY  05WCCP1      2.1030      10WCCP1     -0.099
    FIRSTTRY  15WCCP1     -0.1750      25WCCP1      2.491
    FIRSTTRY  05ECCP1      0.1750      10ECCP1     -0.058
    FIRSTTRY  15ECCP1     -0.0430      25ECCP1      0.060
    FIRSTTRY  05WECP5      0.2190      10WECP5     -0.026
    FIRSTTRY  15WECP5     -0.0330      25WECP5      0.187
    FIRSTTRY  05EECP5      0.6570      10EECP5     -0.065
    FIRSTTRY  15EECP5     -0.0830      25EECP5      0.471
    FIRSTTRY  05WECP1      0.5410      10WECP1     -0.034
    FIRSTTRY  15WECP1     -0.0550      25WECP1      0.590
    FIRSTTRY  05EECP1      1.1930      10EECP1     -0.075
    FIRSTTRY  15EECP1     -0.1200      25EECP1      1.301
    FIRSTTRY  05WECP3      0.4320      10WECP3     -0.027
    FIRSTTRY  15WECP3     -0.0440      25WECP3      0.472
    FIRSTTRY  05EECP3      0.3050      10EECP3     -0.019
    FIRSTTRY  15EECP3     -0.0310      25EECP3      0.333
    FIRSTTRY  05WECP2      0.0130      10WECP2     -0.001
    FIRSTTRY  15WECP2     -0.0020      25WECP2      0.016
    FIRSTTRY  05EECP2      0.0730      10EECP2     -0.005
    FIRSTTRY  15EECP2     -0.0070      25EECP2      0.079
    FIRSTTRY  05WECP6      0.0040      25WECP6      0.004
    FIRSTTRY  05EECP4      0.0507      25EECP4      0.0959
    FIRSTTRY  05WOCP5      0.0880      25WOCP5      0.147
    FIRSTTRY  05WTCP2      0.2420      05ETCP2      0.517
    FIRSTTRY  05WDCP1      1.1300      10WDCP1      0.627
    FIRSTTRY  05EDCP1      1.0300      10EDCP1      0.605
    FIRSTTRY  05WDCP2      0.1020      10WDCP2      0.050
    FIRSTTRY  05EDCP2      0.3880      10EDCP2      0.171
    FIRSTTRY  05WDCP3      0.0700      10WDCP3      0.043
    FIRSTTRY  05EDCP3      0.2300      10EDCP3      0.137
    FIRSTTRY  05WOPR1      2.4170      10WOPR1      1.374
    FIRSTTRY  15WOPR1      0.7330      25WOPR1      0.3131
    FIRSTTRY  05EOPR1      0.0026      10EOPR1      0.0014
    FIRSTTRY  15EOPR1      0.0006      25EOPR1      0.0002
    FIRSTTRY  05WGPR1     11.6650      10WGPR1      9.557
    FIRSTTRY  15WGPR1      5.5330      25WGPR1      4.461
    FIRSTTRY  05EGPR1      0.0006      10EGPR1      0.0004
    FIRSTTRY  15EGPR1      0.0002      25EGPR1      0.0001
    FIRSTTRY  00WCRL1   1587.0000      00WCRL2    106.0
    FIRSTTRY  00ECRL1     22.0000      00ECRL2      1.4
    FIRSTTRY  00WORL1      6.0000      00WORL2      6.0
    FIRSTTRY  00WORL3      4.4000      00WORL4      3.3
    FIRSTTRY  00WORL5    200.0000      00EORL1      3.0
    FIRSTTRY  00EORL2      2.0000      00WGRL1     39.0
    FIRSTTRY  00WGRL2     59.0000      00WGRL3     44.0
    FIRSTTRY  00WGRL4     93.0000      00EGRL1     16.0
    FIRSTTRY  00EGRL2     29.0000
 BOUNDS
  LO B            05WDFC       0.6000
  LO B            10WDFC       0.7000
  LO B            15WDFC       1.0000
  LO B            25WDFC       2.6000
  LO B            35WDFC       3.5000
  LO B            45WDFC       4.6000
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FILE: RBI      DATA     A    04/17/80   22:34:00  UNIVERSITY OF WATERLOO

 LO B          55WDFC       12.2561
 LO B          05EDFC        1.3000
 LO B          10EDFC        1.5000
 LO B          15EDFC        2.0000
 LO B          25EDFC        5.2000
 LO B          35EDFC        6.9000
 LO B          45EDFC        9.0000
 LO B          55EDFC       23.6145
 LO B          05WIND        0.5000
 LO B          10WIND        0.6000
 LO B          15WIND        0.8000
 LO B          25WIND        2.2000
 LO B          35WIND        2.8000
 LO B          45WIND        3.8000
 LO B          55WIND       10.8171
 LO B          05EIND        1.3000
 LO B          10EIND        1.5000
 LO B          15EIND        2.0000
 LO B          25EIND        5.3000
 LO B          35EIND        6.9000
 LO B          45EIND        9.0000
 LO B          55EIND       23.6145
 LO B          05WRTR        0.0888
 LO B          10WRTR        0.1008
 LO B          15WRTR        0.1331
 LO B          25WRTR        0.3586
 LO B          35WRTR        0.4510
 LO B          45WRTR        0.5971
 LO B          55WRTR        1.6148
 LO B          05ERTR        0.1833
 LO B          10ERTR        0.2029
 LO B          15ERTR        0.2608
 LO B          25ERTR        0.6664
 LO B          35ERTR        0.8377
 LO B          45ERTR        1.1087
 LO B          55ERTR        2.9963
 LO B          05WOTR        0.0352
 LO B          10WOTR        0.0473
 LO B          15WOTR        0.0718
 LO B          25WOTR        0.2128
 LO B          35WOTR        0.2978
 LO B          45WOTR        0.3827
 LO B          55WOTR        0.9748
 LO B          05EOTR        0.0749
 LO B          10EOTR        0.0985
 LO B          15EOTR        0.1451
 LO B          25EOTR        0.4086
 LO B          35EOTR        0.5711
 LO B          45EOTR        0.7345
 LO B          55EOTR        1.8738
 UP B          05WCE         0.2150
 UP B          10WCE         0.5790
 UP B          15WCE         0.8790
 LO B          15WCE         0.5790
 LO B          25WCE         1.7580
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FILE: RBI      DATA      A    04/17/80  22:34:00  UNIVERSITY OF WATERLOO

 LO B          35WCE          1.7580
 UP B          05WCEX         1.7000
 UP B          10WCEX         2.2000
 UP B          15WCEX         2.8000
 UP B          25WCEX         9.2000
 UP B          35WCEX        14.8000
 UP B          45WCEX        24.2000
 UP B          55WCEX       107.0678
 UP B          05ECX1         0.5060
 UP B          10ECX1         1.0120
 UP B          15ECX1         2.0240
 FX B          05WOX6         0.0000
 FX B          05WOX5         0.1810
 FX B          10WOX5         0.3720
 FX B          15WOX5         0.7670
 FX B          25WOX5         2.7560
 UP B          05WOEX         0.5970
 UP B          10WOEX         0.1520
 UP B          15WOEX         0.0730
 UP B          25WOEX         0.0670
 FX B          35WOEX         0.0000
 FX B          45WOEX         0.0000
 FX B          55WOEX         0.0000
 UP B          05EOX1         0.0040
 UP B          10EOX1         0.0500
 UP B          15EOX1         0.2500
 FX B          05EOX2         0.0000
 FX B          10EOX2         0.0000
 UP B          15EOX2         0.0500
 UP B          25EOX2         0.5000
 FX B          05EOX3         0.0000
 FX B          05WLDC         0.0000
 FX B          10WLDC         0.0000
 FX B          05WGX5         0.0000
 UP B          10WGX5         0.0005
 UP B          15WGX5         0.0010
 UP B          25WGX5         0.0020
 UP B          35WGX5         0.0020
 UP B          45WGX5         0.0020
 UP B          55WGX5         0.0033
 FX B          05WGD6         0.0000
 FX B          10WGD6         0.0000
 UP B          05WGE          4.0920
 UP B          10WGE          4.8600
 UP B          15WGE          7.0080
 UP B          05WGEX         5.4000
 UP B          10WGEX         8.4000
 UP B          15WGEX         3.7000
 UP B          25WGEX         0.3000
 FX B          35WGEX         0.0000
 FX B          45WGEX         0.0000
 FX B          55WGEX         0.0000
 UP B          05EGX1         0.0010
 UP B          10EGX1         0.0010
 UP B          15EGX1         2.4000
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FILE: RBI       DATA      A    04/17/80  22:34:00  UNIVERSITY OF WATERLOO

 FX B           05EGX2        0.0000
 FX B           10EGX2        0.0000
 FX B           15EGX2        0.0000
 UP B           25EGX2        4.8000
 FX B           05EGX3        0.0000
 UP B           10EGX3        0.0010
 UP B           15EGX3        0.0020
 UP B           25EGX3        0.0040
 UP B           35EGX3        0.0040
 UP B           45EGX3        0.0040
 UP B           55EGX3        0.0065
 UP B           05WEX5        0.4500
 UP B           10WEX5        0.6500
 UP B           15WEX5        0.8600
 UP B           25WEX5        2.5400
 UP B           35WEX5        2.5400
 UP B           45WEX5        2.5400
 UP B           55WEX5        4.1337
 FX B           05WED4        0.0000
 FX B           10WED4        0.0000
 UP B           05WEEX        0.0161
 UP B           10WEEX        0.0169
 UP B           15WEEX        0.0178
 UP B           25WEEX        0.0393
 UP B           35WEEX        0.0434
 UP B           45WEEX        0.0480
 UP B           55WEEX        0.0926
 UP B           05EEX5        1.0100
 UP B           10EEX5        1.3100
 UP B           15EEX5        1.6100
 UP B           25EEX5        4.4200
 UP B           35EEX5        4.4200
 UP B           45EEX5        4.4200
 UP B           55EEX5        7.1934
 UP B           05EEEX        0.0333
 UP B           10EEEX        0.0350
 UP B           15EEEX        0.0368
 UP B           25EEEX        0.0814
 UP B           35EEEX        0.0898
 UP B           45EEEX        0.0992
 UP B           55EEEX        0.1909
 FX INITIAL     05WDFC        2.519136
 FX INITIAL     10WDFC        2.866363
 FX INITIAL     15WDFC        3.245430
 FX INITIAL     25WDFC        7.370743
 FX INITIAL     35WDFC       11.07340
 FX INITIAL     45WDFC       14.0
 FX INITIAL     55WDFC       18.89231
 FX INITIAL     05EDFC        7.835372
 FX INITIAL     10EDFC        8.480367
 FX INITIAL     15EDFC       10.56194
 FX INITIAL     25EDFC       24.49453
 FX INITIAL     35EDFC       28.91066
 FX INITIAL     45EDFC       35.77590
 FX INITIAL     55EDFC       68.15528
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FILE: RBI      DATA     A    04/17/80  22:34:00  UNIVERSITY OF WATERLOO

 FX INITIAL   05WIND        2.215426
 FX INITIAL   10WIND        2.724187
 FX INITIAL   15WIND        3.571787
 FX INITIAL   25WIND        9.451235
 FX INITIAL   35WIND       12.01701
 FX INITIAL   45WIND       15.49563
 FX INITIAL   55WIND       27.89744
 FX INITIAL   05EIND        6.286454
 FX INITIAL   10EIND        7.998949
 FX INITIAL   15EIND       10.82588
 FX INITIAL   25EIND       30.57776
 FX INITIAL   35EIND       38.36301
 FX INITIAL   45EIND       50.22871
 FX INITIAL   55EIND       90.42886
 FX INITIAL   05WRTR        0.4643166
 FX INITIAL   10WRTR        0.5542955
 FX INITIAL   15WRTR        0.6742355
 FX INITIAL   25WRTR        1.791336
 FX INITIAL   35WRTR        2.318520
 FX INITIAL   45WRTR        2.871982
 FX INITIAL   55WRTR        4.481712
 FX INITIAL   05ERTR        0.9786513
 FX INITIAL   10ERTR        1.171560
 FX INITIAL   15ERTR        1.430596
 FX INITIAL   25ERTR        3.742112
 FX INITIAL   35ERTR        4.852761
 FX INITIAL   45ERTR        6.017024
 FX INITIAL   55ERTR        9.389605
 FX INITIAL   05WOTR        0.1422828
 FX INITIAL   10WOTR        0.1590812
 FX INITIAL   15WOTR        0.1894716
 FX INITIAL   25WOTR        0.5077520
 FX INITIAL   35WOTR        0.6468614
 FX INITIAL   45WOTR        0.8290694
 FX INITIAL   55WOTR        1.373961
 FX INITIAL   05EOTR        0.3343579
 FX INITIAL   10EOTR        0.3797880
 FX INITIAL   15EOTR        0.4604514
 FX INITIAL   25EOTR        1.216528
 FX INITIAL   35EOTR        1.548524
 FX INITIAL   45EOTR        1.983952
 FX INITIAL   55EOTR        3.287870
 ENDATA
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The following is the raw output from the MINOS solution of the base case. The interested reader can look for any information on the base case not reported earlier (e.g. many dual activities and reduced costs, slack activities, etc.).

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FILE: SOLN     DATA     A   05/04/80  13:45:00  UNIVERSITY OF WATERLOO  PAGE 001

1
 PROBLEM NAME    ENERSEC                 OBJECTIVE VALUE     8.3887582555D 01

 STATUS          OPTIMAL SOLN            PHASE         3     ITERATION      91

 OBJECTIVE       OBJECTIV  (MIN)
 RHS             FIRSTTRY
 RANGES
 BOUNDS          B

 SECTION 1 - ROWS

  NUMBER   ...ROW..   AT   ...ACTIVITY...   SLACK ACTIVITY   ..LOWER LIMIT.   ..UPPER LIMIT.   .DUAL ACTIVITY    ..I

     961   OBJECTIV   BS    2.019484D 01    -2.019484D 01    -9.999999E 29     9.999999E 29    -1.000000D 00      1
     962   05WCCP1    EQ    2.103000D 00     0.0              2.103000E 00     2.103000E 00     0.0               2
     963   05WCCP2    EQ    0.0              0.0              0.0              0.0              2.047760D-02      3
     964   05ECCP1    EQ    1.750000D-01     0.0              1.750000E-01     1.750000E-01     4.288769D-03      4
     965   05ECCP2    EQ    0.0              0.0              0.0              0.0             -6.411040D-03      5
     966   05WOPR1    EQ    2.417000D 00     0.0              2.417000E 00     2.417000E 00     3.261669D-02      6
     967   05WOPR2    EQ    0.0              0.0              0.0              0.0             -1.069141D-03      7
     968   05WOPR3    EQ    0.0              0.0              0.0              0.0              1.463599D-02      8
     969   05WOPR4    EQ    0.0              0.0              0.0              0.0              5.493523D-01      9
     970   05WOCP5    EQ    8.800000D-02     0.0              8.800000E-02     8.800000E-02     6.468713D-03     10
     971   05WOCP6    EQ    0.0              0.0              0.0              0.0              2.263300D-02     11
     972   05WOCPL    EQ    0.0              0.0              0.0              0.0              1.397948D-01     12
     973   05EOPR1    EQ    2.600000D-03     0.0              2.600000E-03     2.600000E-03     5.744617D-04     13
     974   05EOPR2    EQ    0.0              0.0              0.0              0.0             -3.336202D-05     14
     975   05EOCP3    EQ    0.0              0.0              0.0              0.0              0.0              15
     976   05WGPR1    EQ    1.166500D 01     0.0              1.166500E 01     1.166500E 01    -1.530361D-02     16
     977   05WGPR2    EQ    0.0              0.0              0.0              0.0             -7.087722D-04     17
     978   05WGPR3    EQ    0.0              0.0              0.0              0.0             -9.396715D-02     18
     979   05WGPR4    EQ    0.0              0.0              0.0              0.0             -7.892588D-02     19
     980   05WGCP5    EQ    0.0              0.0              0.0              0.0              6.260280D-19     20
     981   05WGCP6    EQ    0.0              0.0              0.0              0.0              1.108572D-01     21
     982   05EGPR1    EQ    5.999999D-04     0.0              5.999999E-04     5.999999E-04    -2.052871D-03     22
     983   05EGPR2    EQ    0.0              0.0              0.0              0.0             -6.839958D-09     23
     984   05EGCP3    EQ    0.0              0.0              0.0              0.0              2.257958D-03     24
     985   05WECP1    EQ    5.409999D-01     0.0              5.409999E-01     5.409999E-01     1.750115D-02     25
     986   05WECP2    EQ    1.300000D-02     0.0              1.300000E-02     1.300000E-02     8.010416D-01     26
     987   05WECP3    EQ    4.320000D-01     0.0              4.320000E-01     4.320000E-01     1.034482D-01     27
     988   05WECP4    EQ    0.0              0.0              0.0              0.0              2.238535D-01     28
     989   05WECP5    EQ    2.190000D-01     0.0              2.190000E-01     2.190000E-01    -5.868456D-02     29
     990   05WECP6    EQ    3.999997D-03     0.0              3.999997E-03     3.999997E-03     1.835022D 00     30
     991   05EECP1    EQ    1.193000D 00     0.0              1.193000E 00     1.193000E 00     1.939209D-01     31
     992   05EECP2    EQ    7.299995D-02     0.0              7.299995E-02     7.299995E-02     1.068544D 00     32
     993   05EECP3    EQ    3.049999D-01     0.0              3.049999E-01     3.049999E-01     2.540259D-01     33
     994   05EECP4    EQ    5.070000D-02     0.0              5.070000E-02     5.070000E-02     1.924536D-01     34
     995   05EECP5    EQ    6.569999D-01     0.0              6.569999E-01     6.569999E-01    -5.459852D-02     35
     996   05EECP6    EQ    0.0              0.0              0.0              0.0              1.924536D-01     36
     997   05WTCP1    EQ    0.0              0.0              0.0              0.0              4.481883D-01     37
     998   05WTCP2    EQ    2.420000D-01     0.0              2.420000E-01     2.420000E-01    -2.386549D-08     38
     999   05ETCP1    EQ    0.0              0.0              0.0              0.0             -2.379909D-01     39
    1000   05ETCP2    EQ    5.170000D-01     0.0              5.170000E-01     5.170000E-01    -2.003305D-07     40
    1001   05WDCP1    EQ    1.129999D 00     0.0              1.129999E 00     1.129999E 00     4.718221D-05     41
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1002  05WDCP2   EQ    1.020000D-01   0.0            1.020000E-01   1.020000E-01   2.504637D-01   42
1003  05WDCP3   EQ    6.999999D-02   0.0            6.999999E-02   6.999999E-02   7.223879D-01   43
1004  05WDCP4   EQ    0.0            0.0            0.0            0.0            1.445806D 00   44
1005  05WDCP5   EQ    0.0            0.0            0.0            0.0            8.980664D-02   45
1006  05WDCP6   EQ    0.0            0.0            0.0            0.0            1.368402D-01   46
1007  05EDCP1   EQ    1.030000D 00   0.0            1.030000E 00   1.030000E 00  -1.032046D-03   47
1008  05EDCP2   EQ    3.880000D-01   0.0            3.880000E-01   3.880000E-01  -4.155573D-02   48
1009  05EDCP3   EQ    2.300000D-01   0.0            2.300000E-01   2.300000E-01   3.651602D-03   49
1010  05EDCP4   EQ    0.0            0.0            0.0            0.0            3.566456D-01   50
1011  05EDCP5   EQ    0.0            0.0            0.0            0.0            8.133217D-03   51
1012  05EDCP6   EQ    0.0            0.0            0.0            0.0            2.827514D-02   52
1013  05WCSB    EQ    0.0            0.0            0.0            0.0            1.242337D-02   53
1014  05ECSB    EQ    0.0            0.0            0.0            0.0            9.630036D-02   54
1015  05WOSBO   EQ    0.0            0.0            0.0            0.0            3.199354D-01   55
1016  05WOSBL   EQ    0.0            0.0            0.0            0.0            3.450555D-01   56
1017  05EOSBO   EQ    0.0            0.0            0.0            0.0            6.705935D-01   57
1018  05EOSBL   EQ    0.0            0.0            0.0            0.0            5.376841D-01   58
1019  05NOMSS   BS   -2.968650D 00   2.968650D 00  -9.999999E 29   0.0            0.0            59
1020  05NOMEM   UL    0.0            0.0           -9.999999E 29   0.0           -3.196121D-01   60
1021  05WGSB    EQ    0.0            0.0            0.0            0.0            6.466562D-02   61
1022  05EGSB    EQ    0.0            0.0            0.0            0.0            1.392658D-01   62
1023  05WESBE   EQ    0.0            0.0            0.0            0.0            5.664908D-01   63
1024  05WEMH    UL    0.0            0.0           -9.999999E 29   0.0           -2.923785D-01   64
1025  05EESBE   EQ    0.0            0.0            0.0            0.0            5.596840D-01   65
1026  05EEMH    UL    0.0            0.0           -9.999999E 29   0.0           -2.951257D-01   66
1027  05WTSBL   EQ    0.0            0.0            0.0            0.0           -8.231638D-01   67
1028  05WTSBA   EQ    0.0            0.0            0.0            0.0            1.136410D 00   68
1029  05WTMEA   BS    0.0            0.0           -9.999999E 29   0.0            0.0            69
1030  05ETSBL   EQ    0.0            0.0            0.0            0.0           -9.661188D-01   70
1031  05ETSBA   EQ    0.0            0.0            0.0            0.0            1.338487D 00   71
1032  05ETMEA   BS    0.0            0.0           -9.999999E 29   0.0            0.0            72
1033  05WISB    EQ    0.0            0.0            0.0            0.0            8.739986D-02   73
1034  05WISLG   BS   -1.266851D-01   1.266851D-01  -9.999999E 29   0.0            0.0            74
1035  05WISLL   UL    0.0            0.0           -9.999999E 29   0.0           -2.162451D-03   75
1036  05WISLC   BS   -8.445653D-02   8.445653D-02  -9.999999E 29   0.0            0.0            76
1037  05WISLE   UL    0.0            0.0           -9.999999E 29   0.0           -1.113857D-01   77
1038  05WISUG   BS    8.445634D-02  -8.445634D-02   0.0            9.999999E 29   0.0            78
1039  05WISUL   BS    2.111414D-01  -2.111414D-01   0.0            9.999999E 29   0.0            79
1040  05WISUC   LL    0.0            0.0            0.0            9.999999E 29   1.602404D-02   80
1041  05WISUE   BS    1.266848D-01  -1.266848D-01   0.0            9.999999E 29   0.0            81
1042  05EISB    EQ    0.0            0.0            0.0            0.0            1.392381D-01   82
1043  05EISLG   UL    0.0            0.0           -9.999999E 29   0.0           -2.862167D-02   83
1044  05EISLL   BS   -6.535906D-01   6.535906D-01  -9.999999E 29   0.0            0.0            84
1045  05EISLC   BS   -7.791410D-07   7.791410D-07  -9.999999E 29   0.0            0.0            85
1046  05EISLE   UL    0.0            0.0           -9.999999E 29   0.0           -6.597788D-03   86
1047  05EISUG   BS    6.535906D-01  -6.535906D-01   0.0            9.999999E 29   0.0            87
1048  05EISUL   LL    0.0            0.0            0.0            9.999999E 29   7.544805D-03   88
1049  05EISUC   BS    2.614353D-01  -2.614353D-01   0.0            9.999999E 29   0.0            89
1050  05EISUE   BS    3.921545D-01  -3.921545D-01   0.0            9.999999E 29   0.0            90
1051  05WDSBE   EQ    0.0            0.0            0.0            0.0            1.528916D 00   91
1052  05WDSBH   EQ    0.0            0.0            0.0            0.0            3.015292D-01   92
1053  05WDSEO   EQ    0.0            0.0            0.0            0.0            4.480998D-01   93
1054  05WDSUP   BS    0.0            0.0           -9.999999E 29   0.0            0.0            94
1055  05WDSUS   BS    0.0            0.0           -9.999999E 29   0.0            0.0            95
1056  05WDSUC   BS    0.0            0.0           -9.999999E 29   0.0            0.0            96
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1057  05WDMCG   BS  -4.695382D-02   4.695382D-02   -9.999999E 29   0.0             0.0             97
1058  05EDSBE   EQ   0.0            0.0             0.0            0.0             1.180604D 00    98
1059  05EDSBH   EQ   0.0            0.0             0.0            0.0             4.100943D-01    99
1060  05EDSEO   EQ   0.0            0.0             0.0            0.0             3.460153D-01   100
1061  05EDSUP   BS   0.0            0.0            -9.999999E 29   0.0             0.0           101
1062  05EDSUS   BS   0.0            0.0            -9.999999E 29   0.0             0.0           102
1063  05EDSUC   UL   0.0            0.0            -9.999999E 29   0.0            -1.453585D-02  103
1064  05EDMCG   BS   0.0            0.0            -9.999999E 29   0.0             0.0           104
1065  05NMMEC   UL   0.0            0.0            -9.999999E 29   0.0            -6.209199D-01  105
1066  10WCCP1   EQ  -9.899998D-02   0.0            -9.899998E-02  -9.899998E-02    0.0           106
1067  10WCCP2   EQ   0.0            0.0             0.0            0.0             8.059199D-03  107
1068  10ECCP1   EQ  -5.800000D-02   0.0            -5.800000E-02  -5.800000E-02    3.654824D-03  108
1069  10ECCP2   EQ   0.0            0.0             0.0            0.0            -8.081604D-03  109
1070  10WOPR1   EQ   1.374000D 00   0.0             1.374000E 00   1.374000E 00   -5.771355D-02  110
1071  10WOPR2   EQ   0.0            0.0             0.0            0.0             1.963508D-03  111
1072  10WOPR3   EQ   0.0            0.0             0.0            0.0            -3.563766D-02  112
1073  10WOPR4   EQ   0.0            0.0             0.0            0.0             2.236521D-01  113
1074  10WOCP5   EQ   0.0            0.0             0.0            0.0            -1.713513D-09  114
1075  10WOCP6   EQ   0.0            0.0             0.0            0.0             4.526600D-02  115
1076  10WOCPL   EQ   0.0            0.0             0.0            0.0             5.940305D-02  116
1077  10EOPR1   EQ   1.400000D-03   0.0             1.400000E-03   1.400000E-03   -6.223746D-04  117
1078  10EOPR2   EQ   0.0            0.0             0.0            0.0            -2.348898D-05  118
1079  10EOCP3   EQ   0.0            0.0             0.0            0.0             0.0           119
1080  10WGPR1   EQ   9.556999D 00   0.0             9.556999E 00   9.556999E 00   -2.460494D-03  120
1081  10WGPR2   EQ   0.0            0.0             0.0            0.0             3.658504D-04  121
1082  10WGPR3   EQ   0.0            0.0             0.0            0.0             5.917904D-02  122
1083  10WGPR4   EQ   0.0            0.0             0.0            0.0             7.845652D-02  123
1084  10WGCP5   EQ   0.0            0.0             0.0            0.0             5.917904D-02  124
1085  10WGCP6   EQ   0.0            0.0             0.0            0.0             4.177501D-02  125
1086  10EGPR1   EQ   3.999998D-04   0.0             3.999998E-04   3.999998E-04    9.856160D-04  126
1087  10EGPR2   EQ   0.0            0.0             0.0            0.0             2.092207D-09  127
1088  10EGCP3   EQ   0.0            0.0             0.0            0.0             4.515915D-03  128
1089  10WECP1   EQ  -3.400000D-02   0.0            -3.400000E-02  -3.400000E-02    8.609341D-03  129
1090  10WECP2   EQ  -9.999999D-04   0.0            -9.999999E-04  -9.999999E-04    5.050881D-01  130
1091  10WECP3   EQ  -2.700000D-02   0.0            -2.700000E-02  -2.700000E-02    5.350014D-02  131
1092  10WECP4   EQ   0.0            0.0             0.0            0.0             1.118688D-01  132
1093  10WECP5   EQ  -2.600000D-02   0.0            -2.600000E-02  -2.600000E-02   -2.791422D-02  133
1094  10WECP6   EQ   0.0            0.0             0.0            0.0             9.219944D-01  134
1095  10EECP1   EQ  -7.499999D-02   0.0            -7.499999E-02  -7.499999E-02    1.014083D-01  135
1096  10EECP2   EQ  -4.999999D-03   0.0            -4.999999E-03  -4.999999E-03    5.813048D-01  136
1097  10EECP3   EQ  -1.900000D-02   0.0            -1.900000E-02  -1.900000E-02    1.296853D-01  137
1098  10EECP4   EQ   0.0            0.0             0.0            0.0             8.325280D-02  138
1099  10EECP5   EQ  -6.500000D-02   0.0            -6.500000E-02  -6.500000E-02   -2.361857D-02  139
1100  10EECP6   EQ   0.0            0.0             0.0            0.0             8.962552D-01  140
1101  10WTCP1   EQ   0.0            0.0             0.0            0.0            -4.481883D-01  141
1102  10WTCP2   EQ   0.0            0.0             0.0            0.0             1.521326D-07  142
1103  10ETCP1   EQ   0.0            0.0             0.0            0.0             2.379909D-01  143
1104  10ETCP2   EQ   0.0            0.0             0.0            0.0            -5.316181D-08  144
1105  10WDCP1   EQ   6.270000D-01   0.0             6.270000E-01   6.270000E-01    4.718874D-05  145
1106  10WDCP2   EQ   5.000000D-02   0.0             5.000000E-02   5.000000E-02    2.723216D-01  146
1107  10WDCP3   EQ   4.300000D-02   0.0             4.300000E-02   4.300000E-02    4.378905D-01  147
1108  10WDCP4   EQ   0.0            0.0             0.0            0.0             2.077696D-01  148
1109  10WDCP5   EQ   0.0            0.0             0.0            0.0            -1.971310D-02  149
1110  10WDCP6   EQ   0.0            0.0             0.0            0.0             1.619689D-02  150
1111  10EDCP1   EQ   6.050000D-01   0.0             6.050000E-01   6.050000E-01   -1.032046D-03  151
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1112  10EDCP2   EQ    1.709999D-01    0.0             1.709999E-01    1.709999E-01   -1.355000D-02   152
1113  10EDCP3   EQ    1.370000D-01    0.0             1.370000E-01    1.370000E-01   -4.426708D-02   153
1114  10EDCP4   EQ    0.0             0.0             0.0             0.0            -8.630451D-03   154
1115  10EDCP5   EQ    0.0             0.0             0.0             0.0            -7.357276D-03   155
1116  10EDCP6   EQ    0.0             0.0             0.0             0.0            -1.846219D-03   156
1117  10WCSB    EQ    0.0             0.0             0.0             0.0             7.714085D-03   157
1118  10ECSB    EQ    0.0             0.0             0.0             0.0             6.751173D-02   158
1119  10WOSBO   EQ    0.0             0.0             0.0             0.0             3.161177D-01   159
1120  10WOSBL   EQ    0.0             0.0             0.0             0.0             3.409380D-01   160
1121  10EOSBO   EQ    0.0             0.0             0.0             0.0             5.706138D-01   161
1122  10EOSBL   EQ    0.0             0.0             0.0             0.0             4.205306D-01   162
1123  10NOMSS   BS   -2.900331D 00    2.900331D 00   -9.999999E 29    0.0             0.0            163
1124  10NOMEM   UL    0.0             0.0            -9.999999E 29    0.0            -2.352186D-01   164
1125  10WGSB    EQ    0.0             0.0             0.0             0.0             4.212914D-02   165
1126  10EGSB    EQ    0.0             0.0             0.0             0.0             1.008300D-01   166
1127  10WESBE   EQ    0.0             0.0             0.0             0.0             3.498801D-01   167
1128  10WEMH    UL    0.0             0.0            -9.999999E 29    0.0            -1.708121D-01   168
1129  10EESBE   EQ    0.0             0.0             0.0             0.0             3.671958D-01   169
1130  10EEMH    UL    0.0             0.0            -9.999999E 29    0.0            -1.549449D-01   170
1131  10WTSBL   EQ    0.0             0.0             0.0             0.0            -6.378114D-01   171
1132  10WTSBA   EQ    0.0             0.0             0.0             0.0             6.508903D-01   172
1133  10WTMEA   UL    0.0             0.0            -9.999999E 29    0.0            -2.432262D-02   173
1134  10ETSBL   EQ    0.0             0.0             0.0             0.0            -6.865601D-01   174
1135  10ETSBA   EQ    0.0             0.0             0.0             0.0             7.289798D-01   175
1136  10ETMEA   BS    0.0             0.0            -9.999999E 29    0.0             0.0            176
1137  10WISB    EQ    0.0             0.0             0.0             0.0             5.659431D-02   177
1138  10WISLG   BS   -3.171957D-01    3.171957D-01   -9.999999E 29    0.0             0.0            178
1139  10WISLL   UL    0.0             0.0            -9.999999E 29    0.0            -2.969141D-02   179
1140  10WISLC   BS   -2.114633D-01    2.114633D-01   -9.999999E 29    0.0             0.0            180
1141  10WISLE   UL    0.0             0.0            -9.999999E 29    0.0            -6.628936D-02   181
1142  10WISUG   BS    2.114629D-01   -2.114629D-01    0.0             9.999999E 29    0.0            182
1143  10WISUL   BS    5.286586D-01   -5.286586D-01    0.0             9.999999E 29    0.0            183
1144  10WISUC   LL    0.0             0.0             0.0             9.999999E 29    1.227468D-02   184
1145  10WISUE   BS    3.171952D-01   -3.171952D-01    0.0             9.999999E 29    0.0            185
1146  10EISB    EQ    0.0             0.0             0.0             0.0             9.631911D-02   186
1147  10EISLG   UL    0.0             0.0            -9.999999E 29    0.0            -2.479914D-02   187
1148  10EISLL   UL    0.0             0.0            -9.999999E 29    0.0            -6.437837D-03   188
1149  10EISLC   BS   -6.297491D-01    6.297491D-01   -9.999999E 29    0.0             0.0            189
1150  10EISLE   BS   -9.446241D-01    9.446241D-01   -9.999999E 29    0.0             0.0            190
1151  10EISUG   BS    1.574372D 00   -1.574372D 00    0.0             9.999999E 29    0.0            191
1152  10EISUL   BS    1.574372D 00   -1.574372D 00    0.0             9.999999E 29    0.0            192
1153  10EISUC   LL    0.0             0.0             0.0             9.999999E 29    9.929753D-04   193
1154  10EISUE   BS   -9.383988D-07    9.383988D-07    0.0             9.999999E 29    0.0            194
1155  10WDSBE   EQ    0.0             0.0             0.0             0.0             9.474822D-01   195
1156  10WDSBH   EQ    0.0             0.0             0.0             0.0             1.898062D-01   196
1157  10WDSEO   EQ    0.0             0.0             0.0             0.0             2.776912D-01   197
1158  10WDSUP   BS   -6.104429D-01    6.104429D-01   -9.999999E 29    0.0             0.0            198
1159  10WDSUS   BS   -6.428682D-02    6.428682D-02   -9.999999E 29    0.0             0.0            199
1160  10WDSUC   BS   -2.746287D-01    2.746287D-01   -9.999999E 29    0.0             0.0            200
1161  10WDMCG   BS   -4.427259D-02    4.427259D-02   -9.999999E 29    0.0             0.0            201
1162  10EDSBE   EQ    0.0             0.0             0.0             0.0             7.527457D-01   202
1163  10EDSBH   EQ    0.0             0.0             0.0             0.0             2.740445D-01   203
1164  10EDSEO   EQ    0.0             0.0             0.0             0.0             2.206172D-01   204
1165  10EDSUP   BS   -1.790738D 00    1.790738D 00   -9.999999E 29    0.0             0.0            205
1166  10EDSUS   BS   -1.885858D-01    1.885858D-01   -9.999999E 29    0.0             0.0            206
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 1167  10EDSUC   BS  -1.074443D 00   1.074443D 00   -9.999999E 29   0.0             0.0            207
 1168  10EDMCG   UL   0.0            0.0            -9.999999E 29   0.0            -1.788666D-02   208
 1169  10NMMEC   UL   0.0            0.0            -9.999999E 29   0.0            -3.855500D-01   209
 1170  15WCCP1   EQ  -1.750000D-01   0.0            -1.750000E-01  -1.750000E-01   0.0            210
 1171  15WCCP2   EQ   0.0            0.0             0.0            0.0             3.482000D-04   211
 1172  15ECCP1   EQ  -4.300000D-02   0.0            -4.300000E-02  -4.300000E-02   1.827412D-03   212
 1173  15ECCP2   EQ   0.0            0.0             0.0            0.0            -2.298360D-03   213
 1174  15WOPR1   EQ   7.330000D-01   0.0             7.330000E-01   7.330000E-01  -6.594805D-03   214
 1175  15WOPR2   EQ   0.0            0.0             0.0            0.0            -5.381751D-03   215
 1176  15WOPR3   EQ   0.0            0.0             0.0            0.0             3.561557D-02   216
 1177  15WOPR4   EQ   0.0            0.0             0.0            0.0             3.456913D-03   217
 1178  15WOCP5   EQ   0.0            0.0             0.0            0.0            -8.567563D-10   218
 1179  15WOCP6   EQ   0.0            0.0             0.0            0.0             2.263300D-02   219
 1180  15WOCPL   EQ   0.0            0.0             0.0            0.0             2.207670D-02   220
 1181  15EOPR1   EQ   5.999999D-04   0.0             5.999999E-04   5.999999E-04   2.256035D-03   221
 1182  15EOPR2   EQ   0.0            0.0             0.0            0.0            -4.340538D-05   222
 1183  15EOCP3   EQ   0.0            0.0             0.0            0.0             0.0            223
 1184  15WGPR1   EQ   5.533000D 00   0.0             5.533000E 00   5.533000E 00   5.888804D-03   224
 1185  15WGPR2   EQ   0.0            0.0             0.0            0.0             1.407151D-03   225
 1186  15WGPR3   EQ   0.0            0.0             0.0            0.0             3.537313D-02   226
 1187  15WGPR4   EQ   0.0            0.0             0.0            0.0             2.507334D-03   227
 1188  15WGCP5   BS   0.0            0.0             0.0            0.0             0.0            228
 1189  15WGCP6   EQ   0.0            0.0             0.0            0.0             0.0            229
 1190  15EGPR1   EQ   2.000000D-04   0.0             2.000000E-04   2.000000E-04   4.743399D-03   230
 1191  15EGPR2   EQ   0.0            0.0             0.0            0.0             2.655523D-08   231
 1192  15EGCP3   EQ   0.0            0.0             0.0            0.0             1.412221D-02   232
 1193  15WECP1   EQ  -5.500000D-02   0.0            -5.500000E-02  -5.500000E-02   3.229755D-03   233
 1194  15WECP2   EQ  -2.000000D-03   0.0            -2.000000E-03  -2.000000E-03   1.996495D-01   234
 1195  15WECP3   EQ  -4.400000D-02   0.0            -4.400000E-02  -4.400000E-02   2.141616D-02   235
 1196  15WECP4   EQ   0.0            0.0             0.0            0.0             4.240050D-02   236
 1197  15WECP5   EQ  -3.300000D-02   0.0            -3.300000E-02  -3.300000E-02  -1.049043D-02   237
 1198  15WECP6   EQ   0.0            0.0             0.0            0.0             3.533823D-01   238
 1199  15EECP1   EQ  -1.199999D-01   0.0            -1.199999E-01  -1.199999E-01   3.834377D-02   239
 1200  15EECP2   EQ  -6.999999D-03   0.0            -6.999999E-03  -6.999999E-03   2.086036D-01   240
 1201  15EECP3   EQ  -3.100000D-02   0.0            -3.100000E-02  -3.100000E-02   4.078939D-02   241
 1202  15EECP4   EQ   0.0            0.0             0.0            0.0             3.526589D-02   242
 1203  15EECP5   EQ  -8.299994D-02   0.0            -8.299994E-02  -8.299994E-02  -1.000483D-02   243
 1204  15EECP6   EQ   0.0            0.0             0.0            0.0             3.473470D-01   244
 1205  15WTCP1   EQ   0.0            0.0             0.0            0.0             3.901058D-01   245
 1206  15WTCP2   EQ   0.0            0.0             0.0            0.0             2.500910D-08   246
 1207  15ETCP1   EQ   0.0            0.0             0.0            0.0            -2.301137D-01   247
 1208  15ETCP2   EQ   0.0            0.0             0.0            0.0             5.316181D-08   248
 1209  15WDCP1   EQ   0.0            0.0             0.0            0.0            -9.437095D-05   249
 1210  15WDCP2   EQ   0.0            0.0             0.0            0.0            -1.046868D-01   250
 1211  15WDCP3   EQ   0.0            0.0             0.0            0.0             1.964923D-02   251
 1212  15WDCP4   EQ   0.0            0.0             0.0            0.0            -4.155392D-01   252
 1213  15WDCP5   EQ   0.0            0.0             0.0            0.0            -1.893193D-02   253
 1214  15WDCP6   EQ   0.0            0.0             0.0            0.0            -3.239378D-02   254
 1215  15EDCP1   EQ   0.0            0.0             0.0            0.0             2.064092D-03   255
 1216  15EDCP2   EQ   0.0            0.0             0.0            0.0             5.510573D-02   256
 1217  15EDCP3   EQ   0.0            0.0             0.0            0.0             4.426708D-02   257
 1218  15EDCP4   EQ   0.0            0.0             0.0            0.0             1.726090D-02   258
 1219  15EDCP5   EQ   0.0            0.0             0.0            0.0             1.145315D-02   259
 1220  15EDCP6   EQ   0.0            0.0             0.0            0.0             2.198632D-02   260
 1221  15WCSB    EQ   0.0            0.0             0.0            0.0             4.789715D-03   261
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1222  15ECSB   EQ   0.0             0.0             0.0             0.0             4.062512D-02   262
1223  15WOSBO  EQ   0.0             0.0             0.0             0.0             2.065349D-01   263
1224  15WOSBL  EQ   0.0             0.0             0.0             0.0             2.227512D-01   264
1225  15EOSBO  EQ   0.0             0.0             0.0             0.0             2.185044D-01   265
1226  15EOSBL  EQ   0.0             0.0             0.0             0.0             2.359149D-01   266
1227  15NOMSS  BS  -3.521641D 00    3.521641D 00   -9.999999E 29    0.0             0.0            267
1228  15NOMEM  BS  -2.500000D-01    2.500000D-01   -9.999999E 29    0.0             0.0            268
1229  15WGSB   EQ   0.0             0.0             0.0             0.0             2.771100D-02   269
1230  15EGSB   EQ   0.0             0.0             0.0             0.0             4.772994D-02   270
1231  15WESBE  EQ   0.0             0.0             0.0             0.0             2.168771D-01   271
1232  15WEMH   UL   0.0             0.0            -9.999999E 29    0.0            -1.002704D-01   272
1233  15EESBE  EQ   0.0             0.0             0.0             0.0             2.208179D-01   273
1234  15EEMH   UL   0.0             0.0            -9.999999E 29    0.0            -9.334424D-02   274
1235  15WTSBL  EQ   0.0             0.0             0.0             0.0            -4.070815D-01   275
1236  15WTSBA  EQ   0.0             0.0             0.0             0.0             3.464913D-01   276
1237  15WTMEA  BS  -3.269761D-02    3.269761D-02   -9.999999E 29    0.0             0.0            277
1238  15ETSBL  EQ   0.0             0.0             0.0             0.0            -4.010940D-01   278
1239  15ETSBA  EQ   0.0             0.0             0.0             0.0             3.689776D-01   279
1240  15ETMEA  SBS -6.755552D-02    6.755552D-02   -9.999999E 29    0.0             5.208174D-08   280
1241  15WISB   EQ   0.0             0.0             0.0             0.0             3.696653D-02   281
1242  15WISLG  BS  -6.267598D-01    6.267598D-01   -9.999999E 29    0.0             0.0            282
1243  15WISLL  UL   0.0             0.0            -9.999999E 29    0.0            -1.928695D-02   283
1244  15WISLC  BS  -4.178397D-01    4.178397D-01   -9.999999E 29    0.0             0.0            284
1245  15WISLE  UL   0.0             0.0            -9.999999E 29    0.0            -3.922553D-02   285
1246  15WISUG  BS   4.178395D-01   -4.178395D-01    0.0             9.999999E 29    0.0            286
1247  15WISUL  BS   1.044599D 00   -1.044599D 00    0.0             9.999999E 29    0.0            287
1248  15WISUC  LL   0.0             0.0             0.0             9.999999E 29    9.448239D-03   288
1249  15WISUE  BS   6.267596D-01   -6.267596D-01    0.0             9.999999E 29    0.0            289
1250  15EISB   EQ   0.0             0.0             0.0             0.0             5.770191D-02   290
1251  15EISLG  SBS -2.148546D-01    2.148546D-01   -9.999999E 29    0.0             4.515998D-08   291
1252  15EISLL  BS  -8.944203D-01    8.944203D-01   -9.999999E 29    0.0             0.0            292
1253  15EISLC  SBS -2.777718D-01    2.777718D-01   -9.999999E 29    0.0            -6.917460D-08   293
1254  15EISLE  BS  -1.817751D 00    1.817751D 00   -9.999999E 29    0.0             0.0            294
1255  15EISUG  BS   2.989941D 00   -2.989941D 00    0.0             9.999999E 29    0.0            295
1256  15EISUL  BS   2.310375D 00   -2.310375D 00    0.0             9.999999E 29    0.0            296
1257  15EISUC  BS   1.004146D 00   -1.004146D 00    0.0             9.999999E 29    0.0            297
1258  15EISUE  SBS  1.051265D-01   -1.051265D-01    0.0             9.999999E 29   -4.598140D-09   298
1259  15WDSBE  EQ   0.0             0.0             0.0             0.0             5.879313D-01   299
1260  15WDSBH  EQ   0.0             0.0             0.0             0.0             1.200575D-01   300
1261  15WDSEO  EQ   0.0             0.0             0.0             0.0             1.723128D-01   301
1262  15WDSUP  BS  -1.381365D 00    1.381365D 00   -9.999999E 29    0.0             0.0            302
1263  15WDSUS  BS  -1.451214D-01    1.451214D-01   -9.999999E 29    0.0             0.0            303
1264  15WDSUC  BS  -6.216300D-01    6.216300D-01   -9.999999E 29    0.0             0.0            304
1265  15WDMCG  BS  -5.918467D-02    5.918467D-02   -9.999999E 29    0.0             0.0            305
1266  15EDSBE  EQ   0.0             0.0             0.0             0.0             4.602079D-01   306
1267  15EDSBH  EQ   0.0             0.0             0.0             0.0             1.470230D-01   307
1268  15EDSEO  EQ   0.0             0.0             0.0             0.0             1.348792D-01   308
1269  15EDSUP  BS  -4.493063D 00    4.493063D 00   -9.999999E 29    0.0             0.0            309
1270  15EDSUS  BS  -4.720258D-01    4.720258D-01   -9.999999E 29    0.0             0.0            310
1271  15EDSUC  BS  -2.695215D 00    2.695215D 00   -9.999999E 29    0.0             0.0            311
1272  15EDMCG  BS   0.0             0.0            -9.999999E 29    0.0             0.0            312
1273  15NMMEC  UL   0.0             0.0            -9.999999E 29    0.0            -2.393900D-01   313
1274  25WCCP1  EQ   2.490999D 00    0.0             2.490999E 00    2.490999E 00    0.0            314
1275  25WCCP2  EQ   0.0             0.0             0.0             0.0            -1.251400D-03   315
1276  25ECCP1  EQ   6.000000D-02    0.0             6.000000E-02    6.000000E-02   -2.461358D-03   316
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1277  25ECCP2   EQ   0.0            0.0            0.0            0.0             2.370238D-03   317
1278  25WOPR1   EQ   3.131000D-01   0.0            3.131000E-01   3.131000E-01    5.176391D-02   318
1279  25WOPR2   EQ   0.0            0.0            0.0            0.0             4.072975D-03   319
1280  25WOPR3   EQ   0.0            0.0            0.0            0.0            -2.056295D-05   320
1281  25WOPR4   EQ   0.0            0.0            0.0            0.0            -7.633531D-03   321
1282  25WOCP5   EQ   1.470000D-01   0.0            1.470000E-01   1.470000E-01   -6.468713D-03   322
1283  25WOCP6   EQ   0.0            0.0            0.0            0.0             0.0            323
1284  25WOCPL   EQ   0.0            0.0            0.0            0.0             1.099286D-02   324
1285  25EOPR1   EQ   2.000000D-04   0.0            2.000000E-04   2.000000E-04   -2.291335D-03   325
1286  25EOPR2   EQ   0.0            0.0            0.0            0.0             1.472503D-04   326
1287  25EOCP3   EQ   0.0            0.0            0.0            0.0             0.0            327
1288  25WGPR1   EQ   4.460999D 00   0.0            4.460999E 00   4.460999E 00    9.432895D-03   328
1289  25WGPR2   EQ   0.0            0.0            0.0            0.0            -1.161755D-03   329
1290  25WGPR3   EQ   0.0            0.0            0.0            0.0            -8.634918D-04   330
1291  25WGPR4   EQ   0.0            0.0            0.0            0.0            -2.913630D-03   331
1292  25WGCP5   EQ   0.0            0.0            0.0            0.0            -1.923471D-19   332
1293  25WGCP6   EQ   0.0            0.0            0.0            0.0             0.0            333
1294  25EGPR1   EQ   9.999999D-05   0.0            9.999999E-05   9.999999E-05   -4.444399D-03   334
1295  25EGPR2   EQ   0.0            0.0            0.0            0.0            -3.218816D-08   335
1296  25EGCP3   EQ   0.0            0.0            0.0            0.0             0.0            336
1297  25WECP1   EQ   5.900000D-01   0.0            5.900000E-01   5.900000E-01    1.382504D-03   337
1298  25WECP2   EQ   1.600000D-02   0.0            1.600000E-02   1.600000E-02    9.501050D-02   338
1299  25WECP3   EQ   4.719999D-01   0.0            4.719999E-01   4.719999E-01    1.635329D-02   339
1300  25WECP4   EQ   0.0            0.0            0.0            0.0             8.658630D-03   340
1301  25WECP5   EQ   1.870000D-01   0.0            1.870000E-01   1.870000E-01   -6.394757D-03   341
1302  25WECP6   EQ   3.999997D-03   0.0            3.999997E-03   3.999997E-03    1.716428D-01   342
1303  25EECP1   EQ   1.301000D 00   0.0            1.301000E 00   1.301000E 00    1.337175D-02   343
1304  25EECP2   EQ   7.900000D-02   0.0            7.900000E-02   7.900000E-02    1.010094D-01   344
1305  25EECP3   EQ   3.329999D-01   0.0            3.329999E-01   3.329999E-01    2.251526D-02   345
1306  25EECP4   EQ   9.590000D-02   0.0            9.590000E-02   9.590000E-02    1.872463D-02   346
1307  25EECP5   EQ   4.710000D-01   0.0            4.710000E-01   4.710000E-01   -5.312122D-03   347
1308  25EECP6   EQ   0.0            0.0            0.0            0.0             1.872463D-02   348
1309  25WTCP1   EQ   0.0            0.0            0.0            0.0             2.536006D-01   349
1310  25WTCP2   EQ   0.0            0.0            0.0            0.0            -1.000050D-07   350
1311  25ETCP1   EQ   0.0            0.0            0.0            0.0             2.301138D-01   351
1312  25ETCP2   EQ   0.0            0.0            0.0            0.0            -6.854675D-08   352
1313  25WDCP1   EQ   0.0            0.0            0.0            0.0             4.718645D-05   353
1314  25WDCP2   EQ   0.0            0.0            0.0            0.0             5.234340D-02   354
1315  25WDCP3   EQ   0.0            0.0            0.0            0.0            -9.824616D-03   355
1316  25WDCP4   EQ   0.0            0.0            0.0            0.0             2.077696D-01   356
1317  25WDCP5   EQ   0.0            0.0            0.0            0.0             1.104317D-02   357
1318  25WDCP6   EQ   0.0            0.0            0.0            0.0             1.619689D-02   358
1319  25EDCP1   EQ   0.0            0.0            0.0            0.0            -1.032046D-03   359
1320  25EDCP2   EQ   0.0            0.0            0.0            0.0             2.480540D-03   360
1321  25EDCP3   EQ   0.0            0.0            0.0            0.0             0.0            361
1322  25EDCP4   EQ   0.0            0.0            0.0            0.0            -8.630451D-03   362
1323  25EDCP5   EQ   0.0            0.0            0.0            0.0            -2.868524D-03   363
1324  25EDCP6   EQ   0.0            0.0            0.0            0.0             4.875548D-03   364
1325  25WCSB    EQ   0.0            0.0            0.0            0.0             2.343537D-03   365
1326  25ECSB    EQ   0.0            0.0            0.0            0.0             1.441659D-02   366
1327  25WOSBO   EQ   0.0            0.0            0.0            0.0             9.927222D-02   367
1328  25WOSBL   EQ   0.0            0.0            0.0            0.0             1.070667D-01   368
1329  25EOSBO   EQ   0.0            0.0            0.0            0.0             1.051287D-01   369
1330  25EOSBL   EQ   0.0            0.0            0.0            0.0             1.135054D-01   370
1331  25NOMSS   BS  -7.039652D 00   7.039652D 00  -9.999999E 29   0.0             0.0            371
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1332  25NOMEM   BS   -1.771767D 00    1.771767D 00   -9.999999E 29    0.0             0.0            372
1333  25WGSB    EQ    0.0             0.0             0.0             0.0             1.954536D-02   373
1334  25EGSB    EQ    0.0             0.0             0.0             0.0             2.578193D-02   374
1335  25WESBE   EQ    0.0             0.0             0.0             0.0             1.075196D-01   375
1336  25WEMH    UL    0.0             0.0            -9.999999E 29    0.0            -2.890000D-02   376
1337  25EESBE   EQ    0.0             0.0             0.0             0.0             1.064532D-01   377
1338  25EEMH    UL    0.0             0.0            -9.999999E 29    0.0            -2.403676D-02   378
1339  25WTSBL   EQ    0.0             0.0             0.0             0.0            -1.972568D-01   379
1340  25WTSBA   EQ    0.0             0.0             0.0             0.0             1.438535D-01   380
1341  25WTMEA   SBS  -5.627381D-01    5.627381D-01   -9.999999E 29    0.0             1.155593D-07   381
1342  25ETSBL   EQ    0.0             0.0             0.0             0.0            -1.943251D-01   382
1343  25ETSBA   EQ    0.0             0.0             0.0             0.0             1.532424D-01   383
1344  25ETMEA   SBS  -1.178233D 00    1.178233D 00   -9.999999E 29    0.0             7.920818D-08   384
1345  25WISB    EQ    0.0             0.0             0.0             0.0             2.513045D-02   385
1346  25WISLG   BS   -2.822719D 00    2.822719D 00   -9.999999E 29    0.0             0.0            386
1347  25WISLL   UL    0.0             0.0            -9.999999E 29    0.0            -1.928124D-03   387
1348  25WISLC   BS   -1.881812D 00    1.881812D 00   -9.999999E 29    0.0             0.0            388
1349  25WISLE   UL    0.0             0.0            -9.999999E 29    0.0            -1.256093D-02   389
1350  25WISUG   BS    1.881811D 00   -1.881811D 00    0.0             9.999999E 29    0.0            390
1351  25WISUL   BS    4.704530D 00   -4.704530D 00    0.0             9.999999E 29    0.0            391
1352  25WISUC   LL    0.0             0.0             0.0             9.999999E 29    1.166615D-02   392
1353  25WISUE   BS    2.822718D 00   -2.822718D 00    0.0             9.999999E 29    0.0            393
1354  25EISB    EQ    0.0             0.0             0.0             0.0             2.776677D-02   394
1355  25EISLG   UL    0.0             0.0            -9.999999E 29    0.0            -3.322813D-03   395
1356  25EISLL   BS   -8.357323D 00    8.357323D 00   -9.999999E 29    0.0             0.0            396
1357  25EISLC   BS   -6.051851D 00    6.051851D 00   -9.999999E 29    0.0             0.0            397
1358  25EISLE   SBS  -7.204573D-01    7.204573D-01   -9.999999E 29    0.0            -6.855731D-09   398
1359  25EISUG   BS    1.512963D 01   -1.512963D 01    0.0             9.999999E 29    0.0            399
1360  25EISUL   BS    6.772304D 00   -6.772304D 00    0.0             9.999999E 29    0.0            400
1361  25EISUC   LL    0.0             0.0             0.0             9.999999E 29    5.810690D-03   401
1362  25EISUE   BS    8.357319D 00   -8.357319D 00    0.0             9.999999E 29    0.0            402
1363  25WDSBE   EQ    0.0             0.0             0.0             0.0             2.890710D-01   403
1364  25WDSBH   EQ    0.0             0.0             0.0             0.0             6.649687D-02   404
1365  25WDSEO   EQ    0.0             0.0             0.0             0.0             8.472186D-02   405
1366  25WDSUP   BS   -6.197691D 00    6.197691D 00   -9.999999E 29    0.0             0.0            406
1367  25WDSUS   BS   -6.504674D-01    6.504674D-01   -9.999999E 29    0.0             0.0            407
1368  25WDSUC   BS   -2.788639D 00    2.788639D 00   -9.999999E 29    0.0             0.0            408
1369  25WDMCG   BS   -3.085638D-01    3.085638D-01   -9.999999E 29    0.0             0.0            409
1370  25EDSBE   EQ    0.0             0.0             0.0             0.0             2.235832D-01   410
1371  25EDSBH   EQ    0.0             0.0             0.0             0.0             7.781822D-02   411
1372  25EDSEO   EQ    0.0             0.0             0.0             0.0             6.552849D-02   412
1373  25EDSUP   BS   -2.043285D 01    2.043285D 01   -9.999999E 29    0.0             0.0            413
1374  25EDSUS   BS   -2.144492D 00    2.144492D 00   -9.999999E 29    0.0             0.0            414
1375  25EDSUC   BS   -1.226065D 01    1.226065D 01   -9.999999E 29    0.0             0.0            415
1376  25EDMCG   UL    0.0             0.0            -9.999999E 29    0.0            -6.188460D-03   416
1377  25NMMEC   UL    0.0             0.0            -9.999999E 29    0.0            -1.171300D-01   417
1378  35WCCP1   EQ    0.0             0.0             0.0             0.0             0.0            418
1379  35WCCP2   EQ    0.0             0.0             0.0             0.0             9.032000D-04   419
1380  35ECCP1   EQ    0.0             0.0             0.0             0.0             6.339457D-04   420
1381  35ECCP2   EQ    0.0             0.0             0.0             0.0             1.670564D-03   421
1382  35WOPR1   EQ    0.0             0.0             0.0             0.0             7.452486D-02   422
1383  35WOPR2   EQ    0.0             0.0             0.0             0.0            -1.954065D-03   423
1384  35WOPR3   EQ    0.0             0.0             0.0             0.0             1.972543D-04   424
1385  35WOPR4   EQ    0.0             0.0             0.0             0.0             1.550071D-02   425
1386  35WOCP5   EQ    0.0             0.0             0.0             0.0             6.468714D-03   426
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 1387  35WOCP6   EQ   0.0             0.0             0.0              0.0        -2.263300D-02   427
 1388  35WOCPL   EQ   0.0             0.0             0.0              0.0         3.225478D-03   428
 1389  35EOPR1   EQ   0.0             0.0             0.0              0.0         2.477119D-03   429
 1390  35EOPR2   EQ   0.0             0.0             0.0              0.0        -3.405759D-04   430
 1391  35EOCP3   EQ   0.0             0.0             0.0              0.0         0.0            431
 1392  35WGPR1   EQ   0.0             0.0             0.0              0.0         1.432563D-02   432
 1393  35WGPR2   EQ   0.0             0.0             0.0              0.0         1.324787D-04   433
 1394  35WGPR3   EQ   0.0             0.0             0.0              0.0         1.079365D-03   434
 1395  35WGPR4   EQ   0.0             0.0             0.0              0.0         3.337363D-03   435
 1396  35WGCP5   EQ   0.0             0.0             0.0              0.0        -2.413338D-19   436
 1397  35WGCP6   EQ   0.0             0.0             0.0              0.0         0.0            437
 1398  35EGPR1   EQ   0.0             0.0             0.0              0.0         2.388529D-03   438
 1399  35EGPR2   EQ   0.0             0.0             0.0              0.0         4.023520D-08   439
 1400  35EGCP3   EQ   0.0             0.0             0.0              0.0        -2.257958D-03   440
 1401  35WECP1   EQ   0.0             0.0             0.0              0.0         7.268469D-04   441
 1402  35WECP2   EQ   0.0             0.0             0.0              0.0        -1.997024D-02   442
 1403  35WECP3   EQ   0.0             0.0             0.0              0.0        -4.338842D-03   443
 1404  35WECP4   EQ   0.0             0.0             0.0              0.0         9.248006D-03   444
 1405  35WECP5   EQ   0.0             0.0             0.0              0.0        -7.434190D-04   445
 1406  35WECP6   EQ   0.0             0.0             0.0              0.0        -2.419700D-02   446
 1407  35EECP1   EQ   0.0             0.0             0.0              0.0        -8.539706D-04   447
 1408  35EECP2   EQ   0.0             0.0             0.0              0.0        -1.999706D-02   448
 1409  35EECP3   EQ   0.0             0.0             0.0              0.0         1.224751D-02   449
 1410  35EECP4   EQ   0.0             0.0             0.0              0.0         1.673248D-09   450
 1411  35EECP5   EQ   0.0             0.0             0.0              0.0        -4.746955D-10   451
 1412  35EECP6   EQ   0.0             0.0             0.0              0.0         1.673248D-09   452
 1413  35WTCP1   EQ   0.0             0.0             0.0              0.0         1.035878D-01   453
 1414  35WTCP2   EQ   0.0             0.0             0.0              0.0        -1.441348D-08   454
 1415  35ETCP1   EQ   0.0             0.0             0.0              0.0         1.053539D-01   455
 1416  35ETCP2   EQ   0.0             0.0             0.0              0.0        -8.994560D-09   456
 1417  35WDCP1   EQ   0.0             0.0             0.0              0.0        -9.437291D-05   457
 1418  35WDCP2   EQ   0.0             0.0             0.0              0.0         4.003706D-04   458
 1419  35WDCP3   EQ   0.0             0.0             0.0              0.0         1.964923D-02   459
 1420  35WDCP4   EQ   0.0             0.0             0.0              0.0         4.103712D-02   460
 1421  35WDCP5   EQ   0.0             0.0             0.0              0.0        -1.186619D-03   461
 1422  35WDCP6   EQ   0.0             0.0             0.0              0.0         8.004227D-04   462
 1423  35EDCP1   EQ   0.0             0.0             0.0              0.0         2.064092D-03   463
 1424  35EDCP2   EQ   0.0             0.0             0.0              0.0         2.379660D-03   464
 1425  35EDCP3   EQ   0.0             0.0             0.0              0.0         0.0            465
 1426  35EDCP4   EQ   0.0             0.0             0.0              0.0         1.726090D-02   466
 1427  35EDCP5   EQ   0.0             0.0             0.0              0.0        -2.396169D-03   467
 1428  35EDCP6   EQ   0.0             0.0             0.0              0.0         0.0            468
 1429  35WCSB    EQ   0.0             0.0             0.0              0.0         9.035614D-04   469
 1430  35ECSB    EQ   0.0             0.0             0.0              0.0         5.558370D-03   470
 1431  35WOSBO   EQ   0.0             0.0             0.0              0.0         4.772328D-02   471
 1432  35WOSBL   EQ   0.0             0.0             0.0              0.0         5.147032D-02   472
 1433  35EOSBO   EQ   0.0             0.0             0.0              0.0         4.998128D-02   473
 1434  35EOSBL   EQ   0.0             0.0             0.0              0.0         5.396381D-02   474
 1435  35NOMSS   BS  -6.527657D 00    6.527657D 00   -9.999999E 29     0.0         0.0            475
 1436  35NOMEM   BS  -2.057495D 00    2.057495D 00   -9.999999E 29     0.0         0.0            476
 1437  35WGSB    EQ   0.0             0.0             0.0              0.0         1.156095D-02   477
 1438  35EGSB    EQ   0.0             0.0             0.0              0.0         1.414192D-02   478
 1439  35WESBE   EQ   0.0             0.0             0.0              0.0         3.953759D-02   479
 1440  35WEMH    UL   0.0             0.0            -9.999999E 29     0.0        -3.009554D-03   480
 1441  35EESBE   EQ   0.0             0.0             0.0              0.0         4.885331D-02   481
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1442  35EEMH   BS   -5.470978D 00   5.470978D 00  -9.999999E 29   0.0              0.0            482
1443  35WTSBL  EQ    0.0            0.0            0.0            0.0             -8.624352D-02   483
1444  35WTSBA  EQ    0.0            0.0            0.0            0.0              5.222721D-02   484
1445  35WTMEA  SBS  -1.371011D 00   1.371011D 00  -9.999999E 29   0.0              9.079932D-09   485
1446  35ETSBL  EQ    0.0            0.0            0.0            0.0             -8.512421D-02   486
1447  35ETSBA  EQ    0.0            0.0            0.0            0.0              5.538868D-02   487
1448  35ETMEA  SBS  -2.869631D 00   2.869631D 00  -9.999999E 29   0.0              5.666224D-09   488
1449  35WISB   EQ    0.0            0.0            0.0            0.0              1.289993D-02   489
1450  35WISLG  UL    0.0            0.0           -9.999999E 29   0.0             -1.524695D-03   490
1451  35WISLL  BS   -3.605654D 00   3.605654D 00  -9.999999E 29   0.0              0.0            491
1452  35WISLC  BS   -2.403768D 00   2.403768D 00  -9.999999E 29   0.0              0.0            492
1453  35WISLE  UL    0.0            0.0           -9.999999E 29   0.0             -1.070286D-03   493
1454  35WISUG  BS    6.009420D 00  -6.009420D 00   0.0            9.999999E 29     0.0            494
1455  35WISUL  BS    2.403767D 00  -2.403767D 00   0.0            9.999999E 29     0.0            495
1456  35WISUC  LL    0.0            0.0            0.0            9.999999E 29     7.708715D-03   496
1457  35WISUE  BS    3.605652D 00  -3.605652D 00   0.0            9.999999E 29     0.0            497
1458  35EISB   EQ    0.0            0.0            0.0            0.0              1.317565D-02   498
1459  35EISLG  UL    0.0            0.0           -9.999999E 29   0.0             -3.754118D-03   499
1460  35EISLL  BS   -4.573751D-06   4.573751D-06  -9.999999E 29   0.0              0.0            500
1461  35EISLC  BS   -7.673481D 00   7.673481D 00  -9.999999E 29   0.0              0.0            501
1462  35EISLE  BS   -1.151022D 01   1.151022D 01  -9.999999E 29   0.0              0.0            502
1463  35EISUG  BS    1.918370D 01  -1.918370D 01   0.0            9.999999E 29     0.0            503
1464  35EISUL  BS    1.918370D 01  -1.918370D 01   0.0            9.999999E 29     0.0            504
1465  35EISUC  LL    0.0            0.0            0.0            9.999999E 29     4.710393D-03   505
1466  35EISUE  LL    0.0            0.0            0.0            9.999999E 29     1.811222D-04   506
1467  35WDSBE  EQ    0.0            0.0            0.0            0.0              1.095356D-01   507
1468  35WDSBH  EQ    0.0            0.0            0.0            0.0              3.108254D-02   508
1469  35WDSEO  EQ    0.0            0.0            0.0            0.0              3.210304D-02   509
1470  35WDSUP  BS   -6.787515D 00   6.787515D 00  -9.999999E 29   0.0              0.0            510
1471  35WDSUS  BS   -1.425527D 00   1.425527D 00  -9.999999E 29   0.0              0.0            511
1472  35WDSUC  BS   -2.557526D 00   2.557526D 00  -9.999999E 29   0.0              0.0            512
1473  35WDMCG  UL    0.0            0.0           -9.999999E 29   0.0             -2.268858D-03   513
1474  35EDSBE  EQ    0.0            0.0            0.0            0.0              9.401331D-02   514
1475  35EDSBH  EQ    0.0            0.0            0.0            0.0              3.229209D-02   515
1476  35EDSEO  EQ    0.0            0.0            0.0            0.0              2.755373D-02   516
1477  35EDSUP  BS   -2.403488D 01   2.403488D 01  -9.999999E 29   0.0              0.0            517
1478  35EDSUS  UL    0.0            0.0           -9.999999E 29   0.0             -4.091277D-04   518
1479  35EDSUC  BS   -1.442204D 01   1.442204D 01  -9.999999E 29   0.0              0.0            519
1480  35EDMCG  UL    0.0            0.0           -9.999999E 29   0.0             -3.675966D-03   520
1481  35NMMEC  UL    0.0            0.0           -9.999999E 29   0.0             -4.516000D-02   521
1482  45WCCP1  EQ    0.0            0.0            0.0            0.0              0.0            522
1483  45WCCP2  EQ    0.0            0.0            0.0            0.0              3.482000D-04   523
1484  45ECCP1  EQ    0.0            0.0            0.0            0.0              1.827412D-03   524
1485  45ECCP2  EQ    0.0            0.0            0.0            0.0              0.0            525
1486  45WOPR1  EQ    0.0            0.0            0.0            0.0              9.025614D-02   526
1487  45WOPR2  EQ    0.0            0.0            0.0            0.0              2.677216D-03   527
1488  45WOPR3  EQ    0.0            0.0            0.0            0.0             -7.214660D-04   528
1489  45WOPR4  EQ    0.0            0.0            0.0            0.0              3.481996D-03   529
1490  45WOCP5  EQ    0.0            0.0            0.0            0.0             -8.567563D-10   530
1491  45WOCP6  EQ    0.0            0.0            0.0            0.0              2.263300D-02   531
1492  45WOCPL  EQ    0.0            0.0            0.0            0.0              9.761443D-04   532
1493  45EOPR1  EQ    0.0            0.0            0.0            0.0              1.127090D-02   533
1494  45EOPR2  EQ    0.0            0.0            0.0            0.0              1.282037D-04   534
1495  45EOCP3  EQ    0.0            0.0            0.0            0.0              0.0            535
1496  45WGPR1  EQ    0.0            0.0            0.0            0.0              1.935126D-02   536
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1497  45WGPR2   EQ   0.0             0.0             0.0             0.0         3.770614D-03  537
1498  45WGPR3   EQ   0.0             0.0             0.0             0.0         0.0           538
1499  45WGPR4   EQ   0.0             0.0             0.0             0.0         8.704991D-04  539
1500  45WGCP5   EQ   0.0             0.0             0.0             0.0         8.673617D-19  540
1501  45WGCP6   EQ   0.0             0.0             0.0             0.0         0.0           541
1502  45EGPR1   EQ   0.0             0.0             0.0             0.0         9.048487D-03  542
1503  45EGPR2   EQ   0.0             0.0             0.0             0.0         0.0           543
1504  45EGCP3   EQ   0.0             0.0             0.0             0.0         2.257958D-03  544
1505  45WECP1   EQ   0.0             0.0             0.0             0.0         3.124682D-04  545
1506  45WECP2   EQ   0.0             0.0             0.0             0.0         2.130739D-02  546
1507  45WECP3   EQ   0.0             0.0             0.0             0.0         4.538074D-03  547
1508  45WECP4   EQ   0.0             0.0             0.0             0.0         3.855064D-03  548
1509  45WECP5   EQ   0.0             0.0             0.0             0.0        -2.507622D-09  549
1510  45WECP6   EQ   0.0             0.0             0.0             0.0         2.646320D-02  550
1511  45EECP1   EQ   0.0             0.0             0.0             0.0         1.677739D-03  551
1512  45EECP2   EQ   0.0             0.0             0.0             0.0         1.999706D-02  552
1513  45EECP3   EQ   0.0             0.0             0.0             0.0         4.721652D-03  553
1514  45EECP4   EQ   0.0             0.0             0.0             0.0         7.071695D-10  554
1515  45EECP5   EQ   0.0             0.0             0.0             0.0        -2.006219D-10  555
1516  45EECP6   EQ   0.0             0.0             0.0             0.0         7.071695D-10  556
1517  45WTCP1   EQ   0.0             0.0             0.0             0.0         3.718831D-02  557
1518  45WTCP2   EQ   0.0             0.0             0.0             0.0         1.086074D-08  558
1519  45ETCP1   EQ   0.0             0.0             0.0             0.0         0.0           559
1520  45ETCP2   EQ   0.0             0.0             0.0             0.0         0.0           560
1521  45WDCP1   EQ   0.0             0.0             0.0             0.0         1.887458D-04  561
1522  45WDCP2   EQ   0.0             0.0             0.0             0.0        -8.007412D-04  562
1523  45WDCP3   EQ   0.0             0.0             0.0             0.0         6.151607D-03  563
1524  45WDCP4   EQ   0.0             0.0             0.0             0.0        -2.234958D-03  564
1525  45WDCP5   EQ   0.0             0.0             0.0             0.0        -7.811684D-04  565
1526  45WDCP6   EQ   0.0             0.0             0.0             0.0         0.0           566
1527  45EDCP1   EQ   0.0             0.0             0.0             0.0         0.0           567
1528  45EDCP2   EQ   0.0             0.0             0.0             0.0         3.609917D-03  568
1529  45EDCP3   EQ   0.0             0.0             0.0             0.0         0.0           569
1530  45EDCP4   EQ   0.0             0.0             0.0             0.0         6.654391D-03  570
1531  45EDCP5   EQ   0.0             0.0             0.0             0.0        -9.237666D-04  571
1532  45EDCP6   EQ   0.0             0.0             0.0             0.0         0.0           572
1533  45WCSB    EQ   0.0             0.0             0.0             0.0         3.483393D-04  573
1534  45ECSB    EQ   0.0             0.0             0.0             0.0         2.142855D-03  574
1535  45WOSBO   EQ   0.0             0.0             0.0             0.0         2.089200D-02  575
1536  45WOSBL   EQ   0.0             0.0             0.0             0.0         2.253235D-02  576
1537  45EOSBO   EQ   0.0             0.0             0.0             0.0         2.176250D-02  577
1538  45EOSBL   EQ   0.0             0.0             0.0             0.0         2.349654D-02  578
1539  45NOMSS   BS  -7.067690D 00    7.067690D 00   -9.999999E 29    0.0         0.0           579
1540  45NOMEM   BS  -7.393491D-01    7.393491D-01   -9.999999E 29    0.0         0.0           580
1541  45WGSB    EQ   0.0             0.0             0.0             0.0         4.928102D-03  581
1542  45EGSB    EQ   0.0             0.0             0.0             0.0         5.451982D-03  582
1543  45WESBE   EQ   0.0             0.0             0.0             0.0         1.492341D-02  583
1544  45WEMH    SBS -2.500197D-02    2.500197D-02   -9.999999E 29    0.0        -1.264252D-08  584
1545  45EESBE   EQ   0.0             0.0             0.0             0.0         1.883384D-02  585
1546  45EEMH    SBS -1.848452D 00    1.848452D 00   -9.999999E 29    0.0         3.325929D-09  586
1547  45WTSBL   EQ   0.0             0.0             0.0             0.0        -3.593805D-02  587
1548  45WTSBA   EQ   0.0             0.0             0.0             0.0         2.115113D-02  588
1549  45WTMEA   SBS -1.915365D 00    1.915365D 00   -9.999999E 29    0.0        -6.066435D-09  589
1550  45ETSBL   EQ   0.0             0.0             0.0             0.0        -3.550944D-02  590
1551  45ETSBA   EQ   0.0             0.0             0.0             0.0         2.237103D-02  591
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1552  45ETMEA  BS   -4.012902D 00   4.012902D 00  -9.999999E 29   0.0             0.0             592
1553  45WISB   EQ    0.0            0.0            0.0            0.0             5.624396D-03    593
1554  45WISLG  UL    0.0            0.0           -9.999999E 29   0.0            -4.908475D-04    594
1555  45WISLL  BS   -1.847495D-06   1.847495D-06  -9.999999E 29   0.0             0.0             595
1556  45WISLC  BS   -3.099583D 00   3.099583D 00  -9.999999E 29   0.0             0.0             596
1557  45WISLE  BS   -4.649374D 00   4.649374D 00  -9.999999E 29   0.0             0.0             597
1558  45WISUG  BS    7.748957D 00  -7.748957D 00   0.0            9.999999E 29    0.0             598
1559  45WISUL  BS    7.748955D 00  -7.748955D 00   0.0            9.999999E 29    0.0             599
1560  45WISUC  LL    0.0            0.0            0.0            9.999999E 29    3.623087D-03    600
1561  45WISUE  LL    0.0            0.0            0.0            9.999999E 29    3.321300D-04    601
1562  45EISB   EQ    0.0            0.0            0.0            0.0             5.009625D-03    602
1563  45EISLG  UL    0.0            0.0           -9.999999E 29   0.0            -1.517126D-03    603
1564  45EISLL  UL    0.0            0.0           -9.999999E 29   0.0            -7.217668D-04    604
1565  45EISLC  SBS  -1.004691D 01   1.004691D 01  -9.999999E 29   0.0             2.131128D-09    605
1566  45EISLE  BS   -1.507037D 01   1.507037D 01  -9.999999E 29   0.0             0.0             606
1567  45EISUG  BS    2.511727D 01  -2.511727D 01   0.0            9.999999E 29    0.0             607
1568  45EISUL  BS    2.511727D 01  -2.511727D 01   0.0            9.999999E 29    0.0             608
1569  45EISUC  LL    0.0            0.0            0.0            9.999999E 29    1.746111D-03    609
1570  45EISUE  BS   -5.988424D-06   5.988424D-06   0.0            9.999999E 29    0.0             610
1571  45WDSBE  EQ    0.0            0.0            0.0            0.0             4.190890D-02    611
1572  45WDSBH  EQ    0.0            0.0            0.0            0.0             1.230659D-02    612
1573  45WDSEO  EQ    0.0            0.0            0.0            0.0             1.228280D-02    613
1574  45WDSUP  BS   -8.239928D 00   8.239928D 00  -9.999999E 29   0.0             0.0             614
1575  45WDSUS  UL    0.0            0.0           -9.999999E 29   0.0            -1.512795D-05    615
1576  45WDSUC  BS   -1.328753D 00   1.328753D 00  -9.999999E 29   0.0             0.0             616
1577  45WDMCG  UL    0.0            0.0           -9.999999E 29   0.0            -1.198302D-03    617
1578  45EDSBE  EQ    0.0            0.0            0.0            0.0             3.624384D-02    618
1579  45EDSBH  EQ    0.0            0.0            0.0            0.0             1.244918D-02    619
1580  45EDSEO  EQ    0.0            0.0            0.0            0.0             1.062246D-02    620
1581  45EDSUP  BS   -2.974882D 01   2.974882D 01  -9.999999E 29   0.0             0.0             621
1582  45EDSUS  UL    0.0            0.0           -9.999999E 29   0.0            -1.577261D-04    622
1583  45EDSUC  BS   -1.785067D 01   1.785067D 01  -9.999999E 29   0.0             0.0             623
1584  45EDMCG  UL    0.0            0.0           -9.999999E 29   0.0            -1.417046D-03    624
1585  45NMMEC  UL    0.0            0.0           -9.999999E 29   0.0            -1.741000D-02    625
1586  55WCCP1  EQ    0.0            0.0            0.0            0.0             0.0             626
1587  55WCCP2  EQ    0.0            0.0            0.0            0.0             0.0             627
1588  55ECCP1  EQ    0.0            0.0            0.0            0.0             0.0             628
1589  55ECCP2  EQ    0.0            0.0            0.0            0.0             0.0             629
1590  55WOPR1  EQ    0.0            0.0            0.0            0.0             0.0             630
1591  55WOPR2  EQ    0.0            0.0            0.0            0.0             6.957216D-03    631
1592  55WOPR3  EQ    0.0            0.0            0.0            0.0             1.418533D-03    632
1593  55WOPR4  EQ    0.0            0.0            0.0            0.0             1.341998D-03    633
1594  55WOCP5  EQ    0.0            0.0            0.0            0.0             0.0             634
1595  55WOCP6  EQ    0.0            0.0            0.0            0.0             0.0             635
1596  55WOCPL  EQ    0.0            0.0            0.0            0.0             0.0             636
1597  55EOPR1  EQ    0.0            0.0            0.0            0.0             1.715590D-02    637
1598  55EOPR2  EQ    0.0            0.0            0.0            0.0             2.803203D-03    638
1599  55EOCP3  EQ    0.0            0.0            0.0            0.0             0.0             639
1600  55WGPR1  EQ    0.0            0.0            0.0            0.0             0.0             640
1601  55WGPR2  EQ    0.0            0.0            0.0            0.0             5.589615D-03    641
1602  55WGPR3  EQ    0.0            0.0            0.0            0.0             0.0             642
1603  55WGPR4  EQ    0.0            0.0            0.0            0.0             3.354995D-04    643
1604  55WGCP5  EQ    0.0            0.0            0.0            0.0            -6.260280D-19    644
1605  55WGCP6  EQ    0.0            0.0            0.0            0.0             0.0             645
1606  55EGPR1  EQ    0.0            0.0            0.0            0.0             0.0             646
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1607  55EGPR2   EQ   0.0              0.0              0.0              0.0          0.0             647
1608  55EGCP3   EQ   0.0              0.0              0.0              0.0          0.0             648
1609  55WECP1   EQ   0.0              0.0              0.0              0.0          1.204286D-04    649
1610  55WECP2   EQ   0.0              0.0              0.0              0.0          7.985532D-10    650
1611  55WECP3   EQ   0.0              0.0              0.0              0.0          1.189831D-10    651
1612  55WECP4   EQ   0.0              0.0              0.0              0.0          1.353389D-09    652
1613  55WECP5   EQ   0.0              0.0              0.0              0.0         -4.439402D-10    653
1614  55WECP6   EQ   0.0              0.0              0.0              0.0          1.353389D-09    654
1615  55EECP1   EQ   0.0              0.0              0.0              0.0          6.466179D-04    655
1616  55EECP2   EQ   0.0              0.0              0.0              0.0         -1.404416D-09    656
1617  55EECP3   EQ   0.0              0.0              0.0              0.0         -2.093178D-10    657
1618  55EECP4   EQ   0.0              0.0              0.0              0.0         -2.380418D-09    658
1619  55EECP5   EQ   0.0              0.0              0.0              0.0          6.753173D-10    659
1620  55EECP6   EQ   0.0              0.0              0.0              0.0         -2.380418D-09    660
1621  55WTCP1   EQ   0.0              0.0              0.0              0.0          0.0             661
1622  55WTCP2   EQ   0.0              0.0              0.0              0.0          0.0             662
1623  55ETCP1   EQ   0.0              0.0              0.0              0.0          0.0             663
1624  55ETCP2   EQ   0.0              0.0              0.0              0.0          0.0             664
1625  55WDCP1   EQ   0.0              0.0              0.0              0.0          0.0             665
1626  55WDCP2   EQ   0.0              0.0              0.0              0.0          1.601482D-03    666
1627  55WDCP3   EQ   0.0              0.0              0.0              0.0          0.0             667
1628  55WDCP4   EQ   0.0              0.0              0.0              0.0          4.469915D-03    668
1629  55WDCP5   EQ   0.0              0.0              0.0              0.0         -3.010711D-04    669
1630  55WDCP6   EQ   0.0              0.0              0.0              0.0          0.0             670
1631  55EDCP1   EQ   0.0              0.0              0.0              0.0          0.0             671
1632  55EDCP2   EQ   0.0              0.0              0.0              0.0          1.391297D-03    672
1633  55EDCP3   EQ   0.0              0.0              0.0              0.0          0.0             673
1634  55EDCP4   EQ   0.0              0.0              0.0              0.0          2.564669D-03    674
1635  55EDCP5   EQ   0.0              0.0              0.0              0.0         -3.560302D-04    675
1636  55EDCP6   EQ   0.0              0.0              0.0              0.0          0.0             676
1637  55WCSB    EQ   0.0              0.0              0.0              0.0          1.342536D-04    677
1638  55ECSB    EQ   0.0              0.0              0.0              0.0          8.258787D-04    678
1639  55WOSBO   EQ   0.0              0.0              0.0              0.0          8.051995D-03    679
1640  55WOSBL   EQ   0.0              0.0              0.0              0.0          8.684205D-03    680
1641  55EOSBO   EQ   0.0              0.0              0.0              0.0          8.387494D-03    681
1642  55EOSBL   EQ   0.0              0.0              0.0              0.0          9.055814D-03    682
1643  55NOMSS   BS  -1.161293D 01     1.161293D 01    -9.999999E 29     0.0          0.0             683
1644  55NOMEM   BS  -1.273885D-01     1.273885D-01    -9.999999E 29     0.0          0.0             684
1645  55WGSB    EQ   0.0              0.0              0.0              0.0          1.899342D-03    685
1646  55EGSB    EQ   0.0              0.0              0.0              0.0          2.101251D-03    686
1647  55WESBE   EQ   0.0              0.0              0.0              0.0          5.751639D-03    687
1648  55WEMH   SBS  -2.895186D-01     2.895186D-01    -9.999999E 29     0.0         -4.287528D-09    688
1649  55EESBE   EQ   0.0              0.0              0.0              0.0          7.258762D-03    689
1650  55EEMH   SBS  -2.965781D 00     2.965781D 00    -9.999999E 29     0.0          7.289456D-09    690
1651  55WTSBL   EQ   0.0              0.0              0.0              0.0         -1.385090D-02    691
1652  55WTSBA   EQ   0.0              0.0              0.0              0.0          8.151869D-03    692
1653  55WTMEA   BS  -2.988915D 00     2.988915D 00    -9.999999E 29     0.0          0.0             693
1654  55ETSBL   EQ   0.0              0.0              0.0              0.0         -1.368571D-02    694
1655  55ETSBA   EQ   0.0              0.0              0.0              0.0          8.622032D-03    695
1656  55ETMEA   BS  -6.262107D 00     6.262107D 00    -9.999999E 29     0.0          0.0             696
1657  55WISB    EQ   0.0              0.0              0.0              0.0          2.167701D-03    697
1658  55WISLG   UL   0.0              0.0             -9.999999E 29     0.0         -1.891779D-04    698
1659  55WISLL   BS  -3.326142D-06     3.326142D-06    -9.999999E 29     0.0          0.0             699
1660  55WISLC   BS  -5.580340D 00     5.580340D 00    -9.999999E 29     0.0          0.0             700
1661  55WISLE   BS  -8.370511D 00     8.370511D 00    -9.999999E 29     0.0          0.0             701
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  1662  55WISUG   BS    1.395085D 01   -1.395085D 01    0.0             9.999999E 29   0.0             702
  1663  55WISUL   BS    1.395085D 01   -1.395085D 01    0.0             9.999999E 29   0.0             703
  1664  55WISUC   LL    0.0             0.0             0.0             9.999999E 29   1.396376D-03    704
  1665  55WISUE   LL    0.0             0.0             0.0             9.999999E 29   1.280065D-04    705
  1666  55EISB    EQ    0.0             0.0             0.0             0.0            2.208938D-03    706
  1667  55EISLG   UL    0.0             0.0            -9.999999E 29    0.0           -3.065397D-04    707
  1668  55EISLL   BS   -1.078120D-05    1.078120D-05   -9.999999E 29    0.0            0.0             708
  1669  55EISLC   BS   -1.808786D 01    1.808786D 01   -9.999999E 29    0.0            0.0             709
  1670  55EISLE   BS   -2.713179D 01    2.713179D 01   -9.999999E 29    0.0            0.0             710
  1671  55EISUG   BS    4.521964D 01   -4.521964D 01    0.0             9.999999E 29   0.0             711
  1672  55EISUL   BS    4.521963D 01   -4.521963D 01    0.0             9.999999E 29   0.0             712
  1673  55EISUC   LL    0.0             0.0             0.0             9.999999E 29   9.511468D-04    713
  1674  55EISUE   LL    0.0             0.0             0.0             9.999999E 29   2.781756D-04    714
  1675  55WDSBE   EQ    0.0             0.0             0.0             0.0            1.615213D-02    715
  1676  55WDSBH   EQ    0.0             0.0             0.0             0.0            4.838804D-03    716
  1677  55WDSEO   EQ    0.0             0.0             0.0             0.0            4.733919D-03    717
  1678  55WDSUP   BS   -1.658196D 01    1.658196D 01   -9.999999E 29    0.0            0.0             718
  1679  55WDSUS   UL    0.0             0.0            -9.999999E 29    0.0           -1.015471D-04    719
  1680  55WDSUC   UL    0.0             0.0            -9.999999E 29    0.0           -9.571602D-05    720
  1681  55WDMCG   UL    0.0             0.0            -9.999999E 29    0.0           -7.182051D-04    721
  1682  55EDSBE   EQ    0.0             0.0             0.0             0.0            1.396876D-02    722
  1683  55EDSBH   EQ    0.0             0.0             0.0             0.0            4.798048D-03    723
  1684  55EDSEO   EQ    0.0             0.0             0.0             0.0            4.094009D-03    724
  1685  55EDSUP   BS   -5.997652D 01    5.997652D 01   -9.999999E 29    0.0            0.0             725
  1686  55EDSUS   UL    0.0             0.0            -9.999999E 29    0.0           -6.079015D-05    726
  1687  55EDSUC   BS   -3.598868D 01    3.598868D 01   -9.999999E 29    0.0            0.0             727
  1688  55EDMCG   UL    0.0             0.0            -9.999999E 29    0.0           -8.493100D-04    728
  1689  55NMMEC   UL    0.0             0.0            -9.999999E 29    0.0           -6.709997D-03    729
  1690  00WCRL1   BS    2.750576D 02    1.311942D 03   -9.999999E 29    1.587000E 03   0.0             730
  1691  00WCRL2   BS    0.0             1.060000D 02   -9.999999E 29    1.060000E 02   0.0             731
  1692  00ECRL1   UL    2.200000D 01    0.0            -9.999999E 29    2.200000E 01  -2.576181D-03    732
  1693  00ECRL2   BS    0.0             1.400000D 00   -9.999999E 29    1.400000E 00   0.0             733
  1694  00WORL1   UL    6.000000D 00    0.0            -9.999999E 29    6.000000E 00  -1.041841D-01    734
  1695  00WORL2   UL    6.000000D 00    0.0            -9.999999E 29    6.000000E 00  -9.641214D-03    735
  1696  00WORL3   UL    4.400000D 00    0.0            -9.999999E 29    4.400000E 00  -2.760531D-03    736
  1697  00WORL4   BS    0.0             3.299999D 00   -9.999999E 29    3.299999E 00   0.0             737
  1698  00WORL5   BS    2.023855D 01    1.797614D 02   -9.999999E 29    2.000000E 02   0.0             738
  1699  00EORL1   UL    3.000000D 00    0.0            -9.999999E 29    3.000000E 00  -2.084640D-02    739
  1700  00EORL2   UL    2.000000D 00    0.0            -9.999999E 29    2.000000E 00  -4.480701D-03    740
  1701  00WGRL1   UL    3.900000D 01    0.0            -9.999999E 29    3.900000E 01  -2.318146D-02    741
  1702  00WGRL2   UL    5.900000D 01    0.0            -9.999999E 29    5.900000E 01  -6.730314D-03    742
  1703  00WGRL3   BS    1.035641D 01    3.364359D 01   -9.999999E 29    4.400000E 01   0.0             743
  1704  00WGRL4   BS    0.0             9.300000D 01   -9.999999E 29    9.300000E 01   0.0             744
  1705  00EGRL1   UL    1.600000D 01    0.0            -9.999999E 29    1.600000E 01  -1.322689D-02    745
  1706  00EGRL2   BS    1.842453D 01    1.057547D 01   -9.999999E 29    2.900000E 01   0.0             746
1
 SECTION 2 - COLUMNS

  NUMBER  .COLUMN.  AT   ...ACTIVITY...  .OBJ GRADIENT.  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.   M+J

      1   05WDFC    BS    2.506470D 00   -3.211550D-01    6.000000E-01    9.999999E 29   0.0             747
      2   05EDFC    BS    7.817615D 00   -4.015141D-01    1.299999E 00    9.999999E 29   0.0             748
      3   05WIND   SBS    2.111414D 00   -1.120867D-01    5.000000E-01    9.999999E 29   0.0             749
      4   05EIND    BS    6.535909D 00   -1.438778D-01    1.299999E 00    9.999999E 29   0.0             750
      5   05WRTR    BS    4.631726D-01   -1.136410D 00    8.879995E-02    9.999999E 29   0.0             751
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  6  05ERTR    BS    9.760887D-01   -1.338487D 00   1.833000E-01   9.999999E 29    0.0               752
  7  05WOTR   SBS    1.356842D-01   -5.637848D-01   3.520000E-02   9.999999E 29    0.0               753
  8  05EOTR   SBS    3.187045D-01   -6.616947D-01   7.489997E-02   9.999999E 29    0.0               754
  9  10WDFC    BS    2.819598D 00   -2.015740D-01   7.000000E-01   9.999999E 29    0.0               755
 10  10EDFC    BS    8.271308D 00   -2.668905D-01   1.500000E 00   9.999999E 29    0.0               756
 11  10WIND    BS    2.643293D 00   -7.576276D-02   6.000000E-01   9.999999E 29    0.0               757
 12  10EIND    BS    7.871859D 00   -1.022885D-01   1.500000E 00   9.999999E 29    0.0               758
 13  10WRTR    BS    5.457094D-01   -6.508903D-01   1.008000E-01   9.999999E 29    0.0               759
 14  10ERTR    BS    1.153815D 00   -7.289798D-01   2.029000E-01   9.999999E 29    0.0               760
 15  10WOTR   SBS    1.542840D-01   -4.224227D-01   4.730000E-02   9.999999E 29   -1.888006D-07      761
 16  10EOTR   SBS    3.684915D-01   -4.547087D-01   9.849995E-02   9.999999E 29    0.0               762
 17  15WDFC    BS    3.189482D 00   -1.270545D-01   1.000000E 00   9.999999E 29    0.0               763
 18  15EDFC    BS    1.037419D 01   -1.453969D-01   2.000000E 00   9.999999E 29    0.0               764
 19  15WIND    BS    3.481998D 00   -4.686408D-02   8.000000E-01   9.999999E 29    0.0               765
 20  15EIND    BS    1.068265D 01   -5.770191D-02   2.000000E 00   9.999999E 29    0.0               766
 21  15WRTR    BS    6.672445D-01   -3.464913D-01   1.331000E-01   9.999999E 29    0.0               767
 22  15ERTR    BS    1.415437D 00   -3.689776D-01   2.607999E-01   9.999999E 29    0.0               768
 23  15WOTR   SBS    1.853626D-01   -2.609393D-01   7.179999E-02   9.999999E 29    0.0               769
 24  15EOTR   SBS    4.504731D-01   -2.571012D-01   1.451000E-01   9.999999E 29    0.0               770
 25  25WDFC    BS    7.155861D 00   -6.893719D-02   2.599999E 00   9.999999E 29    0.0               771
 26  25EDFC    BS    2.359179D 01   -7.617262D-02   5.200000E 00   9.999999E 29    0.0               772
 27  25WIND   SBS    9.409060D 00   -2.433561D-02   2.200000E 00   9.999999E 29    0.0               773
 28  25EIND    BS    3.025925D 01   -2.635584D-02   5.299999E 00   9.999999E 29    0.0               774
 29  25WRTR    BS    1.755974D 00   -1.438535D-01   3.586000E-01   9.999999E 29    0.0               775
 30  25ERTR    BS    3.669500D 00   -1.532424D-01   6.664000E-01   9.999999E 29    0.0               776
 31  25WOTR   SBS    5.032155D-01   -1.188275D-01   2.128000E-01   9.999999E 29    0.0               777
 32  25EOTR    BS    1.205433D 00   -1.170614D-01   4.086000E-01   9.999999E 29    0.0               778
 33  35WDFC    BS    7.836872D 00   -3.121918D-02   3.500000E 00   9.999999E 29    0.0               779
 34  35EDFC    BS    2.775070D 01   -3.158320D-02   6.900000E 00   9.999999E 29    0.0               780
 35  35WIND    BS    1.201884D 01   -1.095385D-02   2.799999E 00   9.999999E 29    0.0               781
 36  35EIND    BS    3.836741D 01   -1.204738D-02   6.900000E 00   9.999999E 29    0.0               782
 37  35WRTR    BS    2.285048D 00   -5.222721D-02   4.510000E-01   9.999999E 29    0.0               783
 38  35ERTR    BS    4.782780D 00   -5.538868D-02   8.376999E-01   9.999999E 29    0.0               784
 39  35WOTR   SBS    6.469606D-01   -5.043519D-02   2.977999E-01   9.999999E 29    0.0               785
 40  35EOTR    BS    1.548704D 00   -4.978063D-02   5.711000E-01   9.999999E 29    0.0               786
 41  45WDFC    BS    9.513830D 00   -1.229790D-02   4.599999E 00   9.999999E 29    0.0               787
 42  45EDFC   SBS    3.434803D 01   -1.214720D-02   9.000000E 00   9.999999E 29    0.0               788
 43  45WIND   SBS    1.549791D 01   -4.420539D-03   3.799999E 00   9.999999E 29    0.0               789
 44  45EIND    BS    5.023454D 01   -4.709680D-03   9.000000E 00   9.999999E 29    0.0               790
 45  45WRTR    BS    2.830521D 00   -2.115113D-02   5.971000E-01   9.999999E 29    0.0               791
 46  45ERTR    BS    5.930256D 00   -2.237103D-02   1.108700E 00   9.999999E 29    0.0               792
 47  45WOTR   SBS    8.291962D-01   -2.101657D-02   3.827000E-01   9.999999E 29    0.0               793
 48  45EOTR   SBS    1.984182D 00   -2.076591D-02   7.345000E-01   9.999999E 29    0.0               794
 49  55WDFC   SBS    1.914555D 01   -4.750518D-03   1.225610E 01   9.999999E 29    0.0               795
 50  55EDFC   SBS    6.924896D 01   -4.681661D-03   2.361449E 01   9.999999E 29    0.0               796
 51  55WIND    BS    2.790170D 01   -1.703703D-03   1.081710E 01   9.999999E 29    0.0               797
 52  55EIND    BS    9.043929D 01   -1.815161D-03   2.361449E 01   9.999999E 29    0.0               798
 53  55WRTR   SBS    4.417011D 00   -8.151880D-03   1.614799E 00   9.999999E 29    0.0               799
 54  55ERTR   SBS    9.254124D 00   -8.622045D-03   2.996300E 00   9.999999E 29    0.0               800
 55  55WOTR   SBS    1.374167D 00   -8.100068D-03   9.748000E-01   9.999999E 29    0.0               801
 56  55EOTR   SBS    3.288255D 00   -8.003374D-03   1.873799E 00   9.999999E 29    0.0               802
 57  05WCX3    BS    0.0             0.0            0.0            9.999999E 29    0.0               803
 58  05WCX4    BS    0.0             0.0            0.0            9.999999E 29    0.0               804
 59  05WCX6    BS    2.038606D-01    0.0            0.0            9.999999E 29    0.0               805
 60  05WCD1    BS    6.753566D-01    0.0            0.0            9.999999E 29    0.0               806
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 61  05WCD2   LL   0.0            0.0        0.0        9.999999E 29    1.887800D-02   807
 62  05WCE    UL   2.150000D-01   0.0        0.0        2.150000E-01   -1.986446D-02   808
 63  05WCEX   UL   1.700000D 00   0.0        0.0        1.700000E 00   -6.022426D-02   809
 64  05ECX4   BS   1.186982D 00   0.0        0.0        9.999999E 29    0.0            810
 65  05ECD1   BS   3.310000D-01   0.0        0.0        9.999999E 29    0.0            811
 66  05ECD2   BS   0.0            0.0        0.0        9.999999E 29    0.0            812
 67  05ECIM   BS   1.660411D 00   0.0        0.0        9.999999E 29    0.0            813
 68  05WOX6   EQ   0.0            0.0        0.0        0.0             1.254997D 00   814
 69  05WOD1   BS   3.666499D-01   0.0        0.0        9.999999E 29    0.0            815
 70  05WOD2   BS   0.0            0.0        0.0        9.999999E 29    0.0            816
 71  05WOD3   BS   0.0            0.0        0.0        9.999999E 29    0.0            817
 72  05WOD4   LL   0.0            0.0        0.0        9.999999E 29    7.707692D-01   818
 73  05WOD5   BS   9.299999D-02   0.0        0.0        9.999999E 29    0.0            819
 74  05WOD6   BS   0.0            0.0        0.0        9.999999E 29    0.0            820
 75  05WOEX   UL   5.969999D-01   0.0        0.0        5.969999E-01   -5.866071D-01   821
 76  05WOE    BS   1.640118D 00   0.0        0.0        9.999999E 29    0.0            822
 77  05WOG    BS   7.275315D-01   0.0        0.0        9.999999E 29    0.0            823
 78  05EOX3   EQ   0.0            0.0        0.0        0.0             1.054297D 00   824
 79  05EOD1   BS   1.399997D-03   0.0        0.0        9.999999E 29    0.0            825
 80  05EOD2   BS   0.0            0.0        0.0        9.999999E 29    0.0            826
 81  05EOD3   BS   0.0            0.0        0.0        9.999999E 29    0.0            827
 82  05EOIM   BS   1.393138D 00   0.0        0.0        9.999999E 29    0.0            828
 83  05EOG    BS   3.037256D 00   0.0        0.0        9.999999E 29    0.0            829
 84  05WLX1   BS   1.300000D-02   0.0        0.0        9.999999E 29    0.0            830
 85  05WLX2   BS   1.020000D-01   0.0        0.0        9.999999E 29    0.0            831
 86  05WLX3   BS   1.242309D-01   0.0        0.0        9.999999E 29    0.0            832
 87  05WLX4   BS   4.353363D-01   0.0        0.0        9.999999E 29    0.0            833
 88  05WLDC   EQ   0.0            0.0        0.0        0.0             1.650061D-01   834
 89  05ELX1   BS   7.299995D-02   0.0        0.0        9.999999E 29    0.0            835
 90  05ELX2   BS   1.170387D 00   0.0        0.0        9.999999E 29    0.0            836
 91  05ELX3   BS   6.298527D-01   0.0        0.0        9.999999E 29    0.0            837
 92  05ELX4   BS   9.398666D-01   0.0        0.0        9.999999E 29    0.0            838
 93  05WGX5   EQ   0.0            0.0        0.0        0.0             1.572964D-01   839
 94  05WGD1   BS   1.875663D 00   0.0        0.0        9.999999E 29    0.0            840
 95  05WGD2   BS   1.240053D 00   0.0        0.0        9.999999E 29    0.0            841
 96  05WGD3   BS   0.0            0.0        0.0        9.999999E 29    0.0            842
 97  05WGD4   BS   0.0            0.0        0.0        9.999999E 29    0.0            843
 98  05WGD5   BS   0.0            0.0        0.0        9.999999E 29    0.0            844
 99  05WGD6   EQ   0.0            0.0        0.0        0.0             1.108572D-01   845
100  05WGX7   BS   4.320000D-01   0.0        0.0        9.999999E 29    0.0            846
101  05WGX8   BS   2.027426D 00   0.0        0.0        9.999999E 29    0.0            847
102  05WGX9   BS   1.102903D 00   0.0        0.0        9.999999E 29    0.0            848
103  05WGE    UL   4.091999D 00   0.0        0.0        4.091999E 00   -4.143049D-02   849
104  05WGEX   UL   5.400000D 00   0.0        0.0        5.400000E 00   -3.902801D-02   850
105  05EGX3   EQ   0.0            0.0        0.0        0.0             2.407136D-02   851
106  05EGD1   BS   4.000000D-04   0.0        0.0        9.999999E 29    0.0            852
107  05EGD2   BS   0.0            0.0        0.0        9.999999E 29    0.0            853
108  05EGD3   BS   0.0            0.0        0.0        9.999999E 29    0.0            854
109  05EGX4   BS   3.049999D-01   0.0        0.0        9.999999E 29    0.0            855
110  05EGX5   BS   1.970581D 00   0.0        0.0        9.999999E 29    0.0            856
111  05EGX6   BS   1.645511D 00   0.0        0.0        9.999999E 29    0.0            857
112  05WEX4   BS   0.0            0.0        0.0        9.999999E 29    0.0            858
113  05EEX4   BS   1.006939D-01   0.0        0.0        9.999999E 29    0.0            859
114  05WEX5   BS   2.531223D-01   0.0        0.0        4.500000E-01    0.0            860
115  05WEX6   BS   3.999997D-03   0.0        0.0        9.999999E 29    0.0            861
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 116  05WED5    BS   3.412232D-02  0.0        0.0        9.999999E 29  0.0            862
 117  05WED6    LL   0.0           0.0        0.0        9.999999E 29  1.933950D 00   863
 118  05WED1   SBS   1.173846D-01  0.0        0.0        9.999999E 29  2.297495D-07   864
 119  05WED2    LL   0.0           0.0        0.0        9.999999E 29  8.622983D-01   865
 120  05WED3    LL   0.0           0.0        0.0        9.999999E 29  1.131037D-01   866
 121  05WED4    EQ   0.0           0.0        0.0        0.0           3.025772D-02   867
 122  05WEX9    BS   1.417098D-01  0.0        0.0        9.999999E 29  0.0            868
 123  05WEX10   BS   0.0           0.0        0.0        9.999999E 29  0.0            869
 124  05WEX11   BS   1.683635D-01  0.0        0.0        9.999999E 29  0.0            870
 125  05WEEX    UL   1.610000D-02  0.0        0.0        1.610000E-02 -3.338430D-01   871
 126  05WCX5    BS   6.583845D-01  0.0        0.0        9.999999E 29  0.0            872
 127  05EEX5   SBS   8.332227D-01  0.0        0.0        1.009999E 00 -2.841174D-07   873
 128  05EEX6    LL   0.0           0.0        0.0        9.999999E 29  1.616620D 00   874
 129  05EED5    BS   1.762228D-01  0.0        0.0        9.999999E 29  0.0            875
 130  05EED6    BS   0.0           0.0        0.0        9.999999E 29  0.0            876
 131  05EED1    LL   0.0           0.0        0.0        9.999999E 29  1.978826D-01   877
 132  05EED2    LL   0.0           0.0        0.0        9.999999E 29  1.136942D 00   878
 133  05EED3    LL   0.0           0.0        0.0        9.999999E 29  2.917666D-01   879
 134  05EED4    BS   4.999388D-02  0.0        0.0        9.999999E 29  0.0            880
 135  05EEX9    BS   4.405800D-01  0.0        0.0        9.999999E 29  0.0            881
 136  05EEX10   LL   0.0           0.0        0.0        9.999999E 29  1.968144D-01   882
 137  05EEX11   BS   5.367932D-01  0.0        0.0        9.999999E 29  0.0            883
 138  05EEEX    UL   3.330000D-02  0.0        0.0        3.330000E-02 -3.406498D-01   884
 139  05ECX3    BS   1.193000D 00  0.0        0.0        9.999999E 29  0.0            885
 140  05WLA     BS   3.424062D-01  0.0        0.0        9.999999E 29  0.0            886
 141  05WTD1    BS   0.0           0.0        0.0        9.999999E 29  0.0            887
 142  05WTD2   SBS   1.004062D-01  0.0        0.0        9.999999E 29  1.282671D-07   888
 143  05ELA     BS   7.215859D-01  0.0        0.0        9.999999E 29  0.0            889
 144  05ETD1    BS   0.0           0.0        0.0        9.999999E 29  0.0            890
 145  05ETD2   SBS   2.045859D-01  0.0        0.0        9.999999E 29 -2.534923D-07   891
 146  05WER     BS   6.999999D-02  0.0        0.0        9.999999E 29  0.0            892
 147  05WEH     BS   0.0           0.0        0.0        9.999999E 29  0.0            893
 148  05WEO     BS   9.836352D-02  0.0        0.0        9.999999E 29  0.0            894
 149  05WDD1    BS   8.974268D-01  0.0        0.0        9.999999E 29  0.0            895
 150  05WDD2    LL   0.0           0.0        0.0        9.999999E 29  4.180984D-01   896
 151  05WDD3    LL   0.0           0.0        0.0        9.999999E 29  1.179928D 00   897
 152  05WDD4    LL   0.0           0.0        0.0        9.999999E 29  1.238036D 00   898
 153  05WDX5    BS   0.0           0.0        0.0        9.999999E 29  0.0            899
 154  05WDX6    BS   0.0           0.0        0.0        9.999999E 29  0.0            900
 155  05WDD5    LL   0.0           0.0        0.0        9.999999E 29  1.107064D-01   901
 156  05WDD6    LL   0.0           0.0        0.0        9.999999E 29  1.206433D-01   902
 157  05EER     BS   2.300000D-01  0.0        0.0        9.999999E 29  0.0            903
 158  05EEH     BS   0.0           0.0        0.0        9.999999E 29  0.0            904
 159  05EEO     BS   3.067933D-01  0.0        0.0        9.999999E 29  0.0            905
 160  05EDD1    BS   9.405818D-01  0.0        0.0        9.999999E 29  0.0            906
 161  05EDD2    BS   7.823874D-01  0.0        0.0        9.999999E 29  0.0            907
 162  05EDD3    LL   0.0           0.0        0.0        9.999999E 29  3.651602D-03   908
 163  05EDD4    LL   0.0           0.0        0.0        9.999999E 29  3.652760D-01   909
 164  05EDX5    BS   0.0           0.0        0.0        9.999999E 29  0.0            910
 165  05EDX6    BS   0.0           0.0        0.0        9.999999E 29  0.0            911
 166  05EDD5    BS   0.0           0.0        0.0        9.999999E 29  0.0            912
 167  05EDD6    LL   0.0           0.0        0.0        9.999999E 29  4.841524D-02   913
 168  05WCX1    BS   2.778356D 00  0.0        0.0        9.999999E 29  0.0            914
 169  05WCX2    BS   0.0           0.0        0.0        9.999999E 29  0.0            915
 170  05ECX1    UL   5.060000D-01  0.0        0.0        5.060000E-01 -4.462675D-02   916
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171  05ECX2   LL   0.0            0.0    0.0            9.999999E 29   1.434033D-03  917
172  05WOX1   BS   2.783650D 00   0.0    0.0            9.999999E 29   0.0           918
173  05WOX2   LL   0.0            0.0    0.0            9.999999E 29   1.875109D-01  919
174  05WOX3   LL   0.0            0.0    0.0            9.999999E 29   2.891091D-01  920
175  05WOX4   BS   0.0            0.0    0.0            9.999999E 29   0.0           921
176  05WOX5   EQ   1.810000D-01   0.0    1.810000E-01   1.810000E-01   4.186997D-01  922
177  05EOX1   UL   3.999997D-03   0.0    0.0            3.999997E-03  -2.156776D-01  923
178  05EOX2   EQ   0.0            0.0    0.0            0.0           -4.515949D-02  924
179  05WGX1   BS   1.354066D 01   0.0    0.0            9.999999E 29   0.0           925
180  05WGX2   BS   1.240053D 00   0.0    0.0            9.999999E 29   0.0           926
181  05WGX3   LL   0.0            0.0    0.0            9.999999E 29   1.920845D-01  927
182  05WGX4   LL   0.0            0.0    0.0            9.999999E 29   2.080892D-01  928
183  05EGX1   UL   9.999999D-04   0.0    0.0            9.999999E-04  -8.088163D-02  929
184  05EGX2   EQ   0.0            0.0    0.0            0.0            5.285938D-02  930
185  10WCX3   BS   0.0            0.0    0.0            9.999999E 29   0.0           931
186  10WCX4   BS   0.0            0.0    0.0            9.999999E 29   0.0           932
187  10WCX6   BS   4.192808D-01   0.0    0.0            9.999999E 29   0.0           933
188  10WCD1   BS   1.255564D 00   0.0    0.0            9.999999E 29   0.0           934
189  10WCD2   LL   0.0            0.0    0.0            9.999999E 29   7.362799D-03  935
190  10WCE    UL   5.790000D-01   0.0    0.0            5.790000E-01  -2.004550D-02  936
191  10WCEX   UL   2.200000D 00   0.0    0.0            2.200000E 00  -4.317850D-02  937
192  10ECX4   BS   2.017730D 00   0.0    0.0            9.999999E 29   0.0           938
193  10ECD1   BS   5.639991D-01   0.0    0.0            9.999999E 29   0.0           939
194  10ECD2   BS   0.0            0.0    0.0            9.999999E 29   0.0           940
195  10ECIM   BS   1.546613D 00   0.0    0.0            9.999999E 29   0.0           941
196  10WOX6   LL   0.0            0.0    0.0            9.999999E 29   6.251242D-01  942
197  10WOD1  SBS   2.524940D-03   0.0    0.0            9.999999E 29   0.0           943
198  10WOD2   BS   7.351563D-01   0.0    0.0            9.999999E 29   0.0           944
199  10WOD3   BS   0.0            0.0    0.0            9.999999E 29   0.0           945
200  10WOD4   LL   0.0            0.0    0.0            9.999999E 29   2.231887D-01  946
201  10WOD5   BS   1.910000D-01   0.0    0.0            9.999999E 29   0.0           947
202  10WOD6   BS   0.0            0.0    0.0            9.999999E 29   0.0           948
203  10WOEX   UL   1.520000D-01   0.0    0.0            1.520000E-01  -3.701612D-01  949
204  10WOE    BS   2.024053D 00   0.0    0.0            9.999999E 29   0.0           950
205  10WOG    BS   6.742774D-01   0.0    0.0            9.999999E 29   0.0           951
206  10EOX3   LL   0.0            0.0    0.0            9.999999E 29   5.743795D-01  952
207  10EOD1   BS   4.720000D-02   0.0    0.0            9.999999E 29   0.0           953
208  10EOD2   BS   0.0            0.0    0.0            9.999999E 29   0.0           954
209  10EOD3   BS   0.0            0.0    0.0            9.999999E 29   0.0           955
210  10EOIM   BS   5.545874D-01   0.0    0.0            9.999999E 29   0.0           956
211  10EOG    BS   2.628641D 00   0.0    0.0            9.999999E 29   0.0           957
212  10WLX1   BS   1.200000D-02   0.0    0.0            9.999999E 29   0.0           958
213  10WLX2   BS   5.000000D-02   0.0    0.0            9.999999E 29   0.0           959
214  10WLX3   BS   1.324847D-01   0.0    0.0            9.999999E 29   0.0           960
215  10WLX4   BS   4.307053D-01   0.0    0.0            9.999999E 29   0.0           961
216  10WLDC   EQ   0.0            0.0    0.0            0.0            8.783973D-02  962
217  10ELX1   BS   6.799996D-02   0.0    0.0            9.999999E 29   0.0           963
218  10ELX2   BS   9.533873D-01   0.0    0.0            9.999999E 29   0.0           964
219  10ELX3   BS   4.745988D-01   0.0    0.0            9.999999E 29   0.0           965
220  10ELX4   BS   9.386610D-01   0.0    0.0            9.999999E 29   0.0           966
221  10WGX5   BS   0.0            0.0    0.0            4.999998E-04   0.0           967
222  10WGD1   LL   0.0            0.0    0.0            9.999999E 29   2.644896D-02  968
223  10WGD2   BS   7.457950D 00   0.0    0.0            9.999999E 29   0.0           969
224  10WGD3   LL   0.0            0.0    0.0            9.999999E 29   9.378366D-02  970
225  10WGD4   LL   0.0            0.0    0.0            9.999999E 29   7.820010D-02  971
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 226   10WGD5    LL    0.0             0.0          0.0          9.999999E 29   5.917904D-02    972
 227   10WGD6    EQ    0.0             0.0          0.0          0.0            4.177501D-02    973
 228   10WGX7    BS    4.050000D-01    0.0          0.0          9.999999E 29   0.0             974
 229   10WGX8    BS    2.767878D 00    0.0          0.0          9.999999E 29   0.0             975
 230   10WGX9    BS    1.346525D 00    0.0          0.0          9.999999E 29   0.0             976
 231   10WGE     UL    4.860000D 00    0.0          0.0          4.860000E 00  -3.750178D-02    977
 232   10WGEX    UL    8.400000D 00    0.0          0.0          8.400000E 00  -3.845080D-02    978
 233   10EGX3    LL    0.0             0.0          0.0          9.999999E-04   9.398669D-03    979
 234   10EGD1    BS    2.000001D-04    0.0          0.0          9.999999E 29   0.0             980
 235   10EGD2    BS    0.0             0.0          0.0          9.999999E 29   0.0             981
 236   10EGD3    BS    0.0             0.0          0.0          9.999999E 29   0.0             982
 237   10EGX4    BS    2.860000D-01    0.0          0.0          9.999999E 29   0.0             983
 238   10EGX5    BS    2.657550D 00    0.0          0.0          9.999999E 29   0.0             984
 239   10EGX6    BS    1.713287D 00    0.0          0.0          9.999999E 29   0.0             985
 240   10WEX4    BS    0.0             0.0          0.0          9.999999E 29   0.0             986
 241   10EEX4    BS    2.543943D-01    0.0          0.0          9.999999E 29   0.0             987
 242   10WEX5    BS    2.607748D-01    0.0          0.0          6.500000E-01   0.0             988
 243   10WEX6    BS    3.999997D-03    0.0          0.0          9.999999E 29   0.0             989
 244   10WED5    BS    3.365252D-02    0.0          0.0          9.999999E 29   0.0             990
 245   10WED6    LL    0.0             0.0          0.0          9.999999E 29   1.088265D 00    991
 246   10WED1    SBS   1.106815D-01    0.0          0.0          9.999999E 29   0.0             992
 247   10WED2    LL    0.0             0.0          0.0          9.999999E 29   5.812583D-01    993
 248   10WED3    LL    0.0             0.0          0.0          9.999999E 29   6.622127D-02    994
 249   10WED4    EQ    0.0             0.0          0.0          0.0            1.906063D-02    995
 250   10WEX9    BS    1.719845D-01    0.0          0.0          9.999999E 29   0.0             996
 251   10WEX10   LL    0.0             0.0          0.0          9.999999E 29   8.553411D-01    997
 252   10WEX11   BS    1.536519D-01    0.0          0.0          9.999999E 29   0.0             998
 253   10WEEX    UL    1.690000D-02    0.0          0.0          1.690000E-02  -2.091673D-01    999
 254   10WCX5    BS    7.350660D-01    0.0          0.0          9.999999E 29   0.0            1000
 255   10EEX5    UL    1.309999D 00    0.0          0.0          1.309999E 00  -2.351404D-02   1001
 256   10EEX6    BS    0.0             0.0          0.0          9.999999E 29   0.0            1002
 257   10EED5    BS    5.417767D-01    0.0          0.0          9.999999E 29   0.0            1003
 258   10EED6    LL    0.0             0.0          0.0          9.999999E 29   8.130024D-01   1004
 259   10EED1    LL    0.0             0.0          0.0          9.999999E 29   1.072500D-01   1005
 260   10EED2    LL    0.0             0.0          0.0          9.999999E 29   6.739762D-01   1006
 261   10EED3    LL    0.0             0.0          0.0          9.999999E 29   1.885971D-01   1007
 262   10EED4    BS    1.537004D-01    0.0          0.0          9.999999E 29   0.0            1008
 263   10EEX9    BS    7.913391D-01    0.0          0.0          9.999999E 29   0.0            1009
 264   10EEX10   BS    0.0             0.0          0.0          9.999999E 29   0.0            1010
 265   10EEX11   BS    7.606476D-01    0.0          0.0          9.999999E 29   0.0            1011
 266   10EEEX    UL    3.500000D-02    0.0          0.0          3.500000E-02  -1.918516D-01   1012
 267   10ECX3    BS    1.118000D 00    0.0          0.0          9.999999E 29   0.0            1013
 268   10WLA     BS    3.285230D-01    0.0          0.0          9.999999E 29   0.0            1014
 269   10WTD1    BS    0.0             0.0          0.0          9.999999E 29   0.0            1015
 270   10WTD2    SBS   2.281168D-01    0.0          0.0          9.999999E 29   1.771417D-07   1016
 271   10ELA     BS    6.946090D-01    0.0          0.0          9.999999E 29   0.0            1017
 272   10ETD1    LL    0.0             0.0          0.0          9.999999E 29   7.877213D-03   1018
 273   10ETD2    BS    4.900231D-01    0.0          0.0          9.999999E 29   0.0            1019
 274   10WER     BS    4.300000D-02    0.0          0.0          9.999999E 29   0.0            1020
 275   10WEH     LL    0.0             0.0          0.0          9.999999E 29   6.705241D-01   1021
 276   10WEO     BS    1.106519D-01    0.0          0.0          9.999999E 29   0.0            1022
 277   10WDD1    SBS   1.243452D 00    0.0          0.0          9.999999E 29   0.0            1023
 278   10WDD2    LL    0.0             0.0          0.0          9.999999E 29   2.199782D-01   1024
 279   10WDD3    LL    0.0             0.0          0.0          9.999999E 29   4.477151D-01   1025
 280   10WDD4    BS    0.0             0.0          0.0          9.999999E 29   0.0            1026
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281  10WDX5   LL   0.0            0.0          0.0           9.999999E 29   6.620905D-02  1027
282  10WDX6   LL   0.0            0.0          0.0           9.999999E 29   6.619520D-02  1028
283  10WDD5   BS   0.0            0.0          0.0           9.999999E 29   0.0           1029
284  10WDD6   BS   0.0            0.0          0.0           9.999999E 29   0.0           1030
285  10EER    BS   4.360497D-01   0.0          0.0           9.999999E 29   0.0           1031
286  10EEH    LL   0.0            0.0          0.0           9.999999E 29   1.173454D-01  1032
287  10EEO    BS   3.245979D-01   0.0          0.0           9.999999E 29   0.0           1033
288  10EDD1   BS   1.111969D 00   0.0          0.0           9.999999E 29   0.0           1034
289  10EDD2   LL   0.0            0.0          0.0           9.999999E 29   4.403627D-02  1035
290  10EDD3   BS   2.990497D-01   0.0          0.0           9.999999E 29   0.0           1036
291  10EDD4   BS   0.0            0.0          0.0           9.999999E 29   0.0           1037
292  10EDX5   BS   0.0            0.0          0.0           9.999999E 29   0.0           1038
293  10EDX6   BS   0.0            0.0          0.0           9.999999E 29   0.0           1039
294  10EDD5   BS   0.0            0.0          0.0           9.999999E 29   0.0           1040
295  10EDD6   LL   0.0            0.0          0.0           9.999999E 29   2.501565D-02  1041
296  10WCX1   BS   3.934921D 00   0.0          0.0           9.999999E 29   0.0           1042
297  10WCX2   BS   0.0            0.0          0.0           9.999999E 29   0.0           1043
298  10ECX1   UL   1.011999D 00   0.0          0.0           1.011999E 00  -3.587847D-02  1044
299  10ECX2   BS   0.0            0.0          0.0           9.999999E 29   0.0           1045
300  10WOX1   BS   1.743174D 00   0.0          0.0           9.999999E 29   0.0           1046
301  10WOX2   BS   7.351563D-01   0.0          0.0           9.999999E 29   0.0           1047
302  10WOX3   LL   0.0            0.0          0.0           9.999999E 29   1.078305D-01  1048
303  10WOX4   BS   0.0            0.0          0.0           9.999999E 29   0.0           1049
304  10WOX5   EQ   3.720000D-01   0.0          3.720000E-01  3.720000E-01   1.465422D-01  1050
305  10EOX1   UL   5.000000D-02   0.0          0.0           5.000000E-02  -2.792600D-01  1051
306  10EOX2   EQ   0.0            0.0          0.0           0.0           -1.805596D-01  1052
307  10WGX1   BS   1.143266D 01   0.0          0.0           9.999999E 29   0.0           1053
308  10WGX2   BS   8.698002D 00   0.0          0.0           9.999999E 29   0.0           1054
309  10WGX3   BS   0.0            0.0          0.0           9.999999E 29   0.0           1055
310  10WGX4   BS   0.0            0.0          0.0           9.999999E 29   0.0           1056
311  10EGX1   UL   9.999999D-04   0.0          0.0           9.999999E-04  -6.122085D-02  1057
312  10EGX2   EQ   0.0            0.0          0.0           0.0            1.906985D-02  1058
313  15WCX3   BS   0.0            0.0          0.0           9.999999E 29   0.0           1059
314  15WCX4   LL   0.0            0.0          0.0           9.999999E 29   2.505788D-02  1060
315  15WCX6   BS   7.684408D-01   0.0          0.0           9.999999E 29   0.0           1061
316  15WCD1   BS   1.517658D 00   0.0          0.0           9.999999E 29   0.0           1062
317  15WCD2   BS   0.0            0.0          0.0           9.999999E 29   0.0           1063
318  15WCE    UL   8.789999D-01   0.0          5.790000E-01  8.789999E-01  -1.115387D-02  1064
319  15WCEX   UL   2.799999D 00   0.0          0.0           2.799999E 00  -3.087939D-02  1065
320  15ECX4   BS   1.903257D 00   0.0          0.0           9.999999E 29   0.0           1066
321  15ECD1   BS   1.055000D 00   0.0          0.0           9.999999E 29   0.0           1067
322  15ECD2   LL   0.0            0.0          0.0           9.999999E 29   5.783244D-03  1068
323  15ECIM   LL   0.0            0.0          0.0           9.999999E 29   6.798455D-03  1069
324  15WOX6   LL   0.0            0.0          0.0           9.999999E 29   3.693070D-01  1070
325  15WOD1   LL   0.0            0.0          0.0           9.999999E 29   1.174437D-01  1071
326  15WOD2   BS   8.176360D-01   0.0          0.0           9.999999E 29   0.0           1072
327  15WOD3   LL   0.0            0.0          0.0           9.999999E 29   3.569334D-02  1073
328  15WOD4   BS   0.0            0.0          0.0           9.999999E 29   0.0           1074
329  15WOD5   BS   3.950000D-01   0.0          0.0           9.999999E 29   0.0           1075
330  15WOD6   BS   0.0            0.0          0.0           9.999999E 29   0.0           1076
331  15WOEX   UL   7.299995D-02   0.0          0.0           7.299995E-02  -3.105473D-01  1077
332  15WOE    BS   2.537902D 00   0.0          0.0           9.999999E 29   0.0           1078
333  15WOG    BS   6.607383D-01   0.0          0.0           9.999999E 29   0.0           1079
334  15EOX3   LL   0.0            0.0          0.0           9.999999E 29   3.799705D-01  1080
335  15EOD1   BS   2.013740D-01   0.0          0.0           9.999999E 29   0.0           1081
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336  15EOD2    BS   0.0              0.0             0.0             9.999999E 29   0.0             1082
337  15EOD3    BS   0.0              0.0             0.0             9.999999E 29   0.0             1083
338  15EOIM    LL   0.0              0.0             0.0             9.999999E 29   2.435180D-01    1084
339  15EOG     BS   2.787902D 00     0.0             0.0             9.999999E 29   0.0             1085
340  15WLX1    BS   9.999997D-03     0.0             0.0             9.999999E 29   0.0             1086
341  15WLX2    LL   0.0              0.0             0.0             9.999999E 29   2.763742D-01    1087
342  15WLX3    BS   1.450130D-01     0.0             0.0             9.999999E 29   0.0             1088
343  15WLX4    BS   4.576235D-01     0.0             0.0             9.999999E 29   0.0             1089
344  15WLDC    LL   0.0              0.0             0.0             9.999999E 29   5.148952D-02    1090
345  15ELX1    BS   6.099996D-02     0.0             0.0             9.999999E 29   0.0             1091
346  15ELX2    BS   7.823874D-01     0.0             0.0             9.999999E 29   0.0             1092
347  15ELX3    BS   7.312997D-01     0.0             0.0             9.999999E 29   0.0             1093
348  15ELX4    BS   1.007468D 00     0.0             0.0             9.999999E 29   0.0             1094
349  15WGX5    LL   0.0              0.0             0.0             9.999999E-04   3.537313D-02    1095
350  15WGD1    LL   0.0              0.0             0.0             9.999999E 29   4.228445D-02    1096
351  15WGD2    BS   2.498928D 00     0.0             0.0             9.999999E 29   0.0             1097
352  15WGD3    LL   0.0              0.0             0.0             9.999999E 29   3.466075D-02    1098
353  15WGD4    BS   0.0              0.0             0.0             9.999999E 29   0.0             1099
354  15WGD5    BS   0.0              0.0             0.0             9.999999E 29   0.0             1100
355  15WGD6    BS   0.0              0.0             0.0             9.999999E 29   0.0             1101
356  15WGX7    BS   3.610000D-01     0.0             0.0             9.999999E 29   0.0             1102
357  15WGX8    BS   3.634751D 00     0.0             0.0             9.999999E 29   0.0             1103
358  15WGX9    BS   1.728710D 00     0.0             0.0             9.999999E 29   0.0             1104
359  15WGE     UL   7.007999D 00     0.0             0.0             7.007999E 00  -7.481120D-03    1105
360  15WGEX    UL   3.700000D 00     0.0             0.0             3.700000E 00  -3.429098D-02    1106
361  15EGX3    BS   0.0              0.0             0.0             2.000000E-03   0.0             1107
362  15EGD1    BS   2.399200D 00     0.0             0.0             9.999999E 29   0.0             1108
363  15EGD2    BS   0.0              0.0             0.0             9.999999E 29   0.0             1109
364  15EGD3    LL   0.0              0.0             0.0             9.999999E 29   1.186425D-02    1110
365  15EGX4    BS   2.550000D-01     0.0             0.0             9.999999E 29   0.0             1111
366  15EGX5    BS   6.531943D 00     0.0             0.0             9.999999E 29   0.0             1112
367  15EGX6    BS   2.225918D 00     0.0             0.0             9.999999E 29   0.0             1113
368  15WEX4    BS   0.0              0.0             0.0             9.999999E 29   0.0             1114
369  15EEX4    BS   3.630503D-01     0.0             0.0             9.999999E 29   0.0             1115
370  15WEX5    BS   2.741401D-01     0.0             0.0             8.600000E-01   0.0             1116
371  15WEX6    BS   3.999997D-03     0.0             0.0             9.999999E 29   0.0             1117
372  15WED5    BS   4.636531D-02     0.0             0.0             9.999999E 29   0.0             1118
373  15WED6    LL   0.0              0.0             0.0             9.999999E 29   5.992335D-01    1119
374  15WED1    BS   1.479617D-01     0.0             0.0             9.999999E 29   0.0             1120
375  15WED2    LL   0.0              0.0             0.0             9.999999E 29   3.264872D-01    1121
376  15WED3    LL   0.0              0.0             0.0             9.999999E 29   4.334522D-02    1122
377  15WED4    LL   0.0              0.0             0.0             9.999999E 29   6.565242D-03    1123
378  15WEX9    BS   2.183902D-01     0.0             0.0             9.999999E 29   0.0             1124
379  15WEX10   BS   0.0              0.0             0.0             9.999999E 29   0.0             1125
380  15WEX11   BS   1.251675D-01     0.0             0.0             9.999999E 29   0.0             1126
381  15WEEX    UL   1.780000D-02     0.0             0.0             1.780000E-02  -1.302383D-01    1127
382  15WCX5    BS   8.280277D-01     0.0             0.0             9.999999E 29   0.0             1128
383  15EEX5    UL   1.610000D 00     0.0             0.0             1.610000E 00  -6.520870D-03    1129
384  15EEX6    BS   0.0              0.0             0.0             9.999999E 29   0.0             1130
385  15EED5    BS   3.830001D-01     0.0             0.0             9.999999E 29   0.0             1131
386  15EED6    LL   0.0              0.0             0.0             9.999999E 29   3.120811D-01    1132
387  15EED1    LL   0.0              0.0             0.0             9.999999E 29   5.758019D-02    1133
388  15EED2    LL   0.0              0.0             0.0             9.999999E 29   3.477243D-01    1134
389  15EED3    LL   0.0              0.0             0.0             9.999999E 29   1.086425D-01    1135
390  15EED4    BS   1.086560D-01     0.0             0.0             9.999999E 29   0.0             1136
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391   15EEX9     BS    1.205897D 00    0.0         0.0           9.999999E 29   0.0              1137
392   15EEX10    LL    0.0             0.0         0.0           9.999999E 29   5.704632D-01     1138
393   15EEX11    BS    7.061730D-01    0.0         0.0           9.999999E 29   0.0              1139
394   15EEEX     UL    3.680000D-02    0.0         0.0           3.680000E-02  -1.262975D-01     1140
395   15ECX3     BS    9.979999D-01    0.0         0.0           9.999999E 29   0.0              1141
396   15WLA      BS    3.388061D-01    0.0         0.0           9.999999E 29   0.0              1142
397   15WTD1     LL    0.0             0.0         0.0           9.999999E 29   6.437065D-01     1143
398   15WTD2     SBS   1.106893D-01    0.0         0.0           9.999999E 29   0.0              1144
399   15ELA      BS    7.187148D-01    0.0         0.0           9.999999E 29   0.0              1145
400   15ETD1     BS    0.0             0.0         0.0           9.999999E 29   0.0              1146
401   15ETD2     BS    2.286917D-01    0.0         0.0           9.999999E 29   0.0              1147
402   15WER      LL    0.0             0.0         0.0           9.999999E 29   2.443475D-01     1148
403   15WEH      LL    0.0             0.0         0.0           9.999999E 29   9.454581D-01     1149
404   15WEO      BS    1.251675D-01    0.0         0.0           9.999999E 29   0.0              1150
405   15WDD1     SBS   1.493872D 00    0.0         0.0           9.999999E 29   0.0              1151
406   15WDD2     BS    0.0             0.0         0.0           9.999999E 29   0.0              1152
407   15WDD3     BS    0.0             0.0         0.0           9.999999E 29   0.0              1153
408   15WDD4     BS    0.0             0.0         0.0           9.999999E 29   0.0              1154
409   15WDX5     LL    0.0             0.0         0.0           9.999999E 29   5.735056D-02     1155
410   15WDX6     LL    0.0             0.0         0.0           9.999999E 29   8.134557D-02     1156
411   15WDD5     BS    0.0             0.0         0.0           9.999999E 29   0.0              1157
412   15WDD6     BS    0.0             0.0         0.0           9.999999E 29   0.0              1158
413   15EER      BS    2.990497D-01    0.0         0.0           9.999999E 29   0.0              1159
414   15EEH      LL    0.0             0.0         0.0           9.999999E 29   2.009221D-01     1160
415   15EEO      BS    4.071233D-01    0.0         0.0           9.999999E 29   0.0              1161
416   15EDD1     BS    4.479393D 00    0.0         0.0           9.999999E 29   0.0              1162
417   15EDD2     LL    0.0             0.0         0.0           9.999999E 29   6.006681D-02     1163
418   15EDD3     LL    0.0             0.0         0.0           9.999999E 29   4.426708D-02     1164
419   15EDD4     BS    0.0             0.0         0.0           9.999999E 29   0.0              1165
420   15EDX5     BS    0.0             0.0         0.0           9.999999E 29   0.0              1166
421   15EDX6     BS    0.0             0.0         0.0           9.999999E 29   0.0              1167
422   15EDD5     BS    0.0             0.0         0.0           9.999999E 29   0.0              1168
423   15EDD6     LL    0.0             0.0         0.0           9.999999E 29   3.173741D-02     1169
424   15WCX1     BS    5.277579D 00    0.0         0.0           9.999999E 29   0.0              1170
425   15WCX2     LL    0.0             0.0         0.0           9.999999E 29   4.439599D-03     1171
426   15ECX1     UL    2.023999D 00    0.0         0.0           2.023999E 00  -2.070078D-02     1172
427   15ECX2     BS    0.0             0.0         0.0           9.999999E 29   0.0              1173
428   15WOX1     BS    9.518483D-01    0.0         0.0           9.999999E 29   0.0              1174
429   15WOX2     BS    1.552792D 00    0.0         0.0           9.999999E 29   0.0              1175
430   15WOX3     BS    0.0             0.0         0.0           9.999999E 29   0.0              1176
431   15WOX4     LL    0.0             0.0         0.0           9.999999E 29   1.251540D-01     1177
432   15WOX5     EQ    7.670000D-01    0.0         7.670000E-01  7.670000E-01   8.073298D-02     1178
433   15EOX1     UL    2.500000D-01    0.0         0.0           2.500000E-01  -3.234109D-02     1179
434   15EOX2     LL    0.0             0.0         0.0           5.000000E-02   2.540965D-02     1180
435   15WGX1     BS    7.408663D 00    0.0         0.0           9.999999E 29   0.0              1181
436   15WGX2     BS    1.119693D 01    0.0         0.0           9.999999E 29   0.0              1182
437   15WGX3     BS    0.0             0.0         0.0           9.999999E 29   0.0              1183
438   15WGX4     LL    0.0             0.0         0.0           9.999999E 29   4.483529D-02     1184
439   15EGX1     UL    2.400000D 00    0.0         0.0           2.400000E 00  -2.287839D-02     1185
440   15EGX2     EQ    0.0             0.0         0.0           0.0            2.609167D-02     1186
441   25WCX3     BS    0.0             0.0         0.0           9.999999E 29   0.0              1187
442   25WCX4     LL    0.0             0.0         0.0           9.999999E 29   8.865948D-03     1188
443   25WCX6     BS    3.244503D 00    0.0         0.0           9.999999E 29   0.0              1189
444   25WCD1     BS    9.668370D 00    0.0         0.0           9.999999E 29   0.0              1190
445   25WCD2     BS    0.0             0.0         0.0           9.999999E 29   0.0              1191
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446  25WCE    SBS   4.490937D 00   0.0         1.757999E 00   9.999999E 29   0.0            1192
447  25WCEX    UL   9.200000D 00   0.0         0.0            9.200000E 00  -2.002829D-02   1193
448  25ECX4    BS   1.043422D 01   0.0         0.0            9.999999E 29   0.0            1194
449  25ECD1    BS   3.291335D 00   0.0         0.0            9.999999E 29   0.0            1195
450  25ECD2    LL   0.0            0.0         0.0            9.999999E 29   4.040802D-03   1196
451  25ECIM    LL   0.0            0.0         0.0            9.999999E 29   1.522595D-02   1197
452  25WOX6    LL   0.0            0.0         0.0            9.999999E 29   1.935527D-01   1198
453  25WOD1    LL   0.0            0.0         0.0            9.999999E 29   9.581620D-02   1199
454  25WOD2    LL   0.0            0.0         0.0            9.999999E 29   3.422286D-03   1200
455  25WOD3    BS   0.0            0.0         0.0            9.999999E 29   0.0            1201
456  25WOD4    BS   0.0            0.0         0.0            9.999999E 29   0.0            1202
457  25WOD5    BS   1.251000D 00   0.0         0.0            9.999999E 29   0.0            1203
458  25WOD6    BS   0.0            0.0         0.0            9.999999E 29   0.0            1204
459  25WOEX    UL   6.699997D-02   0.0         0.0            6.699997E-02  -2.755437D-01   1205
460  25WOE     BS   3.790280D 00   0.0         0.0            9.999999E 29   0.0            1206
461  25WOG     BS   1.410604D 00   0.0         0.0            9.999999E 29   0.0            1207
462  25EOX3    LL   0.0            0.0         0.0            9.999999E 29   1.876962D-01   1208
463  25EOD1    BS   1.406231D 00   0.0         0.0            9.999999E 29   0.0            1209
464  25EOD2    BS   0.0            0.0         0.0            9.999999E 29   0.0            1210
465  25EOD3    BS   0.0            0.0         0.0            9.999999E 29   0.0            1211
466  25EOIM    LL   0.0            0.0         0.0            9.999999E 29   2.696872D-01   1212
467  25EOG     BS   5.562048D 00   0.0         0.0            9.999999E 29   0.0            1213
468  25WLX1    BS   1.600000D-02   0.0         0.0            9.999999E 29   0.0            1214
469  25WLX2    BS   0.0            0.0         0.0            9.999999E 29   0.0            1215
470  25WLX3    BS   2.278222D-01   0.0         0.0            9.999999E 29   0.0            1216
471  25WLX4    BS   1.064090D 00   0.0         0.0            9.999999E 29   0.0            1217
472  25WLDC    LL   0.0            0.0         0.0            9.999999E 29   1.519449D-02   1218
473  25ELX1    BS   7.900000D-02   0.0         0.0            9.999999E 29   0.0            1219
474  25ELX2    BS   0.0            0.0         0.0            9.999999E 29   0.0            1220
475  25ELX3    BS   2.756235D 00   0.0         0.0            9.999999E 29   0.0            1221
476  25ELX4    BS   2.316333D 00   0.0         0.0            9.999999E 29   0.0            1222
477  25WGX5    LL   0.0            0.0         0.0            2.000000E-03   1.202003D-02   1223
478  25WGD1    LL   0.0            0.0         0.0            9.999999E 29   2.631175D-02   1224
479  25WGD2    BS   6.025359D 00   0.0         0.0            9.999999E 29   0.0            1225
480  25WGD3    BS   0.0            0.0         0.0            9.999999E 29   0.0            1226
481  25WGD4    BS   0.0            0.0         0.0            9.999999E 29   0.0            1227
482  25WGD5    LL   0.0            0.0         0.0            9.999999E 29   0.0            1228
483  25WGD6    BS   0.0            0.0         0.0            9.999999E 29   0.0            1229
484  25WGX7    BS   4.719999D-01   0.0         0.0            9.999999E 29   0.0            1230
485  25WGX8    BS   8.154856D 00   0.0         0.0            9.999999E 29   0.0            1231
486  25WGX9    BS   4.427794D 00   0.0         0.0            9.999999E 29   0.0            1232
487  25WGE     BS   1.338080D 01   0.0         0.0            9.999999E 29   0.0            1233
488  25WGEX    UL   3.000000D-01   0.0         0.0            3.000000E-01  -2.683810D-02   1234
489  25EGX3    LL   0.0            0.0         0.0            3.999997E-03   4.583412D-03   1235
490  25EGD1    BS   2.903621D 00   0.0         0.0            9.999999E 29   0.0            1236
491  25EGD2    BS   0.0            0.0         0.0            9.999999E 29   0.0            1237
492  25EGD3    BS   0.0            0.0         0.0            9.999999E 29   0.0            1238
493  25EGX4    BS   3.329999D-01   0.0         0.0            9.999999E 29   0.0            1239
494  25EGX5    BS   1.630519D 01   0.0         0.0            9.999999E 29   0.0            1240
495  25EGX6    BS   3.559911D 00   0.0         0.0            9.999999E 29   0.0            1241
496  25WEX4    LL   0.0            0.0         0.0            9.999999E 29   1.081132D-02   1242
497  25EEX4    BS   1.216219D 00   0.0         0.0            9.999999E 29   0.0            1243
498  25WEX5    BS   6.769973D-01   0.0         0.0            2.540000E 00   0.0            1244
499  25WEX6    BS   3.999997D-03   0.0         0.0            9.999999E 29   0.0            1245
500  25WED5   SBS   2.617170D-01   0.0         0.0            9.999999E 29   1.216016D-07   1246
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FILE: SOLN     DATA     A    05/04/80  13:45:00  UNIVERSITY OF WATERLOO  PAGE 024

 501  25WED6    LL   0.0             0.0          0.0          9.999999E 29   1.521473D-01  1247
 502  25WED1    BS   7.714096D-01    0.0          0.0          9.999999E 29   0.0           1248
 503  25WED2    LL   0.0             0.0          0.0          9.999999E 29   8.350737D-02  1249
 504  25WED3    LL   0.0             0.0          0.0          9.999999E 29   1.463934D-02  1250
 505  25WED4    BS   0.0             0.0          0.0          9.999999E 29   0.0           1251
 506  25WEX9    BS   5.515276D-01    0.0          0.0          9.999999E 29   0.0           1252
 507  25WEX10   BS   0.0             0.0          0.0          9.999999E 29   0.0           1253
 508  25WEX11   BS   2.808235D-01    0.0          0.0          9.999999E 29   0.0           1254
 509  25WEEX    UL   3.930000D-02    0.0          0.0          3.930000E-02  -1.103421D-01  1255
 510  25WCX5    BS   2.113465D 00    0.0          0.0          9.999999E 29   0.0           1256
 511  25EEX5    UL   4.419999D 00    0.0          0.0          4.419999E 00  -1.327634D-03  1257
 512  25EEX6    LL   0.0             0.0          0.0          9.999999E 29   1.526732D-01  1258
 513  25EED5    BS   1.747000D 00    0.0          0.0          9.999999E 29   0.0           1259
 514  25EED6    BS   0.0             0.0          0.0          9.999999E 29   0.0           1260
 515  25EED1    LL   0.0             0.0          0.0          9.999999E 29   9.636145D-03  1261
 516  25EED2    LL   0.0             0.0          0.0          9.999999E 29   8.996211D-02  1262
 517  25EED3    LL   0.0             0.0          0.0          9.999999E 29   3.783790D-02  1263
 518  25EED4    BS   4.956186D-01    0.0          0.0          9.999999E 29   0.0           1264
 519  25EEX9    BS   1.984850D 00    0.0          0.0          9.999999E 29   0.0           1265
 520  25EEX10   BS   0.0             0.0          0.0          9.999999E 29   0.0           1266
 521  25EEX11   BS   3.282486D 00    0.0          0.0          9.999999E 29   0.0           1267
 522  25EEEX    UL   8.139998D-02    0.0          0.0          8.139998E-02  -1.114085D-01  1268
 523  25ECX3    BS   1.301000D 00    0.0          0.0          9.999999E 29   0.0           1269
 524  25WLA     BS   7.609528D-01    0.0          0.0          9.999999E 29   0.0           1270
 525  25WTD1    LL   0.0             0.0          0.0          9.999999E 29   2.536005D-01  1271
 526  25WTD2    BS   6.502636D-01    0.0          0.0          9.999999E 29   0.0           1272
 527  25ELA     BS   1.590181D 00    0.0          0.0          9.999999E 29   0.0           1273
 528  25ETD1    LL   0.0             0.0          0.0          9.999999E 29   2.301137D-01  1274
 529  25ETD2    BS   1.361489D 00    0.0          0.0          9.999999E 29   0.0           1275
 530  25WER     LL   0.0             0.0          0.0          9.999999E 29   1.139408D-01  1276
 531  25WEH     BS   0.0             0.0          0.0          9.999999E 29   0.0           1277
 532  25WEO     BS   2.808235D-01    0.0          0.0          9.999999E 29   0.0           1278
 533  25WDD1    BS   3.923660D 00    0.0          0.0          9.999999E 29   0.0           1279
 534  25WDD2    LL   0.0             0.0          0.0          9.999999E 29   5.254358D-02  1280
 535  25WDD3    BS   0.0             0.0          0.0          9.999999E 29   0.0           1281
 536  25WDD4    LL   0.0             0.0          0.0          9.999999E 29   2.282882D-01  1282
 537  25WDX5    BS   0.0             0.0          0.0          9.999999E 29   0.0           1283
 538  25WDX6    BS   0.0             0.0          0.0          9.999999E 29   0.0           1284
 539  25WDD5    LL   0.0             0.0          0.0          9.999999E 29   9.075382D-03  1285
 540  25WDD6    LL   0.0             0.0          0.0          9.999999E 29   1.659710D-02  1286
 541  25EER     BS   2.356653D 00    0.0          0.0          9.999999E 29   0.0           1287
 542  25EEH     LL   0.0             0.0          0.0          9.999999E 29   7.365546D-02  1288
 543  25EEO     BS   9.258325D-01    0.0          0.0          9.999999E 29   0.0           1289
 544  25EDD1    BS   6.234439D 00    0.0          0.0          9.999999E 29   0.0           1290
 545  25EDD2    LL   0.0             0.0          0.0          9.999999E 29   3.670370D-03  1291
 546  25EDD3    BS   2.057604D 00    0.0          0.0          9.999999E 29   0.0           1292
 547  25EDD4    BS   0.0             0.0          0.0          9.999999E 29   0.0           1293
 548  25EDX5    LL   0.0             0.0          0.0          9.999999E 29   2.590350D-03  1294
 549  25EDX6    BS   0.0             0.0          0.0          9.999999E 29   0.0           1295
 550  25EDD5    BS   0.0             0.0          0.0          9.999999E 29   0.0           1296
 551  25EDD6    LL   0.0             0.0          0.0          9.999999E 29   4.875548D-03  1297
 552  25WCX1    BS   1.905653D 01    0.0          0.0          9.999999E 29   0.0           1298
 553  25WCX2    LL   0.0             0.0          0.0          9.999999E 29   3.594000D-03  1299
 554  25ECX1    BS   7.251333D 00    0.0          0.0          9.999999E 29   0.0           1300
 555  25ECX2    LL   0.0             0.0          0.0          9.999999E 29   1.962620D-03  1301
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556  25WOX1   BS   5.207973D-01   0.0          0.0            9.999999E 29  0.0            1302
557  25WOX2   BS   1.991088D 00   0.0          0.0            9.999999E 29  0.0            1303
558  25WOX3   LL   0.0            0.0          0.0            9.999999E 29  2.063886D-02   1304
559  25WOX4   LL   0.0            0.0          0.0            9.999999E 29  7.234324D-02   1305
560  25WOX5   EQ   2.756000D 00   0.0          2.756000E 00   2.756000E 00  4.775245D-02   1306
561  25EOX1   BS   1.771767D 00   0.0          0.0            9.999999E 29  0.0            1307
562  25EOX2   LL   0.0            0.0          0.0            5.000000E-01  1.633472D-02   1308
563  25WGX1   BS   6.224123D 00   0.0          0.0            9.999999E 29  0.0            1309
564  25WGX2   BS   2.404700D 01   0.0          0.0            9.999999E 29  0.0            1310
565  25WGX3   LL   0.0            0.0          0.0            9.999999E 29  1.288352D-02   1311
566  25WGX4   LL   0.0            0.0          0.0            9.999999E 29  2.079015D-02   1312
567  25EGX1   BS   7.702814D 00   0.0          0.0            9.999999E 29  0.0            1313
568  25EGX2   LL   0.0            0.0          0.0            4.799999E 00  1.043994D-02   1314
569  35WCX3   BS   0.0            0.0          0.0            9.999999E 29  0.0            1315
570  35WCX4   LL   0.0            0.0          0.0            9.999999E 29  1.136047D-03   1316
571  35WCX6   BS   4.144427D 00   0.0          0.0            9.999999E 29  0.0            1317
572  35WCD1   BS   1.209054D 01   0.0          0.0            9.999999E 29  0.0            1318
573  35WCD2   LL   0.0            0.0          0.0            9.999999E 29  1.251400D-03   1319
574  35WCE    SBS  6.377749D 00   0.0          1.757999E 00   9.999999E 29  0.0            1320
575  35WCEX   UL   1.480000D 01   0.0          0.0            1.480000E 01 -7.721998D-03   1321
576  35ECX4   BS   1.323014D 01   0.0          0.0            9.999999E 29  0.0            1322
577  35ECD1   LL   0.0            0.0          0.0            9.999999E 29  2.461358D-03   1323
578  35ECD2   LL   0.0            0.0          0.0            9.999999E 29  1.670564D-03   1324
579  35ECIM   LL   0.0            0.0          0.0            9.999999E 29  5.870443D-03   1325
580  35WOX6   LL   0.0            0.0          0.0            9.999999E 29  8.780972D-02   1326
581  35WOD1   LL   0.0            0.0          0.0            9.999999E 29  1.169452D-01   1327
582  35WOD2   SBS  7.061815D-01   0.0          0.0            9.999999E 29  0.0            1328
583  35WOD3   SBS  6.351919D-01   0.0          0.0            9.999999E 29  0.0            1329
584  35WOD4   LL   0.0            0.0          0.0            9.999999E 29  1.727144D-02   1330
585  35WOD5   LL   0.0            0.0          0.0            9.999999E 29  6.468713D-03   1331
586  35WOD6   BS   0.0            0.0          0.0            9.999999E 29  0.0            1332
587  35WOEX   EQ   0.0            0.0          0.0            0.0          -9.678871D-02   1333
588  35WOE    BS   1.875167D 00   0.0          0.0            9.999999E 29  0.0            1334
589  35WOG    BS   2.594995D 00   0.0          0.0            9.999999E 29  0.0            1335
590  35EOX3   LL   0.0            0.0          0.0            9.999999E 29  6.291872D-02   1336
591  35EOD1   LL   0.0            0.0          0.0            9.999999E 29  9.490030D-03   1337
592  35EOD2   BS   1.273885D 00   0.0          0.0            9.999999E 29  0.0            1338
593  35EOD3   BS   0.0            0.0          0.0            9.999999E 29  0.0            1339
594  35EOIM   LL   0.0            0.0          0.0            9.999999E 29  9.453071D-02   1340
595  35EOG    BS   3.932662D 00   0.0          0.0            9.999999E 29  0.0            1341
596  35WLX1   LL   0.0            0.0          0.0            9.999999E 29  6.781960D-02   1342
597  35WLX2   LL   0.0            0.0          0.0            9.999999E 29  9.092009D-03   1343
598  35WLX3   BS   1.164053D 00   0.0          0.0            9.999999E 29  0.0            1344
599  35WLX4   BS   1.242026D 00   0.0          0.0            9.999999E 29  0.0            1345
600  35WLDC   LL   0.0            0.0          0.0            9.999999E 29  4.201623D-03   1346
601  35ELX1   LL   0.0            0.0          0.0            9.999999E 29  6.488351D-02   1347
602  35ELX2   BS   0.0            0.0          0.0            9.999999E 29  0.0            1348
603  35ELX3   BS   9.289939D-01   0.0          0.0            9.999999E 29  0.0            1349
604  35ELX4   BS   2.713438D 00   0.0          0.0            9.999999E 29  0.0            1350
605  35WGX5   LL   0.0            0.0          0.0            2.000000E-03  1.079365D-03   1351
606  35WGD1   LL   0.0            0.0          0.0            9.999999E 29  2.980664D-02   1352
607  35WGD2   LL   0.0            0.0          0.0            9.999999E 29  4.714062D-03   1353
608  35WGD3   LL   0.0            0.0          0.0            9.999999E 29  1.079365D-03   1354
609  35WGD4   LL   0.0            0.0          0.0            9.999999E 29  4.127702D-03   1355
610  35WGD5   BS   0.0            0.0          0.0            9.999999E 29  0.0            1356
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611  35WGD6     BS  0.0             0.0          0.0          9.999999E 29   0.0            1357
612  35WGX7     LL  0.0             0.0          0.0          9.999999E 29   1.482206D-02   1358
613  35WGX8     BS  8.277647D 00    0.0          0.0          9.999999E 29   0.0            1359
614  35WGX9     BS  1.413981D 00    0.0          0.0          9.999999E 29   0.0            1360
615  35WGE     SBS  9.067993D-01    0.0          0.0          9.999999E 29   0.0            1361
616  35WGEX     EQ  0.0             0.0          0.0          0.0           -6.322404D-03   1362
617  35EGX3     BS  3.999997D-03    0.0          0.0          3.999997E-03   0.0            1363
618  35EGD1     LL  0.0             0.0          0.0          9.999999E 29   9.627318D-03   1364
619  35EGD2    SBS  2.476446D 00    0.0          0.0          9.999999E 29   0.0            1365
620  35EGD3     BS  3.999997D-03    0.0          0.0          9.999999E 29   0.0            1366
621  35EGX4     BS  0.0             0.0          0.0          9.999999E 29   0.0            1367
622  35EGX5     BS  3.117220D 00    0.0          0.0          9.999999E 29   0.0            1368
623  35EGX6     BS  4.513811D 00    0.0          0.0          9.999999E 29   0.0            1369
624  35WEX4     BS  0.0             0.0          0.0          9.999999E 29   0.0            1370
625  35EEX4     BS  8.277018D 00    0.0          0.0          9.999999E 29   0.0            1371
626  35WEX5     BS  8.769980D-01    0.0          0.0          2.540000E 00   0.0            1372
627  35WEX6     LL  0.0             0.0          0.0          9.999999E 29   9.209678D-02   1373
628  35WED5    SBS  4.211230D-01    0.0          0.0          9.999999E 29   0.0            1374
629  35WED6     BS  0.0             0.0          0.0          9.999999E 29   0.0            1375
630  35WED1     BS  1.241258D 00    0.0          0.0          9.999999E 29   0.0            1376
631  35WED2     BS  0.0             0.0          0.0          9.999999E 29   0.0            1377
632  35WED3     BS  0.0             0.0          0.0          9.999999E 29   0.0            1378
633  35WED4     LL  0.0             0.0          0.0          9.999999E 29   1.083688D-02   1379
634  35WEX9     BS  7.045042D-01    0.0          0.0          9.999999E 29   0.0            1380
635  35WEX10    BS  0.0             0.0          0.0          9.999999E 29   0.0            1381
636  35WEX11    BS  3.075490D-01    0.0          0.0          9.999999E 29   0.0            1382
637  35WEEX     UL  4.340000D-02    0.0          0.0          4.340000E-02  -4.445999D-02   1383
638  35WCX5     BS  2.647339D 00    0.0          0.0          9.999999E 29   0.0            1384
639  35EEX5     UL  4.419999D 00    0.0          0.0          4.419999E 00  -9.663769D-03   1385
640  35EEX6     LL  0.0             0.0          0.0          9.999999E 29   5.897943D-02   1386
641  35EED5     BS  6.472227D-01    0.0          0.0          9.999999E 29   0.0            1387
642  35EED6     BS  0.0             0.0          0.0          9.999999E 29   0.0            1388
643  35EED1     BS  0.0             0.0          0.0          9.999999E 29   0.0            1389
644  35EED2     BS  0.0             0.0          0.0          9.999999E 29   0.0            1390
645  35EED3     LL  0.0             0.0          0.0          9.999999E 29   1.696916D-02   1391
646  35EED4     BS  7.206693D 00    0.0          0.0          9.999999E 29   0.0            1392
647  35EEX9     BS  5.622422D 00    0.0          0.0          9.999999E 29   0.0            1393
648  35EEX10    BS  0.0             0.0          0.0          9.999999E 29   0.0            1394
649  35EEX11    BS  5.959484D 00    0.0          0.0          9.999999E 29   0.0            1395
650  35EEEX     UL  8.979994D-02    0.0          0.0          8.979994E-02  -3.514427D-02   1396
651  35ECX3     LL  0.0             0.0          0.0          9.999999E 29   5.205871D-03   1397
652  35WLA      BS  8.636838D-01    0.0          0.0          9.999999E 29   0.0            1398
653  35WTD1     LL  0.0             0.0          0.0          9.999999E 29   1.035878D-01   1399
654  35WTD2     BS  8.636838D-01    0.0          0.0          9.999999E 29   0.0            1400
655  35ELA      BS  1.807756D 00    0.0          0.0          9.999999E 29   0.0            1401
656  35ETD1     LL  0.0             0.0          0.0          9.999999E 29   1.053539D-01   1402
657  35ETD2     BS  1.807756D 00    0.0          0.0          9.999999E 29   0.0            1403
658  35WER      BS  0.0             0.0          0.0          9.999999E 29   0.0            1404
659  35WEH      BS  0.0             0.0          0.0          9.999999E 29   0.0            1405
660  35WEO      BS  3.075490D-01    0.0          0.0          9.999999E 29   0.0            1406
661  35WDD1     BS  6.315817D 00    0.0          0.0          9.999999E 29   0.0            1407
662  35WDD2     BS  0.0             0.0          0.0          9.999999E 29   0.0            1408
663  35WDD3     LL  0.0             0.0          0.0          9.999999E 29   2.272504D-02   1409
664  35WDD4     LL  0.0             0.0          0.0          9.999999E 29   3.991964D-02   1410
665  35WDX5     BS  4.965032D-01    0.0          0.0          9.999999E 29   0.0            1411
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666  35WDX6   BS   0.0            0.0        0.0        9.999999E 29   0.0             1412
667  35WDD5   BS   4.965032D-01   0.0        0.0        9.999999E 29   0.0             1413
668  35WDD6   LL   0.0            0.0        0.0        9.999999E 29   8.004227D-04    1414
669  35EER    BS   4.870440D 00   0.0        0.0        9.999999E 29   0.0             1415
670  35EEH    BS   0.0            0.0        0.0        9.999999E 29   0.0             1416
671  35EEO    BS   1.089044D 00   0.0        0.0        9.999999E 29   0.0             1417
672  35EDD1   LL   0.0            0.0        0.0        9.999999E 29   2.064092D-03    1418
673  35EDD2   LL   0.0            0.0        0.0        9.999999E 29   4.184619D-03    1419
674  35EDD3   BS   3.841638D 00   0.0        0.0        9.999999E 29   0.0             1420
675  35EDD4   LL   0.0            0.0        0.0        9.999999E 29   2.058810D-02    1421
676  35EDX5   BS   0.0            0.0        0.0        9.999999E 29   0.0             1422
677  35EDX6   BS   5.047851D 00   0.0        0.0        9.999999E 29   0.0             1423
678  35EDD5   BS   0.0            0.0        0.0        9.999999E 29   0.0             1424
679  35EDD6   BS   5.047851D 00   0.0        0.0        9.999999E 29   0.0             1425
680  35WCX1   BS   2.798071D 01   0.0        0.0        9.999999E 29   0.0             1426
681  35WCX2   BS   0.0            0.0        0.0        9.999999E 29   0.0             1427
682  35ECX1   BS   6.860333D 00   0.0        0.0        9.999999E 29   0.0             1428
683  35ECX2   BS   0.0            0.0        0.0        9.999999E 29   0.0             1429
684  35WOX1   BS   5.302374D-04   0.0        0.0        9.999999E 29   0.0             1430
685  35WOX2   BS   1.318440D 00   0.0        0.0        9.999999E 29   0.0             1431
686  35WOX3   BS   6.351919D-01   0.0        0.0        9.999999E 29   0.0             1432
687  35WOX4   BS   0.0            0.0        0.0        9.999999E 29   0.0             1433
688  35WOX5   BS   2.516000D 00   0.0        0.0        9.999999E 29   0.0             1434
689  35EOX1   BS   7.836098D-01   0.0        0.0        9.999999E 29   0.0             1435
690  35EOX2   BS   1.273885D 00   0.0        0.0        9.999999E 29   0.0             1436
691  35WGX1   BS   3.938892D-01   0.0        0.0        9.999999E 29   0.0             1437
692  35WGX2   BS   1.160614D 01   0.0        0.0        9.999999E 29   0.0             1438
693  35WGX3   BS   0.0            0.0        0.0        9.999999E 29   0.0             1439
694  35WGX4   BS   0.0            0.0        0.0        9.999999E 29   0.0             1440
695  35EGX1   BS   4.578340D 00   0.0        0.0        9.999999E 29   0.0             1441
696  35EGX2   BS   2.476446D 00   0.0        0.0        9.999999E 29   0.0             1442
697  45WCX3   BS   0.0            0.0        0.0        9.999999E 29   0.0             1443
698  45WCX4   LL   0.0            0.0        0.0        9.999999E 29   1.708278D-04    1444
699  45WCX6   BS   5.344108D 00   0.0        0.0        9.999999E 29   0.0             1445
700  45WCD1   BS   2.613996D 01   0.0        0.0        9.999999E 29   0.0             1446
701  45WCD2   LL   0.0            0.0        0.0        9.999999E 29   3.482000D-04    1447
702  45WCE    BS   1.298632D 01   0.0        0.0        9.999999E 29   0.0             1448
703  45WCEX   UL   2.420000D 01   0.0        0.0        2.420000E 01  -2.976970D-03    1449
704  45ECX4   BS   1.732225D 01   0.0        0.0        9.999999E 29   0.0             1450
705  45ECD1   LL   0.0            0.0        0.0        9.999999E 29   1.827412D-03    1451
706  45ECD2   BS   0.0            0.0        0.0        9.999999E 29   0.0             1452
707  45ECIM   LL   0.0            0.0        0.0        9.999999E 29   2.263160D-03    1453
708  45WOX6   BS   0.0            0.0        0.0        9.999999E 29   0.0             1454
709  45WOD1   LL   0.0            0.0        0.0        9.999999E 29   9.025614D-02    1455
710  45WOD2   LL   0.0            0.0        0.0        9.999999E 29   6.215656D-03    1456
711  45WOD3   BS   2.255567D 00   0.0        0.0        9.999999E 29   0.0             1457
712  45WOD4   LL   0.0            0.0        0.0        9.999999E 29   4.164536D-03    1458
713  45WOD5  SBS   1.796329D 00   0.0        0.0        9.999999E 29   0.0             1459
714  45WOD6   LL   0.0            0.0        0.0        9.999999E 29   2.263300D-02    1460
715  45WOEX   EQ   0.0            0.0        0.0        0.0           -3.482000D-02    1461
716  45WOE    BS   4.246779D 00   0.0        0.0        9.999999E 29   0.0             1462
717  45WOG    BS   2.081562D 00   0.0        0.0        9.999999E 29   0.0             1463
718  45EOX3   LL   0.0            0.0        0.0        9.999999E 29   2.176250D-02    1464
719  45EOD1   LL   0.0            0.0        0.0        9.999999E 29   1.999639D-02    1465
720  45EOD2   LL   0.0            0.0        0.0        9.999999E 29   1.553913D-03    1466
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721  45EOD3    BS   0.0             0.0             0.0             9.999999E 29    0.0             1467
722  45EOIM    LL   0.0             0.0             0.0             9.999999E 29    3.394950D-02    1468
723  45EOG     BS   4.986128D 00    0.0             0.0             9.999999E 29    0.0             1469
724  45WLX1    BS   0.0             0.0             0.0             9.999999E 29    0.0             1470
725  45WLX2    LL   0.0             0.0             0.0             9.999999E 29    5.908427D-03    1471
726  45WLX3    BS   3.752525D-01    0.0             0.0             9.999999E 29    0.0             1472
727  45WLX4    BS   1.554771D 00    0.0             0.0             9.999999E 29    0.0             1473
728  45WLDC    LL   0.0             0.0             0.0             9.999999E 29    9.761443D-04    1474
729  45ELX1    BS   0.0             0.0             0.0             9.999999E 29    0.0             1475
730  45ELX2    BS   0.0             0.0             0.0             9.999999E 29    0.0             1476
731  45ELX3    BS   1.216332D 00    0.0             0.0             9.999999E 29    0.0             1477
732  45ELX4    BS   3.401819D 00    0.0             0.0             9.999999E 29    0.0             1478
733  45WGX5    BS   0.0             0.0             0.0             2.000000E-03    0.0             1479
734  45WGD1    LL   0.0             0.0             0.0             9.999999E 29    1.935126D-02    1480
735  45WGD2    LL   0.0             0.0             0.0             9.999999E 29    8.845985D-03    1481
736  45WGD3    BS   3.428061D 00    0.0             0.0             9.999999E 29    0.0             1482
737  45WGD4    LL   0.0             0.0             0.0             9.999999E 29    1.175133D-03    1483
738  45WGD5    BS   0.0             0.0             0.0             9.999999E 29    0.0             1484
739  45WGD6    BS   0.0             0.0             0.0             9.999999E 29    0.0             1485
740  45WGX7    BS   0.0             0.0             0.0             9.999999E 29    0.0             1486
741  45WGX8    BS   3.157908D 00    0.0             0.0             9.999999E 29    0.0             1487
742  45WGX9    BS   1.823283D 00    0.0             0.0             9.999999E 29    0.0             1488
743  45WGE     LL   0.0             0.0             0.0             9.999999E 29    4.711432D-04    1489
744  45WGEX    EQ   0.0             0.0             0.0             0.0            -1.966257D-03    1490
745  45EGX3    UL   3.999997D-03    0.0             0.0             3.999997E-03   -3.128457D-03    1491
746  45EGD1    LL   0.0             0.0             0.0             9.999999E 29    9.048487D-03    1492
747  45EGD2    BS   2.867042D 00    0.0             0.0             9.999999E 29    0.0             1493
748  45EGD3    LL   0.0             0.0             0.0             9.999999E 29    2.257958D-03    1494
749  45EGX4    BS   0.0             0.0             0.0             9.999999E 29    0.0             1495
750  45EGX5    LL   0.0             0.0             0.0             9.999999E 29    7.957611D-04    1496
751  45EGX6    BS   5.909944D 00    0.0             0.0             9.999999E 29    0.0             1497
752  45WEX4    BS   0.0             0.0             0.0             9.999999E 29    0.0             1498
753  45EEX4    BS   1.064987D 01    0.0             0.0             9.999999E 29    0.0             1499
754  45WEX5    BS   2.224493D 00    0.0             0.0             2.540000E 00    0.0             1500
755  45WEX6    BS   0.0             0.0             0.0             9.999999E 29    0.0             1501
756  45WED5    BS   1.495288D 00    0.0             0.0             9.999999E 29    0.0             1502
757  45WED6    LL   0.0             0.0             0.0             9.999999E 29    2.646319D-02    1503
758  45WED1    BS   4.705707D 00    0.0             0.0             9.999999E 29    0.0             1504
759  45WED2    LL   0.0             0.0             0.0             9.999999E 29    2.130738D-02    1505
760  45WED3    LL   0.0             0.0             0.0             9.999999E 29    4.538074D-03    1506
761  45WED4    LL   0.0             0.0             0.0             9.999999E 29    3.855056D-03    1507
762  45WEX9    BS   2.271090D 00    0.0             0.0             9.999999E 29    0.0             1508
763  45WEX10   BS   0.0             0.0             0.0             9.999999E 29    0.0             1509
764  45WEX11   BS   3.733593D-01    0.0             0.0             9.999999E 29    0.0             1510
765  45WEEX    UL   4.800000D-02    0.0             0.0             4.800000E-02   -1.745918D-02    1511
766  45WCX5    BS   6.866337D 00    0.0             0.0             9.999999E 29    0.0             1512
767  45EEX5    UL   4.419999D 00    0.0             0.0             4.419999E 00   -3.725558D-03    1513
768  45EEX6    LL   0.0             0.0             0.0             9.999999E 29    2.273764D-02    1514
769  45EED5    BS   1.642776D 00    0.0             0.0             9.999999E 29    0.0             1515
770  45EED6    BS   0.0             0.0             0.0             9.999999E 29    0.0             1516
771  45EED1    LL   0.0             0.0             0.0             9.999999E 29    2.006810D-03    1517
772  45EED2    LL   0.0             0.0             0.0             9.999999E 29    1.999706D-02    1518
773  45EED3    LL   0.0             0.0             0.0             9.999999E 29    4.721652D-03    1519
774  45EED4    BS   2.838903D 00    0.0             0.0             9.999999E 29    0.0             1520
775  45EEX9    BS   7.361453D 00    0.0             0.0             9.999999E 29    0.0             1521
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776  45EEX10   LL   0.0             0.0          0.0          9.999999E 29   3.818560D-02  1522
777  45EEX11   BS   6.404518D 00    0.0          0.0          9.999999E 29   0.0           1523
778  45EEEX    UL   9.919995D-02    0.0          0.0          9.919995E-02  -1.354876D-02  1524
779  45ECX3    BS   0.0             0.0          0.0          9.999999E 29   0.0           1525
780  45WLA     BS   1.069857D 00    0.0          0.0          9.999999E 29   0.0           1526
781  45WTD1    LL   0.0             0.0          0.0          9.999999E 29   3.718832D-02  1527
782  45WTD2    BS   1.069857D 00    0.0          0.0          9.999999E 29   0.0           1528
783  45ELA     BS   2.241470D 00    0.0          0.0          9.999999E 29   0.0           1529
784  45ETD1    BS   0.0             0.0          0.0          9.999999E 29   0.0           1530
785  45ETD2    BS   2.241470D 00    0.0          0.0          9.999999E 29   0.0           1531
786  45WER     BS   0.0             0.0          0.0          9.999999E 29   0.0           1532
787  45WEH     LL   0.0             0.0          0.0          9.999999E 29   1.552750D-02  1533
788  45WEO     BS   3.733593D-01    0.0          0.0          9.999999E 29   0.0           1534
789  45WDD1    LL   0.0             0.0          0.0          9.999999E 29   1.887458D-04  1535
790  45WDD2    BS   0.0             0.0          0.0          9.999999E 29   0.0           1536
791  45WDD3    LL   0.0             0.0          0.0          9.999999E 29   6.151607D-03  1537
792  45WDD4    BS   0.0             0.0          0.0          9.999999E 29   0.0           1538
793  45WDX5    BS   2.378786D 00    0.0          0.0          9.999999E 29   0.0           1539
794  45WDX6    BS   3.461131D 00    0.0          0.0          9.999999E 29   0.0           1540
795  45WDD5    BS   1.882283D 00    0.0          0.0          9.999999E 29   0.0           1541
796  45WDD6    BS   3.461131D 00    0.0          0.0          9.999999E 29   0.0           1542
797  45EER     BS   5.056569D 00    0.0          0.0          9.999999E 29   0.0           1543
798  45EEH     BS   0.0             0.0          0.0          9.999999E 29   0.0           1544
799  45EEO     BS   1.347949D 00    0.0          0.0          9.999999E 29   0.0           1545
800  45EDD1    BS   0.0             0.0          0.0          9.999999E 29   0.0           1546
801  45EDD2    LL   0.0             0.0          0.0          9.999999E 29   4.305566D-03  1547
802  45EDD3    BS   3.135750D 00    0.0          0.0          9.999999E 29   0.0           1548
803  45EDD4    LL   0.0             0.0          0.0          9.999999E 29   7.936726D-03  1549
804  45EDX5    BS   0.0             0.0          0.0          9.999999E 29   0.0           1550
805  45EDX6    BS   1.249581D 01    0.0          0.0          9.999999E 29   0.0           1551
806  45EDD5    BS   0.0             0.0          0.0          9.999999E 29   0.0           1552
807  45EDD6    BS   9.971886D 00    0.0          0.0          9.999999E 29   0.0           1553
808  45WCX1    BS   4.941653D 01    0.0          0.0          9.999999E 29   0.0           1554
809  45WCX2    BS   0.0             0.0          0.0          9.999999E 29   0.0           1555
810  45ECX1    BS   4.346335D 00    0.0          0.0          9.999999E 29   0.0           1556
811  45ECX2    LL   0.0             0.0          0.0          9.999999E 29   6.440303D-04  1557
812  45WOX1    BS   0.0             0.0          0.0          9.999999E 29   0.0           1558
813  45WOX2    BS   3.319053D-01    0.0          0.0          9.999999E 29   0.0           1559
814  45WOX3    BS   2.554107D 00    0.0          0.0          9.999999E 29   0.0           1560
815  45WOX4    BS   0.0             0.0          0.0          9.999999E 29   0.0           1561
816  45WOX5    BS   3.442328D 00    0.0          0.0          9.999999E 29   0.0           1562
817  45EOX1    BS   1.406230D-01    0.0          0.0          9.999999E 29   0.0           1563
818  45EOX2    BS   5.987261D-01    0.0          0.0          9.999999E 29   0.0           1564
819  45WGX1    BS   0.0             0.0          0.0          9.999999E 29   0.0           1565
820  45WGX2    BS   2.211875D 00    0.0          0.0          9.999999E 29   0.0           1566
821  45WGX3    BS   3.428061D 00    0.0          0.0          9.999999E 29   0.0           1567
822  45WGX4    BS   0.0             0.0          0.0          9.999999E 29   0.0           1568
823  45EGX1    BS   1.316846D 00    0.0          0.0          9.999999E 29   0.0           1569
824  45EGX2    BS   4.848198D 00    0.0          0.0          9.999999E 29   0.0           1570
825  55WCX3    LL   0.0             0.0          0.0          9.999999E 29   3.762163D-04  1571
826  55WCX4    LL   0.0             0.0          0.0          9.999999E 29   6.583883D-05  1572
827  55WCX6    BS   9.621276D 00    0.0          0.0          9.999999E 29   0.0           1573
828  55WCD1    BS   4.959359D 01    0.0          0.0          9.999999E 29   0.0           1574
829  55WCD2    BS   0.0             0.0          0.0          9.999999E 29   0.0           1575
830  55WCE     BS   3.120468D 01    0.0          0.0          9.999999E 29   0.0           1576
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 831  55WCEX   UL   1.070678D 02   0.0         0.0          1.070678E 02   -1.147356D-03  1577
 832  55ECX4   BS   3.118596D 01   0.0         0.0          9.999999E 29    0.0           1578
 833  55ECD1   BS   0.0            0.0         0.0          9.999999E 29    0.0           1579
 834  55ECD2   BS   0.0            0.0         0.0          9.999999E 29    0.0           1580
 835  55ECIM   LL   0.0            0.0         0.0          9.999999E 29    8.722457D-04  1581
 836  55WOX6   LL   0.0            0.0         0.0          9.999999E 29    8.722997D-03  1582
 837  55WOD1   BS   0.0            0.0         0.0          9.999999E 29    0.0           1583
 838  55WOD2   LL   0.0            0.0         0.0          9.999999E 29    1.049565D-02  1584
 839  55WOD3   LL   0.0            0.0         0.0          9.999999E 29    2.139998D-03  1585
 840  55WOD4   LL   0.0            0.0         0.0          9.999999E 29    2.024537D-03  1586
 841  55WOD5   BS   3.234295D 00   0.0         0.0          9.999999E 29    0.0           1587
 842  55WOD6   BS   0.0            0.0         0.0          9.999999E 29    0.0           1588
 843  55WOEX   EQ   0.0            0.0         0.0          0.0            -1.341999D-02  1589
 844  55WOE    BS   8.089612D 00   0.0         0.0          9.999999E 29    0.0           1590
 845  55WOG    BS   3.395929D 00   0.0         0.0          9.999999E 29    0.0           1591
 846  55EOX3   LL   0.0            0.0         0.0          9.999999E 29    8.387497D-03  1592
 847  55EOD1   LL   0.0            0.0         0.0          9.999999E 29    2.588138D-02  1593
 848  55EOD2   LL   0.0            0.0         0.0          9.999999E 29    4.228910D-03  1594
 849  55EOD3   BS   0.0            0.0         0.0          9.999999E 29    0.0           1595
 850  55EOIM   LL   0.0            0.0         0.0          9.999999E 29    1.308449D-02  1596
 851  55EOG    BS   8.217001D 00   0.0         0.0          9.999999E 29    0.0           1597
 852  55WLX1   LL   0.0            0.0         0.0          9.999999E 29    8.212089D-03  1598
 853  55WLX2   BS   0.0            0.0         0.0          9.999999E 29    0.0           1599
 854  55WLX3   BS   6.755867D-01   0.0         0.0          9.999999E 29    0.0           1600
 855  55WLX4   BS   2.473119D 00   0.0         0.0          9.999999E 29    0.0           1601
 856  55WLDC   BS   0.0            0.0         0.0          9.999999E 29    0.0           1602
 857  55ELX1   LL   0.0            0.0         0.0          9.999999E 29    7.707076D-03  1603
 858  55ELX2   BS   0.0            0.0         0.0          9.999999E 29    0.0           1604
 859  55ELX3   BS   2.189816D 00   0.0         0.0          9.999999E 29    0.0           1605
 860  55ELX4   BS   5.420770D 00   0.0         0.0          9.999999E 29    0.0           1606
 861  55WGX5   LL   0.0            0.0         0.0          3.300000E-03    0.0           1607
 862  55WGD1   BS   0.0            0.0         0.0          9.999999E 29    0.0           1608
 863  55WGD2   LL   0.0            0.0         0.0          9.999999E 29    1.066499D-02  1609
 864  55WGD3   BS   1.999826D 00   0.0         0.0          9.999999E 29    0.0           1610
 865  55WGD4   LL   0.0            0.0         0.0          9.999999E 29    6.401331D-04  1611
 866  55WGD5   LL   0.0            0.0         0.0          9.999999E 29    0.0           1612
 867  55WGD6   BS   0.0            0.0         0.0          9.999999E 29    0.0           1613
 868  55WGX7   LL   0.0            0.0         0.0          9.999999E 29    1.749022D-03  1614
 869  55WGX8   BS   2.836564D 00   0.0         0.0          9.999999E 29    0.0           1615
 870  55WGX9   BS   3.282552D 00   0.0         0.0          9.999999E 29    0.0           1616
 871  55WGE    LL   0.0            0.0         0.0          9.999999E 29    1.815835D-04  1617
 872  55WGEX   EQ   0.0            0.0         0.0          0.0            -7.578161D-04  1618
 873  55EGX3   UL   6.499998D-03   0.0         0.0          6.499998E-03   -3.354995D-04  1619
 874  55EGD1   BS   0.0            0.0         0.0          9.999999E 29    0.0           1620
 875  55EGD2   BS   4.089729D 00   0.0         0.0          9.999999E 29    0.0           1621
 876  55EGD3   BS   1.047999D-03   0.0         0.0          9.999999E 29    0.0           1622
 877  55EGX4   LL   0.0            0.0         0.0          9.999999E 29    1.819774D-03  1623
 878  55EGX5   LL   0.0            0.0         0.0          9.999999E 29    3.066941D-04  1624
 879  55EGX6   BS   1.063991D 01   0.0         0.0          9.999999E 29    0.0           1625
 880  55WEX4   LL   0.0            0.0         0.0          9.999999E 29    1.485781D-03  1626
 881  55EEX4   BS   2.143340D 01   0.0         0.0          9.999999E 29    0.0           1627
 882  55WEX5   BS   3.391889D 00   0.0         0.0          4.133699E 00    0.0           1628
 883  55WEX6   LL   0.0            0.0         0.0          9.999999E 29    1.019919D-02  1629
 884  55WED5   BS   3.768786D-01   0.0         0.0          9.999999E 29    0.0           1630
 885  55WED6   BS   0.0            0.0         0.0          9.999999E 29    0.0           1631
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886  55WED1    BS   4.565726D 00   0.0          0.0          9.999999E 29   0.0            1632
887  55WED2    BS   0.0            0.0          0.0          9.999999E 29   0.0            1633
888  55WED3    BS   0.0            0.0          0.0          9.999999E 29   0.0            1634
889  55WED4    BS   0.0            0.0          0.0          9.999999E 29   0.0            1635
890  55WEX9    BS   4.088761D 00   0.0          0.0          9.999999E 29   0.0            1636
891  55WEX10   LL   0.0            0.0          0.0          9.999999E 29   1.433276D-02   1637
892  55WEX11   BS   7.513450D-01   0.0          0.0          9.999999E 29   0.0            1638
893  55WEEX    UL   9.259999D-02   0.0          0.0          9.259999E-02  -6.728952D-03   1639
894  55WCX5    BS   1.865255D 01   0.0          0.0          9.999999E 29   0.0            1640
895  55EEX5    UL   7.193399D 00   0.0          0.0          7.193399E 00  -1.435873D-03   1641
896  55EEX6    LL   0.0            0.0          0.0          9.999999E 29   8.763325D-03   1642
897  55EED5    BS   1.790027D 00   0.0          0.0          9.999999E 29   0.0            1643
898  55EED6    BS   0.0            0.0          0.0          9.999999E 29   0.0            1644
899  55EED1    LL   0.0            0.0          0.0          9.999999E 29   1.202784D-03   1645
900  55EED2    BS   0.0            0.0          0.0          9.999999E 29   0.0            1646
901  55EED3    BS   0.0            0.0          0.0          9.999999E 29   0.0            1647
902  55EED4    BS   4.314990D 00   0.0          0.0          9.999999E 29   0.0            1648
903  55EEX9    BS   1.325312D 01   0.0          0.0          9.999999E 29   0.0            1649
904  55EEX10   LL   0.0            0.0          0.0          9.999999E 29   1.471714D-02   1650
905  55EEX11   BS   1.291213D 01   0.0          0.0          9.999999E 29   0.0            1651
906  55EEEX    UL   1.909000D-01   0.0          0.0          1.909000E-01  -5.221830D-03   1652
907  55ECX3    BS   0.0            0.0          0.0          9.999999E 29   0.0            1653
908  55WLA     BS   1.669506D 00   0.0          0.0          9.999999E 29   0.0            1654
909  55WTD1    BS   0.0            0.0          0.0          9.999999E 29   0.0            1655
910  55WTD2    BS   1.669506D 00   0.0          0.0          9.999999E 29   0.0            1656
911  55ELA     BS   3.497799D 00   0.0          0.0          9.999999E 29   0.0            1657
912  55ETD1    BS   0.0            0.0          0.0          9.999999E 29   0.0            1658
913  55ETD2    BS   3.497799D 00   0.0          0.0          9.999999E 29   0.0            1659
914  55WER     LL   0.0            0.0          0.0          9.999999E 29   2.044308D-03   1660
915  55WEH     BS   0.0            0.0          0.0          9.999999E 29   0.0            1661
916  55WEO     BS   7.513450D-01   0.0          0.0          9.999999E 29   0.0            1662
917  55WDD1    BS   1.891043D 00   0.0          0.0          9.999999E 29   0.0            1663
918  55WDD2    LL   0.0            0.0          0.0          9.999999E 29   2.402224D-03   1664
919  55WDD3    BS   0.0            0.0          0.0          9.999999E 29   0.0            1665
920  55WDD4    LL   0.0            0.0          0.0          9.999999E 29   6.704873D-03   1666
921  55WDX5    BS   7.461021D 00   0.0          0.0          9.999999E 29   0.0            1667
922  55WDX6    BS   6.965151D 00   0.0          0.0          9.999999E 29   0.0            1668
923  55WDD5    BS   1.826290D 00   0.0          0.0          9.999999E 29   0.0            1669
924  55WDD6    BS   3.489724D 00   0.0          0.0          9.999999E 29   0.0            1670
925  55EER     BS   1.019453D 01   0.0          0.0          9.999999E 29   0.0            1671
926  55EEH     BS   0.0            0.0          0.0          9.999999E 29   0.0            1672
927  55EEO     BS   2.717595D 00   0.0          0.0          9.999999E 29   0.0            1673
928  55EDD1    BS   0.0            0.0          0.0          9.999999E 29   0.0            1674
929  55EDD2    LL   0.0            0.0          0.0          9.999999E 29   2.086945D-03   1675
930  55EDD3    BS   5.751107D 00   0.0          0.0          9.999999E 29   0.0            1676
931  55EDD4    LL   0.0            0.0          0.0          9.999999E 29   3.847004D-03   1677
932  55EDX5    BS   0.0            0.0          0.0          9.999999E 29   0.0            1678
933  55EDX6    BS   2.519277D 01   0.0          0.0          9.999999E 29   0.0            1679
934  55EDD5    BS   0.0            0.0          0.0          9.999999E 29   0.0            1680
935  55EDD6    BS   1.347122D 01   0.0          0.0          9.999999E 29   0.0            1681
936  55WCX1    BS   1.666130D 02   0.0          0.0          9.999999E 29   0.0            1682
937  55WCX2    LL   0.0            0.0          0.0          9.999999E 29   1.341999D-04   1683
938  55ECX1    LL   0.0            0.0          0.0          9.999999E 29   2.287598D-03   1684
939  55ECX2    LL   0.0            0.0          0.0          9.999999E 29   2.482161D-04   1685
940  55WOX1    LL   0.0            0.0          0.0          9.999999E 29   9.881614D-02   1686
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   941  55WOX2    BS    7.061813D-02    0.0            0.0             9.999999E 29   0.0            1687
   942  55WOX3    BS    1.210701D 00    0.0            0.0             9.999999E 29   0.0            1688
   943  55WOX4    BS    0.0             0.0            0.0             9.999999E 29   0.0            1689
   944  55WOX5    BS    1.020422D 01    0.0            0.0             9.999999E 29   0.0            1690
   945  55EOX1    BS    0.0             0.0            0.0             9.999999E 29   0.0            1691
   946  55EOX2    BS    1.273885D-01    0.0            0.0             9.999999E 29   0.0            1692
   947  55WGX1    LL    0.0             0.0            0.0             9.999999E 29   2.170526D-02   1693
   948  55WGX2    BS    0.0             0.0            0.0             9.999999E 29   0.0            1694
   949  55WGX3    BS    6.928347D 00    0.0            0.0             9.999999E 29   0.0            1695
   950  55WGX4    BS    0.0             0.0            0.0             9.999999E 29   0.0            1696
   951  55EGX1    LL    0.0             0.0            0.0             9.999999E 29   1.161649D-02   1697
   952  55EGX2    BS    1.109988D 01    0.0            0.0             9.999999E 29   0.0            1698
   953  05EC      BS    9.554531D 00    6.209199D-01   0.0             9.999999E 29   0.0            1699
   954  10EC      BS    1.037167D 01    3.855500D-01   0.0             9.999999E 29   0.0            1700
   955  15EC      BS    1.273102D 01    2.393900D-01   0.0             9.999999E 29   0.0            1701
   956  25EC      BS    3.170204D 01    1.171300D-01   0.0             9.999999E 29   0.0            1702
   957  35EC      BS    4.182937D 01    4.516000D-02   0.0             9.999999E 29   0.0            1703
   958  45EC      BS    5.572787D 01    1.741000D-02   0.0             9.999999E 29   0.0            1704
   959  55EC      BS    9.586741D 01    6.709997D-03   0.0             9.999999E 29   0.0            1705
   960  FIRSTTRY  EQ   -1.000000D 00    0.0           -1.000000E 00   -1.000000E 00   1.928447D 00   1706
```

The FORTRAN program REFORM follows. Its input is the raw output from MINOS, and its output (for the base case) is in Appendix D.

```
FILE: REFORM   FORTRAN  A   07/25/80   18:16:00  UNIVERSITY OF WATERLOO  PAGE 001

$JOB
C INPUT FILES:  1=SOLN DATA  2=EC DATA  3=REPORT DATA
      INTEGER*4 A(8),B(150),C(8)
      LOGICAL*1 BB(150),CC(8)
      DIMENSION X(8,7),PX(8,7),CP(8,7),Y(150,7),EC(7),F(7),DF(7)
      DATA NROWS/104/,NCOLS/128/
C READ DUAL VARIABLES AND NAMES
      DO 1 M=1,66
    1 READ(1,105)
      READ(1,105) C(1),CC(1),CP(1,1)
      READ(1,105) C(2),CC(2),CP(2,1)
      READ(1,105)
      READ(1,105) C(3),CC(3),CP(3,1)
      READ(1,105)
      READ(1,105) C(4),CC(4),CP(4,1)
      READ(1,105)
      READ(1,105)
      DO 2 M=5,7
    2 READ(1,105) C(M),CC(M),CP(M,1)
      READ(1,105)
      READ(1,105) C(8),CC(8),CP(8,1)
      MM=NROWS-64
      DO 3 M=1,MM
    3 READ(1,105)
      DO 5 J=2,7
      DO 4 M=1,51
    4 READ(1,105)
      READ(1,107) CP(1,J),CP(2,J),DUM1,CP(3,J),DUM2
      READ(1,107) CP(4,J),DUM1,DUM2
      READ(1,107) CP(5,J),CP(6,J),CP(7,J)
      READ(1,107) DUM1,CP(8,J)
      DO 5 M=1,MM
    5 READ(1,105)
      DO 7 M=1,22
    7 READ(1,105)
C  READ NAMES AND VALUES OF VARIABLES
      DO 9 I=1,8
    9 READ(1,109) A(I),X(I,1),PX(I,1)
      DO 11 J=2,7
      DO 10 I=1,8
   10 READ(1,110) X(I,J),PX(I,J)
   11 CONTINUE
      DO 15 K=1,NCOLS
   15 READ(1,115) B(K),BB(K),Y(K,1)
      DO 17 J=2,7
      DO 16 K=1,NCOLS
   16 READ(1,117) Y(K,J)
   17 CONTINUE
      DO 20 J=1,7
   20 READ(1,117) EC(J)
C READ DISCOUNT FACTORS FROM EC DATA
      READ(2,225) (DF(J),J=1,7)
C  DEFINE FACTORS TO CONVERT TO ANNUAL BASIS
      DO 30 J=1,7
      IF(J.LT.4) F(J)=0.2
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```
      IF(J.GE.4) F(J)=0.1
   30 CONTINUE
C CONVERT TO UNDISCOUNTED PRICES
      DO 33 J=1,7
      DO 33 I=1,8
      PX(I,J)=-PX(I,J)/DF(J)
   33 CP(I,J)=CP(I,J)/DF(J)
C CONVERT TO ANNUAL BASIS
      DO 40 J=1,7
      DO 35 I=1,8
   35 X(I,J)=X(I,J)*F(J)
      DO 36 K=1,NCOLS
   36 Y(K,J)=Y(K,J)*F(J)
   40 EC(J)=EC(J)*F(J)
C  WRITE NAMES AND VALUES IN NEW FORMAT
      DO 45 I=1,8
   45 WRITE(3,365) C(I),CC(I),(CP(I,J),J=1,7)
      DO 50 I=1,8
   50 WRITE(3,350) A(I),(X(I,J),J=1,7)
      DO 55 I=1,8
   55 WRITE(3,355) A(I),(PX(I,J),J=1,7)
      DO 60 K=1,NCOLS
   60 WRITE(3,360) B(K),BB(K),(Y(K,J),J=1,7)
   70 WRITE(3,370) (EC(J),J=1,7)
C  FORMAT STATEMENTS
  105 FORMAT(12X,A4,A1,69X,E16.6)
  107 FORMAT(86X,E16.6)
  109 FORMAT(12X,A4,6X,2E16.6)
  110 FORMAT(22X,2E16.6)
  115 FORMAT(12X,A4,A1,5X,E16.6)
  117 FORMAT(22X,E16.6)
  225 FORMAT(51X,F9.6)
  350 FORMAT(2X,A4,4X,7F8.4)
  355 FORMAT(2X,'P',A4,3X,7F8.4)
  360 FORMAT(2X,A4,A1,3X,7F8.4)
  365 FORMAT(2X,'P',A4,A1,2X,7F8.4)
  370 FORMAT(2X,'EC',6X,7F8.4)
      STOP
      END
 $ENTRY
```

The following FORTRAN program, GPLT, produces a plot file and corresponding printed values according to the choices made in CHPLT DATA.

```
$JOB
      REAL Z(6,7)
      REAL OUTP(6),SEC(6),PRIM(6)
      REAL WDFC(6),EDFC(6),WIND(6),EIND(6),WRTR(6),ERTR(6)
      REAL WOTR(6),EOTR(6),WCX3(6),WCX4(6),WCX6(6)
      REAL WCE(6),WCEX(6),ECX4(6)
      REAL ECIM(6),WOX6(6)
      REAL WOEX(6),WOE(6),WOG(6),EOX3(6)
      REAL EOIM(6),EOG(6),WLX1(6),WLX2(6),WLX3(6),WLX4(6)
      REAL ELX1(6),ELX2(6),ELX3(6),ELX4(6),WGX5(6)
      REAL WGX7(6),WGX8(6),WGX9(6),WGE(6),WGEX(6),EGX3(6)
      REAL EGX4(6),EGX5(6),EGX6(6),WEX4(6),EEX4(6),WEX5(6)
      REAL WEX6(6),WEX9(6)
      REAL WEX10(6),WEX11(6),WEEX(6),WCX5(6),EEX5(6),EEX6(6)
      REAL EEX9(6),EEX10(6),EEX11(6),EEEX(6),ECX3(6),WLA(6)
      REAL ELA(6)
      REAL WER(6),WEH(6),WEO(6)
      REAL WDX5(6),WDX6(6)
      REAL EER(6),EEH(6),EEO(6)
      REAL EDX5(6),EDX6(6)
      REAL WCX1(6),WCX2(6),ECX1(6),ECX2(6)
      REAL WOX1(6),WOX2(6),WOX3(6),WOX4(6),WOX5(6)
      REAL EOX1(6),EOX2(6)
      REAL WGX1(6),WGX2(6),WGX3(6),WGX4(6)
      REAL EGX1(6),EGX2(6),EC(6)
      REAL PWDFC(6),PEDFC(6),PWIND(6),PEIND(6)
      REAL PWRTR(6),PERTR(6),PWOTR(6),PEOTR(6)
      REAL PWCSB(6),PECSB(6),PWOSBL(6),PEOSBL(6)
      REAL PWGSB(6),PEGSB(6),PWESBE(6),PEESBE(6)
      REAL AGE(6),ALE(6),ACE(6),ALA(6),ALO(6),POIM(6),POEX(6)
      REAL MEDW,MEDE,MEIW,MEIE,MET
      INTEGER*2 PL(27)
      COMPLEX*16 RUNDES,RUNCOM
      COMMON RUNDES,RUNCOM
      DATA RUNDES/'BASE CASE;'/
      DATA RUNCOM/';'/
      COMPLEX*16 A1(3)/'WESTERN;','EASTERN;','IMPORTS;'/
      COMPLEX*16 A15(4)/'ELECTRICITY;','INDUSTRY;','SYNFUELS;','EXPORTS;
     C'/
      COMPLEX*16 A2(7)/'WESTERN;','WEST ARCTIC;','TAR SANDS;','EASTERN;'
     C,'FROM COAL;','FROM BIOMASS;','IMPORTS;'/
      COMPLEX*16 A25(6)/'ELECTRICITY;','DFC;','INDUSTRY;','ROAD TRANSPOR
     CT;','OTHER TRANSPORT;','EXPORTS;'/
      COMPLEX*16 A3(5)/'WESTERN;','WEST ARCTIC;','EASTERN;','FROM COAL;'
     C,'FROM BIOMASS;'/
      COMPLEX*16 A35(4)/'ELECTRICITY;','DFC;','INDUSTRY;','EXPORTS;'/
      COMPLEX*16 A4(5)/'HYDRO;','COAL;','OIL AND GAS;','NUCLEAR;','FROM
     CBIOMASS;'/
      COMPLEX*16 A45(4)/'DFC;','INDUSTRY;','ELECTRIC AUTO;','EXPORTS;'/
      COMPLEX*16 A5(3)/'ROAD, GASOLINE;','ROAD,ELECTRIC;','OTHER TRANSPO
     CRT;'/
      COMPLEX*16 A55(4)/'OIL;','GAS;','COAL;','ELECTRICITY;'/
      COMPLEX*16 A6(6)/'OIL;','GAS;','ELECTRIC RESIS.;','HEAT PUMP;','CO
     CGENERATION;','SOLAR;'/
      COMPLEX*16 A65(4)/'OTHER TRANSPORT;','ROAD TRANSPORT;','INDUSTRY;'
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```
     C,'DFC;'/
      COMPLEX*16 A7(6)/'COAL;','OIL;','GAS;','ELECTRICITY;','COGENERATIO
     CN;','SOLAR;'/
      COMPLEX*16 A8(3)/'OUTPUT;','SECONDARY;','PRIMARY;'/
      COMPLEX*16 A9(7)/'COAL;','OIL;','GAS;','NUCLEAR;','HYDRO;','BIOMAS
     CS;','SOLAR;'/
      COMPLEX*16 A10(2)/'WEST, AT MINE;','EAST,AT TORONTO;'/
      COMPLEX*16 A11(4)/'WEST;','EAST;','IMPORTS;','EXPORTS;'/
      COMPLEX*16 A12(2)/'WEST, WELLHEAD;','EAST,AT TORONTO;'/
      COMPLEX*16 A13(3)/'INDUSTRY;','ROAD TRANSPORT;','DFC;'/
      COMPLEX*16 A14(4)/'DFC;','INDUSTRY;','ROAD TRANSPORT;','OTHER TRAN
     CSPORT;'/
      DATA ACL/.1072/,ACG/0.567/
      DATA AGE/.0850,5*.0879/,ALE/.4942,.5746,4*.59/
      DATA ACE/.0954,.0998,.1028,3*.1113/
      DATA ALA/1.3527,1.6611,1.9694,2.3076,2.6457,2.9839/,AEA/2.388/
      DATA ALO/1.46,1.51,1.56,1.66,1.71,1.71/
      DATA AGI/.85/,ALI/4.13/,ACI/.87/,AEI/3.412/
      DATA AEO/3.412/,AEH/6.824/,AER/3.412/,AGH/.76/,ALH/3.835/
      DATA CBPT/21.0/,OBPB/5.8/,GBPM/1.04/,EBPK/3.412/
      DATA BWC/.9996/,BEC/.9994/,BWL/.9272/,BEL/.9262/
      DATA BWG/.8832/,BEG/.958/
      DATA POIM/1.08,1.48,1.93,3*3.2/
      DATA POEX/1.46,1.78,2.16,3*3.2/
      DATA MEDW/1.55/,MEDE/1.0/,MEIW/.18/,MEIE/-.1/,MET/1.03/
      READ(1,505)  PWCSB,PECSB,PWOSBL,PEOSBL,PWGSB,PEGSB,PWESBE,PEESBE
      READ(1,505)  WDFC,EDFC,WIND,EIND,WRTR,ERTR,WOTR,EOTR
      READ(1,505)  PWDFC,PEDFC,PWIND,PEIND,PWRTR,PERTR,PWOTR,PEOTR
      READ(1,505)  WCX3,WCX4,WCX6
      READ(1,505)
      READ(1,505)
      READ(1,505)  WCE,WCEX,ECX4
      READ(1,505)
      READ(1,505)
      READ(1,505)  ECIM,WOX6
      DO 1 K=1,6
    1 READ(1,505)
      READ(1,505)  WOEX,WOE,WOG,EOX3
      DO 2 K=1,3
    2 READ(1,505)
      READ(1,505)  EOIM,EOG,WLX1,WLX2,WLX3,WLX4
      READ(1,505)
      READ(1,505)  ELX1,ELX2,ELX3,ELX4,WGX5
      DO 3 K=1,6
    3 READ(1,505)
      READ(1,505)  WGX7,WGX8,WGX9,WGE,WGEX,EGX3
      DO 4 K=1,3
    4 READ(1,505)
      READ(1,505)  EGX4,EGX5,EGX6,WEX4,EEX4,WEX5,WEX6
      DO 5 K=1,6
    5 READ(1,505)
      READ(1,505)  WEX9,WEX10,WEX11,WEEX,WCX5,EEX5,EEX6
      DO 6 K=1,6
    6 READ(1,505)
      READ(1,505)  EEX9,EEX10,EEX11,EEEX,ECX3,WLA
```

```
      READ(1,505)
      READ(1,505)
      READ(1,505)  ELA
      READ(1,505)
      READ(1,505)
      READ(1,505)  WER,WEH,WEO
      DO 7 K=1,4
    7 READ(1,505)
      READ(1,505)  WDX5,WDX6
      READ(1,505)
      READ(1,505)
      READ(1,505)  EER,EEH,EEO
      DO 8 K=1,4
    8 READ(1,505)
      READ(1,505)  EDX5,EDX6
      READ(1,505)
      READ(1,505)
      READ(1,505)  WCX1,WCX2,ECX1,ECX2,WOX1,WOX2,WOX3,WOX4,WOX5
      READ(1,505)  EOX1,EOX2,WGX1,WGX2,WGX3,WGX4,EGX1,EGX2,EC
  505 FORMAT(10X,6F8.4)
      READ(2,510)  PL
  510 FORMAT(24X,I1)
C COAL PRODUCTION
 1010 IF(PL(1).EQ.0)  GO TO  1020
      DO  11  I=1,6
   11 Z(I,1)=(WCX1(I)+WCX2(I))/CBPT*10.
      DO  12  I=1,6
   12 Z(I,2)=(ECX1(I)+ECX2(I))/CBPT*10.
      DO  13  I=1,6
   13 Z(I,3)=ECIM(I)/CBPT*10.
      CALL GENPLT(Z,3,'COAL PRODUCTION:',16,'10**8 TONS PER YEAR ',20,A1
     C,4.0,1)
C COAL USE
 1020 IF(PL(2).EQ.0)  GO TO  1030
      DO  14  I=1,6
   14 Z(I,1)=(WCX5(I)+ECX3(I))/CBPT*10.
      DO  15  I=1,6
   15 Z(I,2)=(WCX6(I)+ECX4(I))/CBPT*10.
      DO  16  I=1,6
   16 Z(I,3)=(WCX3(I)+WCX4(I))/CBPT*10.
      DO  17  I=1,6
   17 Z(I,4)=WCEX(I)/CBPT*10.
      CALL GENPLT(Z,4,'COAL USE:',9,'10**8 TONS PER YEAR ',20,A15,4.0,1)
C OIL PRODUCTION
 1030 IF(PL(3).EQ.0)  GO TO  1040
      DO  21  I=1,6
   21 Z(I,1)=WOX1(I)+WOX2(I)
      DO  22  I=1,6
   22 Z(I,2)=WOX3(I)+WOX4(I)
      DO  23  I=1,6
   23 Z(I,3)=WOX5(I)
      DO  24  I=1,6
   24 Z(I,4)=EOX1(I)+EOX2(I)
      DO  25  I=1,6
   25 Z(I,5)=ACL*WCX3(I)
```

```
      DO 26 I=1,6
   26 Z(I,6)=WOX6(I)+EOX3(I)
      DO 27 I=1,6
   27 Z(I,7)=EOIM(I)
      CALL GENPLT(Z,7,'OIL PRODUCTION:',15,'10**9 BBL PER YEAR ',19,A2,1
     C.6,1)
C OIL USE
 1040 IF(PL(4).EQ.0) GO TO 1050
      DO 221 I=1,6
  221 Z(I,1)=WLX1(I)+ELX1(I)
      DO 222 I=1,6
  222 Z(I,2)=WLX2(I)+ELX2(I)
      DO 223 I=1,6
  223 Z(I,3)=WLX3(I)+ELX3(I)
      DO 224 I=1,6
  224 Z(I,4)=WLA(I)+ELA(I)
      DO 225 I=1,6
  225 Z(I,5)=WLX4(I)+ELX4(I)-Z(I,4)
      DO 226 I=1,6
  226 Z(I,6)=WOEX(I)
      CALL GENPLT(Z,6,'OIL USE:',8,'10**9 BBL PER YEAR ',19,A25,1.6,1)
C GAS PRODUCTION
 1050 IF(PL(5).EQ.0) GO TO 1060
      DO 31 I=1,6
   31 Z(I,1)=WGX1(I)+WGX2(I)
      DO 32 I=1,6
   32 Z(I,2)=WGX3(I)+WGX4(I)
      DO 33 I=1,6
   33 Z(I,3)=EGX1(I)+EGX2(I)
      DO 34 I=1,6
   34 Z(I,4)=ACG*WCX4(I)
      DO 35 I=1,6
   35 Z(I,5)=WGX5(I)+EGX3(I)
      CALL GENPLT(Z,5,'GAS PRODUCTION:',15,'TCF PER YEAR ',13,A3,8.0,1)
C GAS USE
 1060 IF(PL(6).EQ.0) GO TO 1070
      DO 36 I=1,6
   36 Z(I,1)=WGX7(I)+EGX4(I)
      DO 37 I=1,6
   37 Z(I,2)=WGX8(I)+EGX5(I)
      DO 38 I=1,6
   38 Z(I,3)=WGX9(I)+EGX6(I)
      DO 39 I=1,6
   39 Z(I,4)=WGEX(I)
      CALL GENPLT(Z,4,'GAS USE:',8,'TCF PER YEAR ',13,A35,8.0,1)
C ELECTRICITY, WEST
 1070 IF(PL(7).EQ.0) GO TO 1080
      DO 51 I=1,6
   51 Z(I,1)=WEX5(I)
      DO 52 I=1,6
   52 Z(I,2)=ACE(I)*WCX5(I)
      DO 54 I=1,6
   54 Z(I,3)=ALE(I)*WLX1(I)+AGE(I)*WGX7(I)
      DO 55 I=1,6
   55 Z(I,4)=WEX4(I)
```

```
      DO 56 I=1,6
   56 Z(I,5)=WEX6(I)
      CALL GENPLT(Z,5,'ELECTRICITY, WEST:',18,'10**12 KWH PER YEAR ',20,
     CA4,0.8,1)
C ELECTRICITY, EAST
 1080 IF(PL(8).EQ.0) GO TO 1090
      DO 61 I=1,6
   61 Z(I,1)=EEX5(I)
      DO 62 I=1,6
   62 Z(I,2)=ACE(I)*ECX3(I)
      DO 64 I=1,6
   64 Z(I,3)=ALE(I)*ELX1(I)+AGE(I)*EGX4(I)
      DO 65 I=1,6
   65 Z(I,4)=EEX4(I)
      DO 66 I=1,6
   66 Z(I,5)=EEX6(I)
      CALL GENPLT(Z,5,'ELECTRICITY, EAST:',18,'10**12 KWH PERYEAR ',20,
     CA4,3.2,1)
C ELECTRICITY USE
 1090 IF(PL(9).EQ.0) GO TO 1100
      DO 261 I=1,6
  261 Z(I,1)=WEX11(I)+EEX11(I)
      DO 262 I=1,6
  262 Z(I,2)=WEX9(I)+EEX9(I)
      DO 263 I=1,6
  263 Z(I,3)=WEX10(I)+EEX10(I)
      DO 264 I=1,6
  264 Z(I,4)=WEEX(I)+EEEX(I)
      CALL GENPLT(Z,4,'ELECTRICITY USE:',16,'10**12 KWH PER YEAR ',20,A4
     C5,3.2,1)
C TRANSPORTATION
 1100 IF(PL(10).EQ.0) GO TO 1110
      DO 71 I=1,6
   71 Z(I,1)=ALA(I)*(WLA(I)+ELA(I))
      DO 72 I=1,6
   72 Z(I,2)=AEA*(WEX10(I)+EEX10(I))
      DO 73 I=1,6
   73 Z(I,3)=WOTR(I)+EOTR(I)
      CALL GENPLT(Z,3,'TRANSPORTATION:',15,'10**15 BTU PER YEAR ',20,A5,
     C2.4,1)
C INDUSTRY
 1110 IF(PL(11).EQ.0) GO TO 1120
      DO 41 I=1,6
   41 Z(I,1)=ALI*(WLX3(I)+ELX3(I))
      DO 42 I=1,6
   42 Z(I,2)=AGI*(WGX9(I)+EGX6(I))
      DO 43 I=1,6
   43 Z(I,3)=ACI*(WCX6(I)+ECX4(I))
      DO 44 I=1,6
   44 Z(I,4)=AEI*(WEX9(I)+EEX9(I))
      CALL GENPLT(Z,4,'INDUSTRY:',9,'10**15 OUTPUT BTU/YR',20,A55,12.,1)
C DFC HEATING, WEST
 1120 IF(PL(12).EQ.0) GO TO 1130
      DO 81 I=1,6
   81 Z(I,1)=ALH*WLX2(I)
```

```
      DO 82 I=1,6
   82 Z(I,2)=AGH*WGX8(I)
      DO 83 I=1,6
   83 Z(I,3)=AER*WER(I)
      DO 84 I=1,6
   84 Z(I,4)=AEH*WEH(I)
      DO 85 I=1,6
   85 Z(I,5)=WDX5(I)
      DO 86 I=1,6
   86 Z(I,6)=WDX6(I)
      CALL GENPLT(Z,6,'DFC HEATING, WEST:',18,'10**15 OUTPUT BTU/YR',20,
     CA6,2.0,1)
C DFC HEATING, EAST
 1130 IF(PL(13).EQ.0) GO TO 1140
      DO 91 I=1,6
   91 Z(I,1)=ALH*ELX2(I)
      DO 92 I=1,6
   92 Z(I,2)=AGH*EGX5(I)
      DO 93 I=1,6
   93 Z(I,3)=AER*EER(I)
      DO 94 I=1,6
   94 Z(I,4)=AEH*EEH(I)
      DO 95 I=1,6
   95 Z(I,5)=EDX5(I)
      DO 96 I=1,6
   96 Z(I,6)=EDX6(I)
      CALL GENPLT(Z,6,'DFC HEATING, EAST:',18,'10**15 OUTPUT BTU/YR',20,
     CA6,4.0,1)
C OUTPUT SHARES, BY SECTOR
 1140 IF(PL(14).EQ.0) GO TO 1150
      DO 74 I=1,6
   74 Z(I,1)=WOTR(I)+EOTR(I)
      DO 75 I=1,6
   75 Z(I,2)=WRTR(I)+ERTR(I)
      DO 76 I=1,6
   76 Z(I,3)=WIND(I)+EIND(I)
      DO 77 I=1,6
   77 Z(I,4)=WDFC(I)+EDFC(I)
      DO 79 I=1,6
      TOTAL=0.0
      DO 78 J=1,4
   78 TOTAL=TOTAL+Z(I,J)
      DO 79 J=1,4
   79 Z(I,J)=Z(I,J)/TOTAL
      CALL GENPLT(Z,4,'OUTPUT SHARES:',14,'FRACTION',8,A65,1.6,1)
C SECONDARY SHARES, BY SECTOR
 1150 IF(PL(15).EQ.0) GO TO 1160
      DO 274 I=1,6
  274 Z(I,1)=OBPB*(WOTR(I)+EOTR(I))/ALO(I)
      DO 275 I=1,6
  275 Z(I,2)=OBPB*(WLA(I)+ELA(I))+EBPK*(WEX10(I)+EEX10(I))
      DO 276 I=1,6
  276 Z(I,3)=GBPM*(WGX9(I)+EGX6(I))+OBPB*(WLX3(I)+ELX3(I))+WCX6(I)+ECX4(
     CI)+EBPK*(WEX9(I)+EEX9(I))
      DO 277 I=1,6
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  277 Z(I,4)=GBPM*(WGX8(I)+EGX5(I))+OBPB*(WLX2(I)+ELX2(I))+EBPK*(WEX11(I
     C)+EEX11(I))+WDX5(I)+EDX5(I)+WDX6(I)+EDX6(I)
      DO 279 I=1,6
      TOTAL=0.0
      DO 278 J=1,4
  278 TOTAL=TOTAL+Z(I,J)
      DO 279 J=1,4
  279 Z(I,J)=Z(I,J)/TOTAL
      CALL GENPLT(Z,4,'SECONDARY SHARES:',17,'FRACTION',8,A65,1.6,1)
C OUTPUT SHARES, BY FUEL
 1160 IF(PL(16).EQ.0) GO TO 1170
      DO 101 I=1,6
  101 Z(I,1)=ACI*(WCX6(I)+ECX4(I))
      DO 102 I=1,6
  102 Z(I,2)=WOTR(I)+EOTR(I)+ALA(I)*(WLA(I)+ELA(I))+ALI*(WLX3(I)+ELX3(I)
     C)+ALH*(WLX2(I)+ELX2(I))
      DO 103 I=1,6
  103 Z(I,3)=AGI*(WGX9(I)+EGX6(I))+AGH*(WGX8(I)+EGX5(I))
      DO 104 I=1,6
  104 Z(I,4)=AEA*(WEX10(I)+EEX10(I))+AEI*(WEX9(I)+EEX9(I))+AER*(WER(I)+E
     CER(I))+AEH*(WEH(I)+EEH(I))+AEO*(WEO(I)+EEO(I))
      DO 105 I=1,6
  105 Z(I,5)=WDX5(I)+EDX5(I)
      DO 106 I=1,6
  106 Z(I,6)=WDX6(I)+EDX6(I)
      DO 109 I=1,6
      TOTAL=0.0
      DO 107 J=1,6
  107 TOTAL=TOTAL+Z(I,J)
      OUTP(I)=TOTAL
      DO 108 J=1,6
  108 Z(I,J)=Z(I,J)/TOTAL
  109 CONTINUE
      CALL GENPLT(Z,6,'OUTPUT SHARES:',14,'FRACTION ',9,A7,1.6,1)
C SECONDARY SHARES, BY FUEL
 1170 IF(PL(17).EQ.0) GO TO 1180
      DO 111 I=1,6
  111 Z(I,1)=WCX6(I)+ECX4(I)
      DO 112 I=1,6
  112 Z(I,2)=OBPB*(WLX4(I)+ELX4(I)+WLX3(I)+ELX3(I)+WLX2(I)+ELX2(I))
      DO 113 I=1,6
  113 Z(I,3)=GBPM*(WGX8(I)+WGX9(I)+EGX6(I)+EGX5(I))
      DO 114 I=1,6
  114 Z(I,4)=EBPK*(WEX11(I)+EEX11(I)+WEX10(I)+EEX10(I)+WEX9(I)+EEX9(I))
      DO 115 I=1,6
  115 Z(I,5)=WDX5(I)+EDX5(I)
      DO 116 I=1,6
  116 Z(I,6)=WDX6(I)+EDX6(I)
      DO 119 I=1,6
      TOTAL=0.0
      DO 117 J=1,6
  117 TOTAL=TOTAL+Z(I,J)
      SEC(I)=TOTAL
      DO 118 J=1,6
  118 Z(I,J)=Z(I,J)/TOTAL
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```
  119 CONTINUE
      CALL GENPLT(Z,6,'SECONDARY SHARES:',17,'FRACTION ',9,A7,1.6,1)
C PRIMARY FUEL SHARES
 1180 IF(PL(18).EQ.0) GO TO 1190
      DO 121 I=1,6
  121 Z(I,1)=WCX1(I)+WCX2(I)+ECX1(I)+ECX2(I)+ECIM(I)-WCEX(I)
      DO 122 I=1,6
  122 Z(I,2)=(WOX1(I)+WOX2(I)+WOX3(I)+WOX4(I)+WOX5(I)+EOX1(I)+EOX2(I)+EO
     CIM(I)-WOEX(I))*OBPB
      DO 123 I=1,6
  123 Z(I,3)=(WGX1(I)+WGX2(I)+WGX3(I)+WGX4(I)+EGX1(I)+EGX2(I)-WGEX(I))*G
     CBPM
      DO 124 I=1,6
  124 Z(I,4)=(WEX4(I)+EEX4(I))*EBPK
      DO 125 I=1,6
  125 Z(I,5)=(WEX5(I)+EEX5(I))*EBPK
      DO 126 I=1,6
  126 Z(I,6)=(WOX6(I)+EOX3(I))*OBPB+(WGX5(I)+EGX3(I))*GBPM+(WEX6(I)+EEX6
     C(I))*EBPK
      DO 127 I=1,6
  127 Z(I,7)=WDX6(I)+EDX6(I)
      DO 131 I=1,6
      TOTAL=0.0
      DO 129 J=1,7
  129 TOTAL=TOTAL+Z(I,J)
      PRIM(I)=TOTAL
      DO 130 J=1,7
  130 Z(I,J)=Z(I,J)/TOTAL
  131 CONTINUE
      CALL GENPLT(Z,7,'PRIMARY FUEL SHARES:',20,'FRACTION ',9,A9,1.6,1)
C TOTAL ENERGY
 1190 IF(PL(19).EQ.0) GO TO 1200
      DO 140 I=1,6
  140 Z(I,1)=OUTP(I)
      DO 141 I=1,6
  141 Z(I,2)=SEC(I)
      DO 142 I=1,6
  142 Z(I,3)=PRIM(I)
      CALL GENPLT(Z,3,'TOTAL ENERGY:',13,'10**15 BTU PER YEAR ',20,A8,32
     C.0,2)
C TOTAL ENERGY, ANNUAL CHANGE
 1200 IF(PL(20).EQ.0) GO TO 1210
      Z(1,1)=((OUTP(1)/3.1346)**.2-1.0)*100.0
      DO 151 I=2,3
  151 Z(I,1)=((OUTP(I)/OUTP(I-1))**.2-1.0)*100.0
      Z(4,1)=((OUTP(4)/OUTP(3))**.1333-1.0)*100.0
      DO 152 I=5,6
  152 Z(I,1)=((OUTP(I)/OUTP(I-1))**.1-1.0)*100.0
      Z(1,2)=((SEC(1)/5.0572)**.2-1.0)*100.0
      DO 153 I=2,3
  153 Z(I,2)=((SEC(I)/SEC(I-1))**.2-1.0)*100.0
      Z(4,2)=((SEC(4)/SEC(3))**.1333-1.0)*100.0
      DO 154 I=5,6
  154 Z(I,2)=((SEC(I)/SEC(I-1))**.1-1.0)*100.0
      Z(1,3)=((PRIM(1)/6.345)**.2-1.0)*100.0
```

```
      DO 155 I=2,3
  155 Z(I,3)=((PRIM(I)/PRIM(I-1))**.2-1.0)*100.0
      Z(4,3)=((PRIM(4)/PRIM(3))**.1333-1.0)*100.0
      DO 156 I=5,6
  156 Z(I,3)=((PRIM(I)/PRIM(I-1))**.1-1.0)*100.0
      CALL GENPLT(Z,3,'TOTAL ENERGY:',13,'% CHANGE PER YEAR ',18,A8,8.0,
     C2)
C COAL PRICES
 1210 IF(PL(21).EQ.0) GO TO 1220
      DO 161 I=1,6
  161 Z(I,1)=PWCSB(I)*CBPT*10.*BWC
      DO 162 I=1,6
  162 Z(I,2)=PECSB(I)*CBPT*10.*BEC
      CALL GENPLT(Z,2,'COAL PRICES:',12,'1975$ PER TON',13,A10,56.,2)
C CRUDE OIL PRICES
 1220 IF(PL(22).EQ.0) GO TO 1230
      DO 165 I=1,6
  165 Z(I,1)=PWOSBL(I)*10.*BWL
      DO 166 I=1,6
  166 Z(I,2)=PEOSBL(I)*10.*BEL
      DO 167 I=1,6
  167 Z(I,3)=POIM(I)*10.
      DO 168 I=1,6
  168 Z(I,4)=POEX(I)*10.
      CALL GENPLT(Z,4,'CRUDE OIL PRICES:',17,'1975$ PER BBL',13,A11,40.,
     C2)
C GAS PRICES
 1230 IF(PL(23).EQ.0) GO TO 1240
      DO 171 I=1,6
  171 Z(I,1)=PWGSB(I)*10.*BWG
      DO 172 I=1,6
  172 Z(I,2)=PEGSB(I)*10.*BEG
      CALL GENPLT(Z,2,'GAS PRICES:',11,'1975$ PER MCF',13,A12,4.0,2)
C WEST ELECTRIC PRICES
 1240 IF(PL(24).EQ.0) GO TO 1250
      DO 175 I=1,6
  175 Z(I,1)=PWESBE(I)+MEIW
      DO 176 I=1,6
  176 Z(I,2)=PWESBE(I)+MET
      DO 177 I=1,6
  177 Z(I,3)=PWESBE(I)+MEDW
      CALL GENPLT(Z,3,'WEST ELECTRIC PRICES',20,'1975 CENTS PER KWH',18,
     CA13,4.0,2)
C EAST ELECTRIC PRICES
 1250 IF(PL(25).EQ.0) GO TO 1260
      DO 181 I=1,6
  181 Z(I,1)=PEESBE(I)+MEIE
      DO 182 I=1,6
  182 Z(I,2)=PEESBE(I)+MET
      DO 183 I=1,6
  183 Z(I,3)=PEESBE(I)+MEDW
      CALL GENPLT(Z,3,'EAST ELECTRIC PRICES',20,'1975 CENTS PER KWH',18,
     CA13,4.0,2)
C OUTPUT PRICES, WEST
 1260 IF(PL(26).EQ.0) GO TO 1270
```

```
      DO 185 I=1,6
  185 Z(I,1)=PWDFC(I)/.5018
      DO 186 I=1,6
  186 Z(I,2)=PWIND(I)/.1434
      DO 187 I=1,6
  187 Z(I,3)=PWRTR(I)/2.2501
      DO 188 I=1,6
  188 Z(I,4)=PWOTR(I)/.8261
      CALL GENPLT(Z,4,'OUTPUT PRICES, WEST:',20,'INDEX (1970=1)',14,A14,
     C4.0,2)
C OUTPUT PRICES, EAST
 1270 IF(PL(27).EQ.0) GO TO 1280
      DO 191 I=1,6
  191 Z(I,1)=PEDFC(I)/.5089
      DO 192 I=1,6
  192 Z(I,2)=PEIND(I)/.1462
      DO 193 I=1,6
  193 Z(I,3)=PERTR(I)/2.3554
      DO 194 I=1,6
  194 Z(I,4)=PEOTR(I)/.8046
      CALL GENPLT(Z,4,'OUTPUT PRICES, EAST:',20,'INDEX (1970=1)',14,A14,
     C4.0,2)
 1280 STOP
      END
      SUBROUTINE GENPLT(Z,N,TITLE,NT,UNIT,NU,A,YMAX,NTYPE)
      DIMENSION Z(6,N),Y(6)
      LOGICAL*1 TITLE(NT),UNIT(NU),YL(20),GL(20),BLNK(20)/20*' '/
      REAL X(6)/1977.5,1982.5,1987.5,1995.0,2005.0,2015.0/
      COMPLEX*16 A(N),RUNDES,RUNCOM
      COMMON RUNDES,RUNCOM
      WRITE(4,400)
      WRITE(4,401)
      WRITE(4,401)
      WRITE(4,401)
      WRITE(4,401)
  400 FORMAT('1')
  401 FORMAT('0')
      WRITE(4,402) RUNDES,RUNCOM
  402 FORMAT('0',20X,2A8,5X,2A8)
      WRITE(4,800) TITLE
      WRITE(4,801) UNIT
      WRITE(4,403)
  403 FORMAT('0',15X,'AVERAGE VALUES FOR THE PERIOD ENDING IN')
      WRITE(4,404)
  404 FORMAT('0',26X,'1980',4X,'1985',4X,'1990',4X,'2000',4X,'2010',4X,'
     C2020')
      WRITE(4,401)
      DO 2 J=1,N
      K=N-J+1
    2 WRITE(4,900) A(K),(Z(I,K),I=1,6)
  800 FORMAT('0',7X,20A1)
  801 FORMAT(7X,' IN UNITS OF   ',20A1)
  900 FORMAT(8X,2A8,6F8.4)
      DO 1 K=1,20
      YL(K)=BLNK(K)
```

```
    1 GL(K)=BLNK(K)
      DO 3 K=1,NU
    3 YL(K)=UNIT(K)
      DO 4 K=1,NT
    4 GL(K)=TITLE(K)
      IF(N.EQ.1) GO TO 11
      IF(NTYPE.EQ.2) GO TO 11
      DO 10 I=1,6
      DO 5 J=2,N
    5 Z(I,J)=Z(I,J)+Z(I,J-1)
   10 CONTINUE
   11 YSF=YMAX/8.0
      DO 15 I=1,6
   15 Y(I)=Z(I,N)
      CALL ORIGIN(-0.1,0.,9)
      CALL GRAPH(6,X,Y,N,103,5.,8.,10.,1975.,YSF,0.0,'YEAR;',YL,GL,A(N))
      CALL LETTRS(0.,-0.1167,0.1167,'|            |           |           |
     C     |           |;',0.,51)
      CALL LETTRS(-0.2,-0.24,0.1167,'1975        1985        1995        2005
     C     2015        2025;',0.,54)
      CALL LETTRS(2.,8.1,0.2,RUNDES,0.,16)
      CALL LETTRS(2.5,7.9,0.1167,RUNCOM,0.,16)
      IF(N.EQ.1) GO TO 40
      NN=N-1
      DO 20 J=1,NN
      K=N-J
      DO 18 I=1,6
   18 Y(I)=Z(I,K)
      CALL GRAPHS(6,X,Y,K,103,A(K))
   20 CONTINUE
   40 CONTINUE
      RETURN
      END
$ENTRY
```

The file CHPLT DATA follows. Inserting a '0' suppresses production of a plot; a '1' tells GPLT to produce a plot.

```
COAL PRODUCTION        1
COAL USE               1
OIL PRODUCTION         1
OIL USE                1
GAS PRODUCTION         1
GAS USE                1
ELECTRICITY, WEST      1
ELECTRICITY, EAST      1
ELECTRICITY USE        1
TRANSPORTATION         1
INDUSTRY               1
DFC HEATING, WEST      1
DFC HEATING, EAST      1
OUTPUT SHARES, SECTOR  1
SECONDARY SHARES, SEC  1
OUTPUT SHARES, FUEL    1
SECONDARY SHARES, FUEL 1
PRIMARY FUEL SHARES    1
TOTAL ENERGY           1
TOTAL ENERGY, ANN.CH.  1
COAL PRICES            1
CRUDE OIL PRICES       1
GAS PRICES             1
WEST ELECTRIC PRICES   1
EAST ELECTRIC PRICES   1
OUTPUT PRICES, WEST    1
OUTPUT PRICES, EAST    1
```