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A techno economic energy model for Ontario.

Damyant. Luthra
University of Windsor

A TECHNO ECONOMIC ENERGY MODEL FOR ONTARIO

by

Damyant Luthra

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ABSTRACT

This dissertation develops an energy planning model for the province of Ontario. The model is a single period model with a target year of 2021 and uses linear programming to minimise the total annualised costs of meeting a set of exogenous end-use demands subject to techno-economic constraints that describe the energy system of the province of Ontario. The model includes a comprehensive detailed description of fuels and technologies of secondary conversion and end-use. The process approach, used to model the energy system extends up to the end-use stage. The model allows for both exports and imports of primary and secondary fuels. Other features include modelling of the petroleum refinery and the electric sector.

Three scenarios, namely, base, low and high energy demand were developed. To demonstrate the use of the model in addressing policy issues, several policy issues were examined.

Some of the important conclusions drawn from this study are the following. In the residential sector natural gas is the optimal fuel for space heating for houses. Further, a reduction itself in space heating demand brought about by building better designed houses is cost effective. In the

transportation sector, electric cars and cars fuelled by compressed natural gas together with gasoline and diesel fuelled cars make up the total demand for cars. This reduction of "top of the barrel" demand permits refineries of lower complexity to operate, thereby reducing overall costs. In the electrical sector, there is an increase in the share of nuclear generation.

The model has been created using WATEMS (Waterloo Energy Modelling System), which provides a very simple and user-friendly environment for data entry, changes to the structure and in running different scenarios.

To Pujya Abubabaji and my family

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LIST OF ABBREVIATIONS

General terms

CNG	Compressed natural gas
LNG	Liquified natural gas

Energy and Power terms

J	Joule (basic unit of energy in SI units)
KJ	Kilojoule (10^3J)
MJ	Megajoule (10^6J)
GJ	Gigajoule (10^9J)
TJ	Terajoule (10^{12}J)
PJ	Petajoule (10^{15}J)
EJ	Exajoule (10^{18}J)
kWh	Kilowatt hour (3.6 MJ)
mWh	Megawatt hour (3.6 GJ)
gWh	Gigawatt hour (3.6 TJ)
W	Watt [basic unit of power (1 J/second)]
KW	Kilowatt (10^3 W)
MW	Megawatt (10^6 W)
GW	Gigawatt (10^9 W)

CHAPTER I

INTRODUCTION

The design of an energy planning framework is extremely broad-based and complex. The experience of the last fifteen years has clearly shown that decisions regarding the energy sector have profound implications on the economy. Further, the production, transportation, conversion and end-use of all forms of energy have varying impacts on the natural environment. Therefore, a comprehensive energy planning framework should include the energy, economic and environmental sectors.

Each of these areas is complex in itself. Although traditionally energy policy falls largely in the domain of economics, econometric techniques, which are based largely on indirect statistical inference, have many drawbacks when used to model the energy sector. Their reliance on historic patterns not only excludes new forms of energy, but also the conclusions drawn from these models depend largely on historic data bases which are often limited in the information they provide. Wassily Leontief, the world famous economist, commenting on the growing undue use of econometric models to describe various phenomena such as the above type, states (Leontief, 1971),

"...econometric work...can be generally characterized as an attempt to compensate for the glaring weakness of the data base available to us by the widest possible use of more and more sophisticated statistical techniques. Alongside the mounting pile of elaborate theoretical models we see a fast-growing stock of equally intricate statistical tools. These are intended to stretch to the limit the meager supply of facts."

Commenting on future directions for model-building in such applications, he further states,

"To deepen the foundation of our analytical system it will be necessary to reach unhesitatingly beyond the limits of the domain of economic phenomena as it has been staked out up to now. The pursuit of a more fundamental understanding of the process of production inevitably leads into the area of engineering sciences".

Keeping with the spirit of Leontief's vision, a model of the energy sector of Ontario was developed. The model is based on a process approach which describes all energy activities in physical terms. Each activity is explicitly represented by technologies that are backed up by an extensive data base. The energy system of Ontario is described by a set of energy activities that start with the extraction stage, followed by conversion, distribution and end-use utilisation. The description includes existing energy types and technologies as well as alternative energy forms and new technologies that are under consideration. It is a single period model with a target year of 2021 that uses linear programming to minimise the total annual discounted costs of meeting a set of exogenous end-use demands subject to techno-economic constraints that describe the energy system of the province of Ontario. The model's major features are :

1. It includes a comprehensive description of fuels and technologies of secondary conversion and end-use. As space heating and transportation sectors are of special importance to Ontario, both these sectors have a high level of detail.
2. Both inter-regional and foreign trade have been considered explicitly for primary and secondary energy fuels.
3. It incorporates a simple refining submodel that is embedded within the main model. This permits the model to address substitutability of petroleum products by alternative fuels and their subsequent effect on the other petroleum products.
4. It includes a submodel for the electrical sector that takes into account the timing of electrical demands and supply. This submodel is part of the main model.
5. The model has been created using the WATEMS [Waterloo Energy Modelling System (Fuller, 1987)] framework. WATEMS is a tool for the creation of a broad class of energy-economic planning models. Data entry is in a spreadsheet format; this in itself makes the input and alterations of model structure and parameters very simple. Further,

computations for estimation of cost and demand parameters have been incorporated within spreadsheets, thus making the task of running and documenting different scenarios very simple.

The model can be used to study various policy issues. A base case scenario that represents a most likely case has been developed for the year 2021. In view of the uncertainty that exists in dealing with the future the model has been run for a low and a high energy demand scenario. Together, these three scenarios provide an environment to draw reasonably robust conclusions from model results. For example, model results for the year 2021, show space heating using induced gas furnace is the most optimal technology for houses of the Intermediate Solar type (a medium-high insulation house category in current description). This result holds true for all three scenarios and is therefore a robust conclusion. Four policy issues have been addressed here. These are a moratorium on new nuclear power plants, increasing electrical exports to the U.S., sensitivity of model results to oil prices and evaluating "soft" strategies for space heating in houses. Results from the first study show a decrease of electrical energy consumption due to an increase in cost of electricity generation, as coal plants replace the otherwise would be new nuclear plants. This study, amongst other findings, highlights the usefulness of such a model in examining issues, as the model takes into account the effects of changes that occur in other sectors due to changes in one sector. The second study highlights the "vulnerability" in increasing electricity exports when additional investment in increasing electrical generation is solely dedicated towards exports. The third study gives the changing picture of the transportation sector with increasing oil prices. For example, results indicate a trend of decreasing gasoline fuelled vehicles with increasing oil prices, the gap being filled by electric and compressed natural gas fuelled vehicles. This study highlights an important feature of the model, namely, modelling of the refinery process, which permits a realistic study of substitution of some of the petroleum products and their simultaneous effects on the refinery. The last study shows energy conservation brought about by designing better built houses, is cost effective, therefore construction of R2000 houses (a very high insulated house design) should be encouraged. The above mentioned policy studies are indicative of the wide range of policy issues that can be studied using the model.

The model adds to the existing modelling effort in Canada in several ways. By itself, it can be used to study various policy issues such as those mentioned above. Further, with the recent development of an energy model for Quebec, the two largest energy consuming provinces in

Canada (Ontario is the largest energy consumer followed by Quebec) have detailed energy models. Together, they both form a major step towards the development of a multiregional model for Canada. The multiregional model would not only be national in scale but would also provide detailed regional structures. This major provision, absent in national models that have been built so far, not only skews results of these models, but also renders them of little use for regional energy planning. In Ontario itself, a possible future link-up with the economic demand models developed at the Ministry of Energy Ontario (MEO) (or a variation of these models), would take a large step in the direction of a comprehensive energy planning framework for the province. Further, submodels of the refinery and the electric sector could form building blocks for future models.

Chapter 2 describes a review of energy planning models described in literature and the contribution made by the model developed here. Chapter 3 describes an overview of WATEMS and the modifications and extensions that were done in the course of creating and using the model. Chapter 4 describes the structure of the model and the modelling process using WATEMS. Also included are the descriptions of computation formulae developed for determining costs and end-use demands. Data collection and transformation to the form required for the base case (a most likely scenario) is described in Chapter 5. Description of data input and the input data spreadsheets are shown in Appendix A. Chapter 6 analyses model results for the base case. Data assumptions and analysis of model results for the low and high energy demand scenarios are described in Chapter 7. Detailed model results for the three scenarios are given in Appendix B. Four policy questions addressed by the model are described in Chapter 9, along with the analysis of the results. This dissertation concludes with the summary of the work and conclusions drawn from this study along with recommendations for future research.

CHAPTER II

REVIEW OF LITERATURE ON ENERGY SYSTEM MODELS

Within the last fifteen years many energy models have been developed to assist in analysing energy policy in different parts of the world. The intention here is to review some of the important models that provide an overview to the state of the art of energy modelling (on a national and regional context) as well as those models which are most relevant to the proposed research. A very comprehensive survey can be found in Manne et al. (1979) and Fuller and Ziemba (1980). This chapter concludes with the motivation for the model, the contribution it makes, and very briefly, the direction of future research possibilities emanating from this work. More on the latter subject is given in Chapter 9.

Hoffman (1972) used the process analysis approach to model the U.S. energy system, further development of which led to the Brookhaven Energy Systems Optimisation Model (BESOM, Hoffman 1973). As mentioned in the previous chapter, the process analysis approach considers the conversion of energy sources and their distribution among end-use demands in physical terms. The description can encompass the entire system of energy production and distribution including new technologies emerging from research and development. BESOM consists of a network representation of the energy flows from primary energy sources through conversion, transportation, distribution and end-use utilisation. The entire U.S. is considered as one region. The demands are specified as space heating, water heating, etc., in the form of functional end-uses as well as application type, such as iron and steel, autos, etc. The model has a linear programming formulation and the optimisation is done on the basis of total costs for a single year subject to supply, demand, environmental and other technical constraints.

Hudson and Jorgenson (H-J, 1974) developed a model based on the interaction of econometric modelling and input-output analysis. The econometric approach uses regression techniques and basically projects past or historic behaviour to the future. The model consists of a production model for nine industrial sectors (five energy and four non-energy sectors), a model for consumer demand and a macroeconomic growth model for the U.S. economy. Supplies and demands are brought into equilibrium by a balance mechanism and related to the patterns of U.S. economic growth. The model can assess the impact of energy policy on both demands and supplies of energy and on the overall level of economic activity. The model has been used to design a tax program for stimulating energy conservation and reducing dependance on imported sources of energy.

Both BESOM and the H-J models have their drawbacks. The process analysis approach in BESOM provides an explicit representation of the technological sector from the extraction to the end-use inclusive of future technological options. However, the process approach cannot be extended to describe economic activity. On the other hand, the econometric approach describes the technological sector in economic terms. Though well suited for describing economic activity at an aggregate level, it obviously cannot be extended to include new technologies which are not already in use.

The H-J and BESOM combined model (Hoffman and Jorgenson, 1977) provides a detailed characterisation of the energy sector and a complete representation of the economy. The econometric model reflects changes in the economy at an aggregate level such as gross national product (GNP), employment, etc., and also includes changes in final demand for energy for a given economic or technical policy. Thus, given the economic environment, the process model determines the optimal use of resources with respect to technical and environmental constraints. The model can be used to study the impact of economic policy on the technological sector as well as the impact of new technologies on the economy. The time period is a single year.

A dynamic version of the combined model has also been developed (Behling et al., 1977). The integrated system, DESOM/LITM (Dynamic energy System Optimisation Model/Long Term Interindustry Transactions Model) generates energy / economic / environmental scenarios to the year 2020. A multiregional static version of the combined model was also developed (Goettle et al., 1977). The entire U.S. was divided into nine regions, which are linked by inter-regional energy and industrial flows.

A successor to DESOM was MARKAL (an acronym for 'market allocation'), a result of an international cooperative effort conducted by Brookhaven National Laboratory, USA and Kernforschungsanlage, in Julich, West Germany (described in Fishbone and Abilock, 1981). MARKAL is a demand driven, multiperiod, linear programming model of energy supply and demand. Its major features include capability for multiobjective analysis, a choice of up to sixteen time periods and an automated data management system. For each time period, the user supplies information for various generic classes of energy technologies or resources, the important ones being, energy carriers such as primary and secondary fuels; processes, which transform energy carriers into one another; conversion systems, which converts fuels into electricity; and demand devices, which change some form of energy into a useful service. The main computer routines for matrix and report generation are written in the PDS/MAGEN language. The optimization code used is the APEX linear programming optimizer. The MARKAL framework has been used for analysing energy policy in several countries.

The Julich Energy Model system (JES) developed at Julich for energy planning for West Germany is a comprehensive energy planning framework (described in Egbert et al., 1981). The integrated framework consists of a simulation model coupled with two optimisation models. The simulation model consists of four modules, the modules for energy supply and demand coupled with a macroeconomic module and an environmental module. The supply and demand modules are linked by two optimisation models, MARKAL and a similar but less detailed model called MESSAGE.

Similar to the Brookhaven models is the Greek Energy System Optimisation Models (GRESOM) developed for energy planning in Greece (described in Samouilidis and Berahas, 1984). GRESOM has been linked with a simplified model of the economy, thus providing a framework for analysing energy economic interactions. Also similar in approach is an energy planning model for Puerto Rico (described in Haddock and Sparrow, 1985).

Manne (1976) developed the Energy Technology Assessment (ETA) model for the U.S. using a combination of process analysis and econometrics. It is a nonlinear programming model which maximises consumers' and producers' surplus, or equivalently, minimises costs of conservation, interfuel substitution and supply. The supply side of ETA is modelled using a conventional linear programming process analysis approach. The demand side of ETA is based on a hybrid of econometrics and process analysis. Energy demands are categorised in two broad categories, electric and non-electric and are estimated based on GNP growth and energy prices. It is a partial equilibrium model as GNP growth is an exogenous variable which is not affected by the energy sector. ETA has been used extensively to study nuclear power issues.

An extension of ETA was ETA-MACRO (Manne, 1977) which combined ETA with a macroeconomic growth model, thus providing a two way linkage between the energy sector and the economy. The general equilibrium model permits the exploration of macroeconomic issues as they are affected by changes in technologies or policies in the energy sector.

The IDES (Integrated Demand and Energy Supply) model (Macal, 1987) is a generalised equilibrium model that integrates energy supply and demand. The energy sector is represented by an energy network that consists of nodes and links. The nodes are of different types, each type representing a particular energy activity such as conversion, electrical generation, etc. An iterative procedure determines the equilibrium solution, i.e. sets of prices and quantities that satisfy all equations and inequalities that desribe the energy sector. The time horizon is up to 30 years in steps of 1 year. The computer code is written in Fortran. IDES can be run on a microcomputer as well as on the main frame. The framework has been used to model the energy sector of a Caribbean nation over a 20 year period.

Debanne (1980) describes a succession of network based energy planning models that looks at North America as a whole. The first model was a one commodity model and did not include transformation processes. Subsequent versions extended into multi-commodity and included transformation processes. The equilibrium models calculate period by period energy prices, demands and supplies. The models are useful for energy planning from a continental point of view.

Several models have been developed for energy planning for Canada. Helliwell et al. (described in Fuller and Ziemba, 1980) developed an econometric model which focusses on the assessment of macroeconomic impacts of large energy projects on the Canadian economy. Exogenous to the model are oil and gas prices, the gross national expenditure (GNE), price of electricity, the growth of hydroelectric supplies and growth of natural gas distribution. Given the above, the model calculates the demands for all end-use sectors. The demands are aggregated in terms of oil, gas, coal and electricity. The supplies are aggregated as frontier natural gas, non frontier natural gas, crude oil, Athabasca synthetic crude oil, coal and electricity. The model can be used to analyse a variety of policies such as trade, energy price and taxation.

The Canadian Explor Model (CEM, described in Fuller and Ziemba, 1980) is a revised version of the basic Explor model developed at Batelle Research Centre in Geneva,for application to European countries. The macroeconomic model covers the entire economy. Though designed for analysing economic policies it contains an energy sector which permits the analysis of certain energy issues such as energy pricing studies., energy conservation programs and impacts of capital invested in the energy sector. The energy sector is divided into coal, crude oil and natural gas, oil products, electric power, gas and other utilities. It is a static model covering the period to 2000.

CANDIDE is a national econometric model of the Canadian economy with an extended energy sector (described in Fuller and Ziemba (1980). The model treats the entire nation as one region. The model has similar applications as CEM.

The Fuller and Ziemba (F-Z) model (Fuller, 1980) is a dynamic model of the Canadian energy sector for long term planning. Similar in many aspects to Manne's ETA model, it uses a combination of process analysis and econometrics.

The supply conversion and distribution are handled using a process approach. Demands are obtained from an econometric model. Nonlinear programming is used to find the supply-demand equilibrium by maximising the producers' and consumers' surplus over all periods. Six time periods cover the span of 45 years from 1975 to 2020, the first three of length five years followed by three of length ten years. A very important distinction in the model is the "regionalising" of the country into two regions, East and West, with the dividing line at the Ontario-Manitoba border. The model has a high level of aggregation. The supply sources are oil, gas, coal, electricity and solar. The demands are classified as road transportation (autos), other transportation (non-auto), industrial, and domestic, farm and commercial (heating and non-heating). The process analysis is carried to the end-use stage only for the heating demand. The other demands are in terms of secondary fuels. Thus interfuel substitution is determined endogenously only for the heating category, for the others, upper and lower limits on the shares of input fuels have been placed. The model is a partial equilibrium model, i.e. it has a one way energy-economy linkage.

The Canadian Balance model developed by Daniel and Golgberg (1981) is a dynamic partial equilibrium econometric model. It consists of a linear programming supply model for Canada which is integrated with the Energy

Mines and Resources (EMR) demand model using a linear programming procedure. The linear programming supply model determines the minimum cost of supply of primary energy resources to meet the demands in each of the time periods. The emphasis on the supply are on the Western fossil fuel resources. The emphasis on the supply side are on Western fossil fuel resources. The EMR demand model derives demands for the primary resources as a function of price. Using various economic and demographic variables obtained from CANDIDE, the economic estimation equations determine sectoral end-use demands from which market sharing equations estimate the share of secondary energy forms which are then translated into demands for primary resources. A linear programming procedure is used to balance supply and demand so as to achieve price compatibility. The model has four time periods covering the span of 20 years (1980-2000), each period having a length of five years.

The WATEMS (Waterloo Energy Modelling System) framework (Fuller, 1987) is a tool for the creation of a broad class of energy-economic planning models. Examples of models that could in principal be built include the F-Z model, ETA, ETA-MACRO, the Brookhaven series of models (BESOM, DESOM, etc.), etc. Data on network structure, costs, efficiencies, etc. are entered into a spreadsheet. This data is then processed by a Fortran program (special purpose matrix generator) that translates the input data in the form required by the mathematical programming package, MINOS [Modular Incore Nonlinear Optimization System (Murtagh and Sanders, 1983)]. The solution obtained is processed by another Fortran program and entered into another spreadsheet for report generation. The framework is flexible. Five basic types of constraints are available to the user to "build" the energy system. The partial reliance on spreadsheets not only makes the input and alterations of model structure very simple but also permits the user to utilise the spreadsheet for pre-processing the data and post-processing the model results. Further, the framework is open to modifications and extensions, thus leaving the user with tremendous flexibility in creating and running the model.

The models that have been described above are national in scale. Apart from the F-Z model, all other models view the entire nation as one region. The latter models have a high level of aggregation such as average supply-demand patterns, average costs of transportation, etc., the averaging process being done over the entire nation. The F-Z model takes the first step in "regionalising" a model that is national in scale. However, it also has a high level of aggregation. For example, the entire Eastern Canada is represented by one region. Further, the model structure itself is relatively small in size. The above models are therefore of limited use, when the objective is to provide an analysis of the energy system on a regional level.

McConaghy and Quon (1980) developed a regional model for short and medium term planning for Alberta. It is a linear programming model with four time periods ranging from 1977 to 1995. The model is formulated using a process analysis approach and is similar in many respects to BESOM. The model concentrates on the supply side and does not carry out the modelling to the end-use stage. The energy resources that are considered are crude oil, coal, oil sands, natural gas, natural gas liquids and renewable energy sources (solar, wind and biomass). The energy demands are classified in terms of energy forms demanded such as electric power, refinery products, etc. The decision variables are energy, capital, material and human resources that are required to satisfy the energy demands. The model minimises the allocation of Alberta's energy resources over a planning period to satisfy future national and provincial energy demands.

In recent years a very detailed energy model of the energy sector has been developed for Quebec (Haurie and Loulou, 1985) using the MARKAL framework. MARKAL-QUEBEC is a multiperiod linear programming model. The description starts with the extraction stage through the process of conversion and distribution and finally through end-use utilisation. The primary objective function is the total system discounted cost, minimisation of which leads to the selection of least-cost energy activities that satisfy the set of exogenous demands. MARKAL-QUEBEC can be used to evaluate a wide range of government policies, new technologies and major energy projects for the province of Quebec.

The Ministry of Energy Ontario has an integrated framework that links a set of energy demand models with a set of models that describe the economy (Jutlah, 1985). For a given economic scenario, the energy demand models determine the demands for various fuel types which in turn are linked by a supply model that translates secondary energy demands to primary energy requirements. The methodology used is a combination of econometrics and technological forecasting. The framework is detailed and essentially provides an accounting tool for determining energy demands by fuel types for a given economic scenario on an annual basis.

Recent discussions with Ontario Hydro (Duda et al., 1987) indicate work in progress on an end-use process model for the industrial sector of Ontario. At present the work is limited to the pulp and paper industry. The model is being developed using the process approach.

The above literature review suggests that a comprehensive energy planning model should have the energy, economic and environmental sectors, a good example being the JES system in West Germany. Secondly, it is essential to develop regional energy models, not only for regional energy planning, but also from the viewpoint of national energy planning, for which a multiregional model is quintessential (this is especially true for Canada, since there is a geographic uneven distribution of energy resources and demands. The Western regions with most of the fossil fuel supplies are the major energy producers, while the heaviest markets are in the East. As the cost of transportation and the development of transportation systems have been a formidable barrier, this has given rise to sizable regional variations in the forms of energy used, which in turn has given rise to energy issues that are markedly different from region to region).

The model developed in this dissertation is a detailed process model for Ontario. To get an idea of the detail that is supported, the Ontario energy structure in the model is described by 419 arcs (variables), while the Eastern region in the F-Z model (the nearest equivalent to Ontario's structure that was available before the model developed here), which also represents an aggregation over Quebec, Ontario, and the Atlantic provinces, is described by approximately 40 arcs (variables). Further, in recent years, energy planning in Ontario, amongst other objectives, has focussed on conservation techniques (for space heating) and alternative energy fuels for transportation. For instance, in the transportation sector which accounts for approximately 50% of the crude oil consumption, alternative fuels such as propane, compressed/liquefied natural gas, alcohols, synthetic liquid hydrocarbons, liquid hydrogen and electricity have been and are under consideration, with some of these being actively promoted. In the residential and commercial sector, conservation techniques have been encouraged for existing buildings and for better designed new buildings (e.g. the R2000 houses). There has also been emphasis on more energy efficient heating equipment and on new methods using active and passive solar energy. Clearly evident is the lack of existing energy planning models to analyse these policy issues, and this fact provides motivation for the model in this work.

The development of this model takes a major step in two directions. Firstly, together with MARKAL-QUEBEC, they form a major part of a national multiregional model. As mentioned in Chapter 1, the multiregional model, encompassing the entire nation, would provide a more accurate and detailed enery planning model at a national as well as a regional level. Secondly, on a regional level only, a possible link with the MEO models (or variants of these), and extension of the model to include environmental effects, would provide Ontario with a comprehensive energy planning framework.

The model in this dissertation has been created using the WATEMS framework. In order to create and run the model some modifications and extensions were done to the framework. These were mainly due to the large size of the model. Amongst other changes, one particular modification was the rewriting of spreadsheet macros in such a way that no modifications were required of them as model structure changed. The above practical feature is extremely useful in the creation of large models, as otherwise one would need to update changes in the macros everytime there are changes in model structure. Extensions to the framework were done in two areas. The first extension was a design of a separate spreadsheet for scenario analysis that made it simple to create and record different scenarios. The second extension introduced a comparison facility in the framework thereby permitting the comparison between two solutions.

The following chapter gives an overview of WATEMS and a detailed description of the modifications and extensions to the framework.

CHAPTER III

WATEMS -- AN OVERVIEW AND MODIFICATIONS AND EXTENSIONS

3.1 Overview of WATEMS

3.1.1 Introduction

As mentioned in the previous chapter, WATEMS is a system designed for the easy construction and updating of a wide range of energy planning models which use mathematical programming techniques. With WATEMS, two broad classes of models can be constructed. One type of model will minimise the total discounted costs of meeting projected demands, examples of such models being BESOM, DESOM, MARKAL, etc. The other type calculates a dynamic, competitive equilibrium, by maximisation of consumers' plus producers' surplus, examples being ETA, F-Z model, etc. The description here is directed mostly to the features provided by WATEMS for modelling the former group of models, since the model developed here belongs to the broad class of cost minimisation models. In addition, since it is a single period model, only some of the features of WATEMS are used. The description concentrates mainly on those features that are actually used. More details can be found in Fuller (1987).

Briefly, data on network structure, costs, resource amounts, conversion efficiencies, process lifetimes and decline curves, bounds, discount rate, number and size of periods, and demand functions are entered into a spreadsheet, along with variable and node names, and names of units. The data is then processed by a Fortran program, which is a special purpose matrix generator and the primary component of WATEMS. The output produced is a translation of the input data in the form required by the mathematical programming package, MINOS. The solution obtained is processed by another Fortran program and entered into another spreadsheet containing titles (node names, variable names, etc.), where it can be manipulated to produce reports consisting of tables and graphs.

3.1.2 Possible constraints and objective functions

WATEMS offers the user five types of constraints, namely, energy balance, retirement and production decline, reserve, share limit, and bounds on variables. The objective function consists of two parts, the linear part made up of discounted costs and a nonlinear part that describes consumers' benefits. The model developed here uses three constraints, namely, the energy balance, share limit and bounds on variables. Further, being a cost minimisation model only the linear portion of the objective function was used. For the reader's convenience, those features of WATEMS that were used are described below. The description is taken mostly from Fuller (1987).

3.1.2.1 Energy balance constraints: Any model built with WATEMS has a network structure; energy from various sources is collected together at nodes, and then sent out from the nodes to various destinations, which are other nodes or final demands. The fundamental variables of the model are the annual rates of flow on the arcs. At each node, m, for each time period, t, there is an energy balance constraint, which says that the amount of energy collected at the node equals the amount of energy sent out. There is provision, for some fraction, β_{mt} of the energy to be lost -- e.g. to represent transportation losses. A loss may alternatively be represented by a conversion efficiency for a process on an incoming arc.

Let X_{it} (a variable) be the annual rate of energy flowing along arc i in period t, with conversion efficiency ϵ_{it}; and let β_{mt} be as above. Let Im be the set of indexes for incoming arcs at node m, and let Om be the indexes for outgoing arcs at node m. Then the energy balance constraint for this node and time period t is:

$$(1-\beta_{mt}) \sum_{i \in Im} \epsilon_{it} X_{it} = \sum_{j \in Om} X_{jt} \text{, for all } t. \qquad \ldots 3.1$$

The user must enter information on the network structure (nodes of origin and destination for each X_{it}), and on numerical values of β_{mt} and ϵ_{it}. The parameters β_{mt} and ϵ_{it} may be specified as constant or varying functions of time. In the latter case, a few parameters specify a function of a certain form; since the model developed here is a single period model, these values are zero.

For a cost minimisation model, the optimal dual variables for constraints 3.1 represents marginal costs. WATEMS calculates marginal costs for each node and sends these to the report spreadsheet.

3.1.2.2 <u>Share limit constraints</u>: It is occasionally necessary to limit the fraction of total incoming (or outgoing) flow at a node that can be supplied by one of the incoming (outgoing) flows; this may be an upper limit, a lower limit, or an equality constraint. If f_{it} is the exogenous fraction in period t, if Im is the set of indexes of all incoming sources at the node m into which X_{it} flows, if Om' is the set of indexes of all outgoing sources at the node m' from which X_{it} flows, and if ϵ_{it} is the conversion efficiency, then the constraint is of this form:

$$\epsilon_{it} X_{it} \begin{matrix} \geq \\ = \\ \leq \end{matrix} f_{it} \sum_{j \in Im} \epsilon_{jt} X_{jt}, \qquad \ldots 3.2a$$

at the incoming node, and,

$$X_{it} \begin{matrix} \geq \\ = \\ \leq \end{matrix} f_{it} \sum_{j \in Om'} X_{jt}, \qquad \ldots 3.2b$$

at the outgoing node.

3.1.2.3 <u>Bounds on variables</u>: WATEMS permits the specification of bounds on any X_{it} variables. These may be upper bounds, lower bounds or fixed inequalities.

3.1.2.4 <u>Objective function (linear part for a cost minimisation model)</u>: WATEMS maximises the negative sum of the total cost of meeting demands for the various sources of supply (the linear part actually is part of a nonlinear objective function that describes the consumers' and producers' surplus that is maximised; however, for cost minimisation models, the linear part is the only objective).

If δ is the annual discount rate, if X_{it} and ϵ_{it} are as in section 3.1.2.1, described earlier, if σ_i is the number of basic units of energy per natural unit of variable i, if c_{it} is the cost per natural unit of output energy, and if w is the length of a period, then the linear part of the objective function is of this form:

$$-\sum_t\sum_i(1+\delta)^{-t}(c_{it}\epsilon_{it}/\sigma_i)wX_{it} \qquad \ldots 3.3$$

where the symbol "t" in the discount factor represents the number of years after year zero to the midpoint of the period in question (for a single period model, t=0); elsewhere in 3.3 , the symbol "t" is an index for the periods as in the earlier definations (which again is not required for a single period model.

These four features were used to model the Ontario energy system. Other features of WATEMS not used here include two sets of constraints, namely, retirement and production decline, and reserve constraints. In addition, there is the nonlinear part of the objective function that permits a calculation of competitive equilibrium of supply and demand, that was not used.

3.1.3 Overview of the input spreadsheet

Data input is in a spreadsheet. The description here is an overview and describes the approach for model creation in WATEMS.

The first few rows of the input spreadsheet are common to all models. These rows include titles that describe the information to be entered and general information about the model.

The next set of rows are used to describe the nodes of the model. Each node is described in a separate row, and is described by a node name and by entries known as "switches". If the first switch is zero then $\beta_{mt}=0$ for the node of that row. If the first switch equals 1 then β_{mt} is constant in all periods and is given by the value entered in the next column. If the first switch equals 2 then β_{mt} would follow a time pattern specified by four parameters, their descriptions being specified in the next four columns (does not apply to the model developed here). The last node information are node units, these being specified in the next column. The order in which the rows are specified is of importance, since the same numerical order is used to specify the structure in the variable information section.

Variable information follows next. Each variable is described in a separate row. The name of the variable is entered in the first column. The next two columns are used to specify the model structure, i.e. the starting and ending node for that variable. The next set of columns are reserved for information regarding various features such as share constraints, bounds, costs, conversion efficiencies, etc. A feature (such as a bound on the variable) can be selected by a "switch", -- an integer placed in the appropriate column of that variable's row. A switch of zero means that the feature is not selected; a small number of positive integers have specific meanings that not only select the feature, but also specify such things as the type of bound (upper, lower, or equality). The first digit of the three digit integer indicates that the bound is on X (X_{it} variables) or on the D variable (the D variables are used for dynamic models; in the model developed here the variables are all of the X type), the second digit specifies an upper, lower or equality bound, and the third digit selects the time pattern for the bound. A similar approach is used to select other features.

3.1.4 Connecting the input and report spreadsheets with MINOS

On completion of the input spreadsheet, macros are invoked that separate the numeric content (space separated format or comma separated format; either way it can be read by a format free FORTRAN statement) and the character information (list of nodes, variables, etc.); the numeric part is uploaded to the main frame by any file transfer program duch as KERMIT, PC-TALK, etc., while the character information is saved in another spreadsheet for the report. In the main frame a Fortran program (special purpose matrix generator) processes this information and converts it into the format required for MINOS. The solution from the optimisation program is processed by another Fortran program that reads the output from MINOS, calculates the marginal costs (prices for models that maximise the consumers' and producers' surplus) from the dual variables of the energy balance constraints, and writes the marginal costs (prices) and X-variable values to a file in comma separated value format. This file is then downloaded and re-entered in the report spreadsheet with the marginal costs (prices) lining up with the corresponding node names and the X-variable values lining up with the corresponding variable names.

The WATEMS framework provides a simple and easy method for creation, alterations and running of energy planning models of the mathematical programming type. The framework is flexible in that, the user can model a wide range of systems or phenomena with the help of the constraints provided. Advantages of using spreadsheets for data entry are only too well known and require no elaboration. However, of particular advantage in their use here is the availability of the unused portion of the spreadsheet for computations for costs, demands, etc., i.e. the WATEMS description of the model extends to column H for node information and column AS for variable information. The columns to the right of these columns can be used for specifying data regarding costs, etc., thus permitting pre-processing of data on the same spreadsheet. In addition, the spreadsheets and the main frame programs can be easily modified and extended in many ways.

In order to create and run the model developed here in WATEMS, minor modifications were required to the WATEMS framework. Further, because of the large size of the model, the WATEMS system has been extended in certain ways to simplify its use. These changes are described in the next section.

3.2 Modifications and extensions to WATEMS

There were a few minor modifications that were done to the WATEMS system. Changes in the matrix generator (FORTRAN program; in particular SPECS subroutine and the objective function cost subroutine) permit the model to be minimised directly rather than by the maximisation of the negative sum of the discounted costs, a form more suitable for the nonlinear consumers' and producers' surplus formulation.

The macro programs in the spreadsheet were rewritten in terms of range names rather than specific addresses. This feature permitted the automatic update of the macros when nodes or variables were added to the model, thus eliminating the simultaneous update of the macro programs which was an unnecessarily time consuming repetitive task especially when working on a large model and on a regular personal computer.

As mentioned in the beginning of the chapter and in some following sections, there were some features of WATEMS that were not used. As the model was large in size, in order to reduce inputting time and overall manageability of the spreadsheet, some of the extra columns that were reserved for these descriptions, were deleted. This required a change in the READ statement of the matrix generator to map the variables with their corresponding values.

The first extension to WATEMS was the introduction of another spreadsheet. This spreadsheet contains a list of parameters that one would like to vary to create different scenarios, such as interest rates, resource,prices, etc., alongside an entry cell for inputting values. These parameters were linked with end-use demand formulae which were entered within the same spreadsheet. Therefore, with any change in the specification of the parameters produced simultaneous recomputations of end-use demands. This spreadsheet, being small in size is easy to work with. On completion of it, the information is automatically mapped on to the required cells in the main spreadsheet and the smaller spreadsheet is saved as a separate file for future reference. The automatic interfacing was brought about by writing two macros. The first one saves the file on two disks, on a separate disk for future record and on the disk that contained the main spreadsheet. On completion of it, it loads the main input spreadsheet. The other macro transfers the information. This macro, named as a "\ 0" macro, automatically invokes itself everytime the WATEMS spreadsheet is loaded (a facility offered in the LOTUS spreadsheet). The resource prices, end-use demands, etc., are mapped on to an "unused portion" of the spreadsheet from where they are linked to the corresponding cells. Thus, to run different scenarios, only the scenario spreadsheet needs to be accessed. Changes are automatically mapped to the main spreadsheet. This facility greatly simplifies and reduces the time to create, run, and save different scenarios.

The second extension to the WATEMS framework was the addition of a new facility for the comparison of results. During the analysis of model, results need to be compared very often. Since there are a large number of variables this facility is useful. This basically involved the writing of a FORTRAN program in the main frame that read data from three files, these being an abbreviated data file of the input data, and the two solution files (the comma separated value formatted output result files). Based on O'Leary's (1987) comments on what should be compared, the program determines whether the basic variables still remain basic, and if so, it determines whether there is any change or not in their values. Conversely, for a nonbasic variable, it determines whether it remains nonbasic or if it has changed to basic. The output results are imported as a text file (as the results contain numeric and character information) into a report spreadsheet which contains the variable names and units. The results align themselves with the corresponding variable names and their units.

These changes in WATEMS permitted an easy construction and running of the model developed here. The next chapter gives a description of the model and the modelling process.

CHAPTER 1V

MODELLING OF THE ONTARIO ENERGY SYSTEM

Before energy can be supplied in usable forms to the consumer a certain sequence of activities is required. Crude oil is transported to the refinery. The refinery produces a range of petroleum products. Some of the products such as fuel oils are transported to power plants for electric power generation as well as transported directly to consuming industries, etc., while products such as gasoline and diesel are transported directly to local supply centres from where they are distributed to consumers. Coal is transported to power plants as well as directly to the end-use consumers (Iron and Steel Industry, etc.). Natural gas is transported to electrical generation power plants as well as to local distribution centres which finally distribute the gas to residential, commercial and industrial consumers. Solar energy follows a different pattern. It is not extractable nor transportable in the way the fossil fuels are and is available on site of utilisation. Finally, the electricity that is available from power plants is transmitted to local distribution centres from where it is distributed for end-use utilisation.

It is this sequence of activities that is modelled for the Ontario energy system. The sequence of activities can be considered as a multistage network that starts from the supply stage, through conversion, transportation and distribution, and ends at the end-use utilisation stage. From an optimisation viewpoint, the problem can be defined as minimising the total costs of all stages subject to supply restrictions, demand requirements and technical constraints that describe the energy system. The aim in constructing the model has been to include as much detail as possible. However, the detail in structure must be supported by an equal level of quality data. Development of the structure and data collection have gone hand in hand, the development in structure prompting the search for data, the availability and type of which, dictated further revisions of the structure. Many data sources have been used to develop the structure, the major ones being EMR (1983a), Ontario Hydro (1985) and documents by the Ministry of Energy Ontario (MEO, 1983,1985a,b).

Much of a WATEMS model's structure can be illustrated with a diagram that shows the energy flows represented in the model. The network diagram of the Ontario energy system is shown in Figure 1 (attached at the end). As mentioned above, the model can be looked upon as a multistage network that starts with supply, through non-electric conversion, electric generation, transportation and distribution, and finally through end-use utilisation. As the end-use utilisation stage is difficult to see in Figure 1, details are shown in Figures 1a and 1b. The modelling of each of the stages are described below.

The model has been designed for a target year of 2021. A major assumption in constructing the model, based on introduction dates and effective lifetimes, was that out of the existing stock that describes the energy system, only some of the existing building structures, most of the existing hydro facilities, and the Bruce "B", Pickering "B", and the Darlington nuclear plants would influence the energy system in 2021.

4.1 Supply stage

The primary energy sources that have been considered are solar, lignite, uranium, hydro, municipal refuse, natural gas, propane, coal, crude oil, wood and agriculture grain crops that include corn, barley and wheat. In addition to being disaggregated by energy type, wherever appropriate they have been further disaggregated by place of origin. The modelling of the supply process essentially involves identifying different supply sources and representing them by separate arcs; each of these arcs then flows into the appropriate supply nodes. Wherever necessary, upper bounds

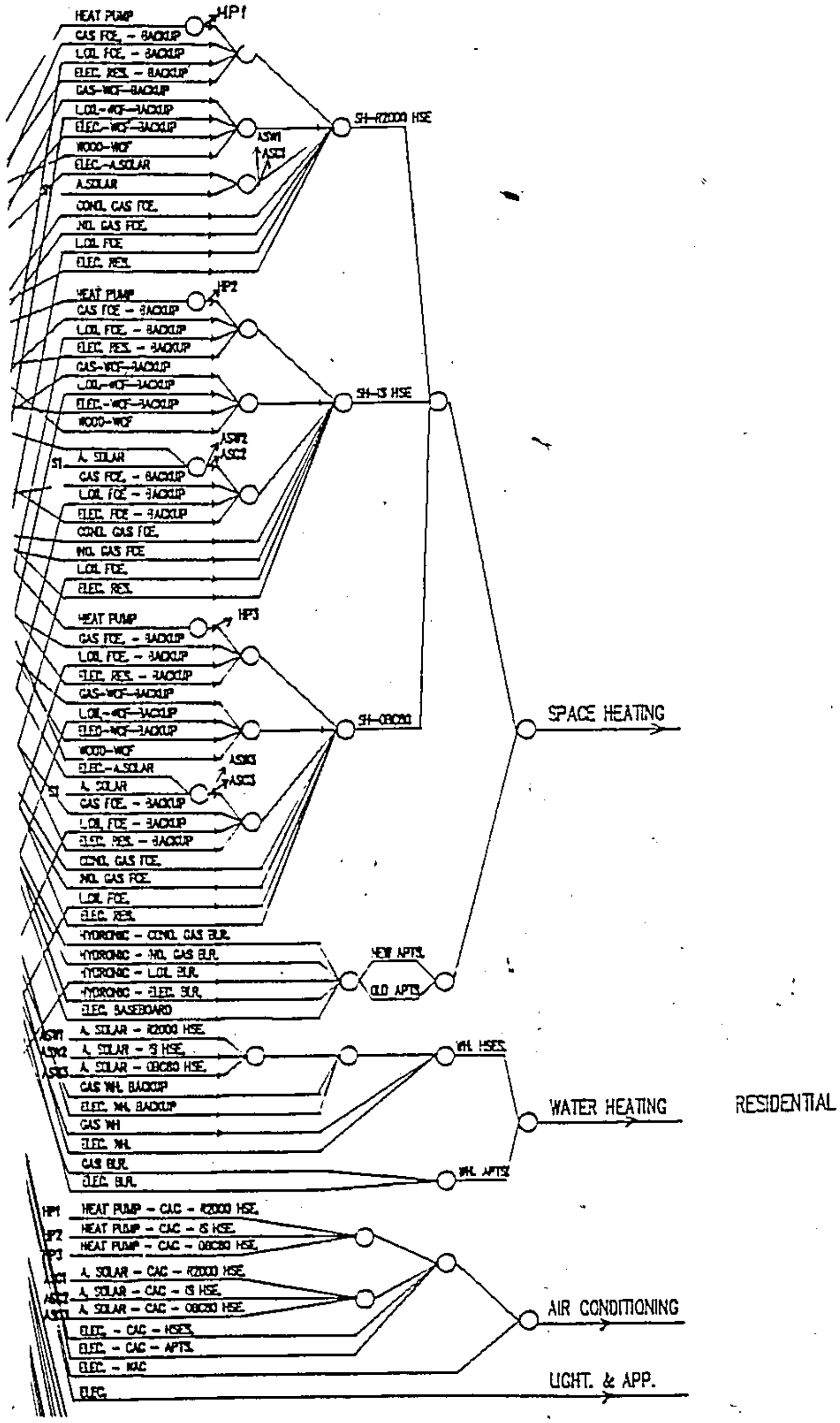


Figure 1a. Enlarged view of the end use stage of the Ontario Energy System shown in Figure 1 (part 1).

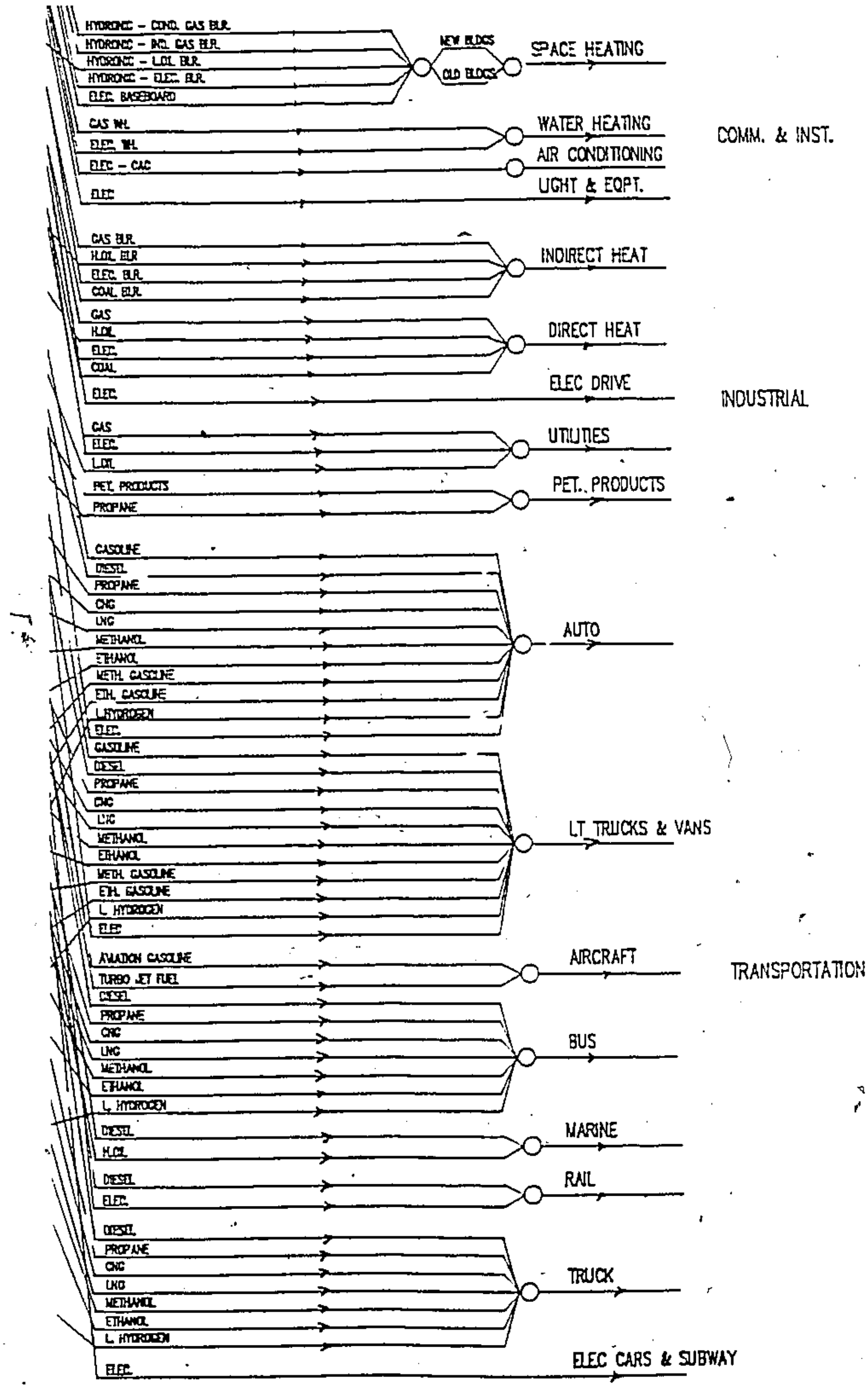


Figure 1b. Enlarged view of the end use stage of the Ontario Energy System shown in Figure 1 (part 2).

have been placed to represent restricted supplies. Also, share constraints that fix the total share of supply from a particular source have been placed in some cases.

Based on future projections, natural gas supplies are represented by two arcs, one representing the major regional import (the Beaufort Sea / Mackenzie delta area, the Arctic Islands or the Eastern Offshore, depending upon future developments), and the other representing very limited quantities from Southern Ontario gasfields. There is an upper bound to the latter. Propane supplies from the West are represented by an arc. This is the major source. In addition, propane is a by-product in crude refining as well as from the MOBIL processes. Each of these potential supply sources are represented by separate arcs that flow from the ouput nodes of the processes into the propane supply node. Crude oil supplies most likely would consist of foreign imports and regional imports from Beaufort Sea / Mackenzie delta, Arctic Islands, Eastern offshore or synthetic crude from oilsands in Alberta, depending upon which sources are developed in the future. Ontario has large quantities of oilshale, but it is unlikely that it will be developed by 2021, given its high cost. Under current policy crude oil is sold at world price regardless of origin, and as there is no indigenous supply within Ontario, crude oil supply is represented in the model by one arc. Bituminous coal supplies are represented by two arcs, US Appalachian and Western Canadian. A share constraint has been placed that forces a fixed share of Western coal. Lignite supplies are assumed to be from Saskatchewan (although Ontario has approximately 170 million tonnes of lignite at Onakawana, the quality and remoteness of location currently make mining these deposits uneconomical; it is assumed to remain so in the year 2021). Future projections for uranium supplies show Saskatchewan having the major share, followed by smaller shares for Ontario, the Northwest Territories and Nova Scotia. Uranium supplies are represented by one arc, the supply being from any of the above. Hydro-electric power is disaggregated by three types: existing hydro stock that would be operating in 2021, new small hydro (2-10 MW), and new large hydro (greater than 10 MW). In addition, some hydro plants are dedicated peaking units (explained in section 4.4) and can only be used for serving peak electric loads. Wherever appropriate, the above broad categories for hydro have been further disaggregated by dedicated peaking units and other hydro units, the latter includes those that could technically be used to service any of the electricity demand modes. Other primary resources, all indigenous to Ontario, are wood, corn, barley, wheat, municipal refuse and solar, each of these being represented by separate arcs.

4.2 Non-electric conversion stage (excluding the refining of crude oil)

The non-electric energy conversion technologies considered in this stage, include the compression and liquefaction of natural gas, syncrude from coal using the SRCII-B process, gasoline from coal, natural gas, and methanol using the MOBIL process, gasoline from coal using the Zinc Chloride process, gasoline and diesel fuel using the SASOL process, methanol from natural gas, coal and wood, ethanol from natural gas, coal, wood, corn, barley and wheat, and liquid hydrogen from natural gas, coal and electricity. Detailed data that includes quantitative description of processes and costs are available in EMR (1983a).

The modelling process here essentially involves identifying for each process, all energy inputs (both, as a fuel and as a feedstock), and outputs. Each conversion process has an associated node. Arcs, representing energy feedstocks and in some cases energy fuels, flow from the output of the supply nodes to the input of the process node. Output flows from the process nodes represent secondary fuels. For gasoline from coal using the Zinc Chloride process, methanol from coal and wood, liquid hydrogen from electricity, and for compressed and liquefied natural gas, there is just one incoming energy flow. The efficiency parameter associated with the incoming arc specifies the efficiency of the process, i.e. the ratio of the output energy produced to the input energy supplied. For all other processes, there are more than one energy flows. Equality share constraints have been placed for the incoming energy flows that specify the proportional share of the different energy inputs required by the process. Both the node loss and the efficiency parameter, have been used to specify the net energy efficiency of the process. In addition, for the MOBIL processes and the SASOL process there are more than one output. Here, equality shares on the outgoing energy flows from the process node have been placed. These specify the proportion of the different energy outputs produced by the process.

Data related to costing was available in the form of capital costs and operating costs. As most of the processes are emerging from research and development programs, the costs are based on pilot plants which are of small and varying capacities. For comparison purposes, additional data was also specified to translate the base costs to an equal capacity basis. The large plants, which are not distribution oriented, e.g coal to syncrude production, etc., are translated to 250,000 gigajoules (GJ) per day capacity. The smaller plants that are distribution oriented, e.g. compressed natural gas plants, are translated to 40,000 GJ/day capacity. Both capacities represent average sizes of plants for the two categories. Further, as these technologies are in the pilot stage, there is an element of uncertainty involved in the investment cost estimations in moving from the pilot stage to actual large scale production. The actual costs usually exceed the estimations since technical problems arise with large scale production which were impossible to foresee at the pilot stage. Thus for each of the plants there is an uncertainty factor that increases the base case costs. Using this data, cash flow calculations that determined the per unit costs based on capital and operating costs, plant lifetimes, and discount rates were done in the following way.

Let c_b, o_b be the capital cost and operating cost (excluding the cost of energy, both, as a fuel and as a feedstock) for the base case pilot plants. Let p_b, P represent the base case and the equal capacity case production rates respectively (P is either 250,000 or 40,000 GJ per day). Then, the capital costs are translated according to plant scale exponents while operating costs are translated linearly, these being given by

$$c_e = c_b * (P/p_b)^{CF} \qquad \text{...4.1}$$

$$O = o_b * (P/p_b) \qquad \text{...4.2}$$

where c_e, O represent the capital and operating costs respectively translated for equal capacity, and CF is the exponent that translates investment costs for the base case to the equal capacity case.

Let UF represent the uncertainty factor and let c_m represent the modified capital cost that includes modification for equal capacity and uncertainty. Then,

$$c_m = c_e * UF \qquad \ldots 4.3$$

The above capital cost does not include interest during the construction period. Let L be the construction lead time, β be the fraction of construction lead time when half expenditures are made, and r the discount rate, then, the modified capital cost including interest, C, is given approximately by,

$$C = c_m/2 * [(1+r)^{L*(1-\beta/2)} + (1+r)^{(L*(1-\beta))/2}] \qquad \ldots 4.4$$

Let T be the plant's operating lifetime and SF be the service factor, i.e. the fraction of the year the plant is working, then the per unit cost of production of the output (excluding the cost of energy), is given by

$$c_p = [C*(A/P,r,T) + O] / (P*365*SF) \qquad \ldots 4.5$$

where,

$$(A/P,r,T) = r / [1 - (1/(1+r)^T] \qquad \ldots 4.6$$

4.3 Refinery

Crude oil is made up of many different hydrocarbons. A refinery separates the components and upgrades them to the specified qualities. The output product mix is not fixed and can be varied within certain limits depending upon the processes that exist in a refinery. The earlier refineries were relatively simple in design: the slate of products essentially reflected the component makeup of the input crude. In the last thirty years or so market demands have tilted towards a larger share for lighter products and newer products have entered the market. Consequently, modern refineries have a large number of processes with complex interconnections between them. Obviously, modelling a realistic refinery is extremely complex and could run into hundreds of variables and constraints. This is not desirable not only from the viewpoint of model size, as this is only a small subsector of the entire model being developed, but also much of the added information that is gained would be of limited use in this context. The objective here was to develop a simple representation which would describe the flexibility that exists in a refinery, which for the purposes of studying interfuel substitution is the most important feature of the refinery.

The refinery operation can be described very briefly as starting with the distillation of crude oil, the distillation products being fractions of hydrocarbon gases, gasolines, straight run oils and heavy residuals. Some of the gasolines can be sent directly to the gasoline blending unit. The heavier gasolines go through a reforming process, the reformed gasoline then is sent to the gasoline blending unit. The oils can be sent directly to the fuel oil blending unit or to the cracking unit, the cracked gasolines are sent for gasoline blending and the cracked oils for fuel oil blending. The heavy residuals are used for producing lube oils or for the blending of heavy oils. The output of the gasoline blending unit is motor gasolines and aviation gasoline. The outputs of the fuel oil blending unit are jet fuel and various fuel oils.

The approach taken here views the refinery as a two stage process. The first stage encompasses the distillation and conversion operations while the second stage represents the blending operation. The first stage yields streams of gasolines, distillates and heavy oils. In the second stage, each of these streams yield various refined products. The output of the first stage permits the output share of each stream to vary between lower and upper bounds. Output shares from the second stage have no restrictions, with the output slate of products being determined by market demands.

The above modelling approach can be used to represent any refinery. As mentioned earlier, the output slate of products is dependant upon the type and number of processes that exist in the refinery. Nelson (1976) defines a measure known as refinery complexity which is described by a number. A low value indicates a refinery with fewer processes and the value of the number increases as the number of processes increases. Earlier refineries, therefore would be described by a lower complexity number in comparison with modern refineries, which are described by higher complexity numbers. In the above modelling approach this is reflected in the range of the output products' share bounds and in the cost. To reflect the different range of refineries in the model, there are two types of refineries, one with a low complexity with lower costs and a smaller share of lighter products, the other with a high complexity that has higher costs and a larger share of lighter products.

The costing for the refinery was done almost in a similar manner as in section 4.2. As base case data permitted directly the costing for an average size refinery, the modification for equal capacity basis did not arise. Neither did the uncertainty factor. All other computations were done similarly to section 4.2 with one minor exception. To avoid the problem of joint costing, the per unit cost of refining is computed in relation to the input crude oil, and is therefore associated with the incoming flow of crude oil to the particular refinery. This in turn implies that the costs are uniformly spread over all refined products, but prices (strictly speaking, marginal costs) of refined products are not necessarily equal, they are determined by the interaction of demands and supply technology.

To summarise, the above approach for modelling the refinery is not only simple but also captures the important feature of flexibility that exists in the refining industry.

4.4 Electric conversion stage

The demand for electricity is time dependent. It varies from hour to hour , the pattern changing from day to day and season to season. A useful representation of electric demand for electric utility planning is the annual load duration curve shown in Figure 2. The annual load curve is obtained from the annual chronological load curve by reordering the loads according to decreasing intensity. The area under the curve represents the total energy requirement in the year.

In order to cater to the demand, power plants are designed and operated to serve different load segments. In general, peaking plants operate for only a few hours per day, either over the entire year or during the peak season to meet short term electricity demands. These units are utilised for up to 20% of the time on an annual basis. Intermediate or cycling plants operate at varying loads each day. The time period of operation is anywhere between 20-65% of the time in a year. Base load units operate at full capacity most of the time. These units are generally utilised for 65-95% of the time.

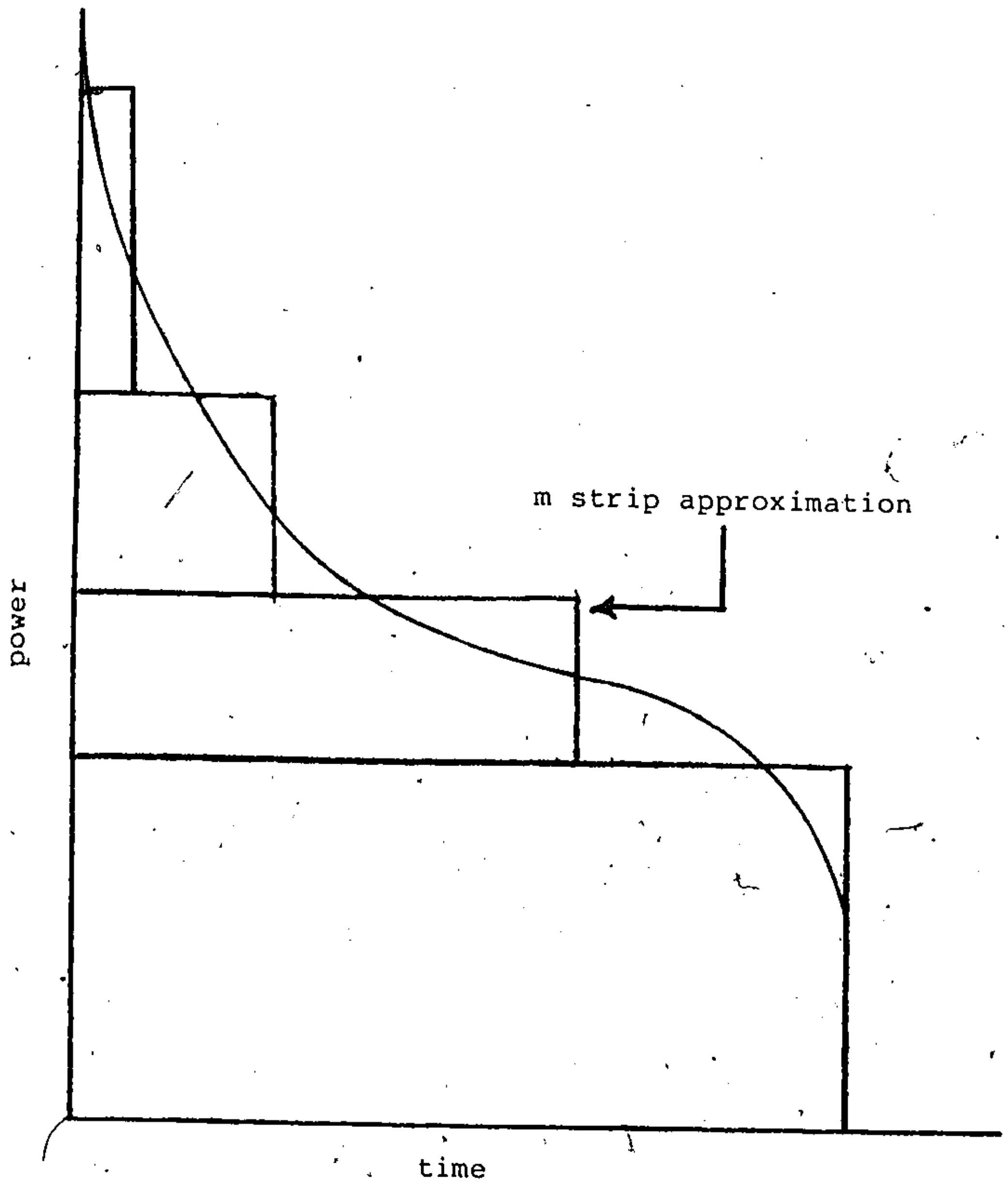


Figure 2. The annual load duration curve and its m strip approximation.
(adapted from Sherali et al. (1982))

The type of power plants used for the above ranges depend upon certain technical features such as quick starting, etc., and upon the capital and generation costs. Generally speaking, gas turbines are used as peaking units, fossil fuel plants for cyclic, and nuclear and fossil fuel plants as base load units. Hydro plants, depending upon their costs and energy availability, are used for all the load ranges.

The basic objective in modelling the electric sector is to minimise the cost of supplying energy while ensuring that demands are satisfied at every instant of time. Sherali et al. (1982) describe a standard linear programming model for utility planning that models the basic relationships between supply sources and demand. The first step involves the discretization of the load duration curve. This can be done in two ways. The curve can be approximated by vertical strips or by horizontal strips. The horizontal strip approximation was used here as this formulation can be adapted more easily to WATEMS with few modifications, as shown later. Approximating the load duration curve by n strips leads to the following formulation.

Let,

c_i = unit (annualised) capacity cost of equipment of type i $(i=1,\ldots,m)$,

f_i = operating cost (per unit of energy) of equipment of type i,

α_j = mesh points of the time axis discretization, where j=1,..,n and $\alpha_0 = 0$, $\alpha_n = 8760$ (hrs/yr),

d_j = energy equivalent of load corresponding to strip j

and let the decision variables be defined as,

x_i = quantity (kilowatts) of equipment of type i,

y_{ij} = quantity (kilowatts) of equipment of type i used to satisfy load j

then the model is given by,

$$\text{minimise} \quad \sum_{i=1}^{m} c_i x_i + \sum_{i=1}^{m}\sum_{j=1}^{n} \alpha_j f_i y_{ij} \qquad \ldots 4.7$$

subject to

$$-x_i + \sum_{j=1}^{n} y_{ij} \leq 0 \qquad i=1,\ldots,m \qquad \ldots 4.8$$

$$\sum_{i=1}^{m} \alpha_j y_{ij} \geq d_j \qquad j=1,\ldots,n \qquad \ldots 4.9$$

$$x_i, y_{ij} \geq 0 \qquad \begin{array}{l} i=1,\ldots,m \\ j=1,\ldots,n \end{array}$$

The set of constraints defined by equation 4.8 are capacity constraints. They ensure that the output power from any equipment type does not exceed its power capacity. The set of constraints defined by equation 4.9 are demand constraints and they ensure that energy supplies meet the demands.

In the Ontario energy model being developed, all variables are in terms of energy. In order to model the electric sector as described above, the above formulation which is based on power variables was modified to energy variables. The modification not only led to a simpler formulation, i.e. fewer variables and fewer constraints, but also was readily implementable in WATEMS. The modifications were done in the following way. Note, that at optimality, equation 4.8 would always be binding. Therefore, substituting for x_i, the problem can be rewritten as,

$$\text{minimise} \quad \sum_{i=1}^{m}\sum_{j=1}^{n}(c_i/\alpha_j + f_i)(\alpha_j y_{ij}) \qquad \ldots 4.10$$

subject to

$$\sum_{i=1}^{m}\alpha_j y_{ij} \geq d_j \qquad j=1,\ldots,n \qquad \ldots 4.11$$

$$y_{ij} \geq 0 \qquad \begin{array}{l} i=1,\ldots,m \\ j=1,\ldots,n \end{array}$$

The term $\alpha_j y_{ij}$ represents the energy flowing from facility i for α_j hours of the year. Representing this by a variable z_{ij}, and as $(c_i/\alpha_j + f_i)$ is the cost per unit of energy, the above formulation can be rewritten as,

$$\text{minimise} \quad \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} z_{ij} \qquad \ldots 4.12$$

subject to

$$\sum_{i=1}^{m} z_{ij} \geq d_j \qquad j=1,\ldots,n \qquad \ldots 4.13$$

$$z_{ij} \geq 0 \qquad i=1,\ldots,m \quad j=1,\ldots,n$$

where c_{ij} is the cost per unit of electrical energy of facility i operating for α_j hours in the year. The above formulation can be readily implemented in WATEMS. Modelling this as part of the existing model requires arcs that flow from the supply or the conversion nodes into the appropriate facility-supply nodes, where each facility-supply node represents a different generation plant. The efficiency of conversion associated with each arc represents the generation efficiency. The electricity produced from each plant could service all or some of the n load segments, depending upon the technical constraints of each plant. This is represented by outgoing energy flows from the facility supply node to any or all of the n load nodes. The cost term associated with each of the arcs represent the per unit cost of operating the plant for that particular mode. Output energy flows from the n nodes flow to the electrical demand node from where they are distributed to end use demands. Equality share constraints on the incoming energy flows at the electrical demand node specify the proportional make up of the load duration curve generated by the n strip approximation. Total electric demand, exogenous to the electricity submodel, is determined endogenously by the main model during the optimisation process, depending upon costs of electric and non-electric fuels and technologies that could possibly satisfy end-use demands.

Electric generation technologies considered are coal fuelled generating plants using pulverised fuel combustion steam generators and steam turbines with subcritical and supercritical steam pressure, and atmospheric fluidised bed combustion technology; lignite fuelled using pulverised fuel combustion with subcritical steam condition; gas fuelled steam turbine generating plants with subcritical and supercritical steam conditions; oil fuelled steam turbine using subcritical steam conditions; municipal refuse fuelled generation (reconditioned plant at Hearn); CANDU nuclear technology of the type existing at the Darlington site; new hydro (small, 2-10 MW) and new hydro (large, >10 MW); hydro plants that are already in existence and will be available in the year 2021 and the Bruce "B", Pickering "B" and Darlington nuclear plant that again would be available for use in the year 2021. In addition, the hydro plants have been subdivided into dedicated peaking units and others, the latter could technically be used for supplying in any mode. All above technologies are currently under consideration by Ontario Hydro for future expansion of the electric sector (Ontario Hydro, 1985).

Four horizontal strips approximate the load duration curve. These strips refer to the base, intermediate, daily peak and seasonal peak segments of total load. Each of these segments could be satisfied by different types of power plants; each power plant, therefore, depending upon its technical feasibility, is permitted to operate in some or all of the load ranges. The costs of operating in each segment are associated with the appropriate arcs. Data for the above plants was available in the form of capital and operating costs. The capital cost did not include interest during construction. This was determined in the manner similar to the earlier calculations described by equation 4.4. Defining K as the capital cost per kW which includes interest, V as the operating and maintainence cost per kW, and A the availability factor, then the levelized cost per kWh, c_j, generated when the plant was operating in mode j (α_j), is given by

$$c_j = (K^*(A/P,r,T) + V) / (A^*\alpha_j) \qquad ...4.14$$

In addition, power plants that are of existing stock as well as new hydro plants, have power constraints that specify the maximum power that is available. To do this, the first step involved the replication of the energy flows in the four arcs that flow from the supply node to the four mode nodes. This was done by introducing a node on each of the four arcs. The β_{mt}'s of these nodes were specified as

-1. The output from each of these nodes (which is twice the input) was shared equally between two outgoing arcs by specifying an output share constraint of 0.5. One set of arcs lead to the n nodes while the other set is the replication of those n arcs. The efficiency parameters in each of the replicated arcs were specified as the inverse of the product of the time and the availability factor. Thus the energy flow emerging from that arc would effectively represent the power associated with the energy supply for that mode. Each of these arcs flow into the associated power node, thus the arc emerging from the power node for a plant reflected the total power operating from that facility. An upper bound on this arc ensured that the power capacity at any time was not exceeded by the capacity available.

4.5 Transportation and distribution stage

After the conversion to secondary energy forms, the fuels are transported or transmitted (in the case of electricity) over long distances, followed by distribution to end-use consumers. Both these activities have a cost and an energy loss associated with each fuel. For each fuel, an arc represents the energy flow for this stage. Each arc is associated with a cost. The arc flows into the transportation and distribution node, the energy loss during transportation and distribution being specified by the node loss parameter.

4.6 End-use utilisation stage

After transportation and distribution energy fuels are consumed to provide services. The energy demands are broadly classified under residential, commercial, industrial and transportation. Each of these sectors has been broken down into demand categories, each demand category being described by applicable technologies.

In the residential sector the demands are subclassified under space heat, water heat, air-conditioning, and electrical appliances and lighting. On a physical basis, the residential sector has been subdivided into houses and apartments,(although a preferable level of disaggregation was single (stand alone) houses, row and town houses, and apartments, lack of data on row and town houses limited the disaggregation to the two categories mentioned above). The houses category are made up of three types that reflect the insulation capabilities, those being the R2000, Intermediate solar (IS) design and houses that have insulation levels that correspond to the minimum levels specified by the 1980 Ontario Building codes (OBC80). Apartments are of two types; those with insulation levels of new apartments built today and future apartments that have a higher insulation level. The heating devices for houses include the efficient oil furnace, induced and condensing gas furnaces, electric furnace and baseboard heaters, heat pump with various back-ups, wood stoves with various back-ups and active solar with various back-ups. Apartment heating includes hydronic systems with different boilers and fuels and electric baseboards. Water heating technologies include gas, electric and solar. The air-conditioning category in addition to window and centralised units include the heat pump (also used for heating in winter) and the solar air-conditioner.

Modelling of the residential sector was done in the following way. Starting with the houses, each house category require different capacity furnaces, thus each category had separate arcs representing the possible technologies that could satisfy the space heating demand. For technologies requiring backup, there is an equality share constraint on the major technology, thus permitting any of the backup technologies to satisfy demand that cannot be met by the major technology. Examples are heat pumps, that are ineffective on cold days, wood furnaces that need constant refuelling and thus cannot be left unattended, and active solar technologies that cannot meet the entire space heating demand. The apartment technologies are described by one set of arcs which serve both categories of apartments. The sum of the energy flows from each category of houses combined together with the total energy flows from apartments give the total space heating demand. Each of the arcs that represent a particular technology has an associated cost and an efficiency. The cost per unit of energy is a simple discounted cash flow calculation, based on the capital cost, operating cost, discount rate and lifetime. The efficiency term is the efficiency of the device. The cost and efficiency description not only applies to space heating but extends to all end-use technologies in all the subsectors. Water heating is modelled in a similar way, with active solar technology requiring backups. The heat pump can be used for heating and air-conditioning. Equality share constraint on the arc for air-conditioning permits the heat pump to serve both air-conditioning and heating.

The commercial sector is described by space heating, water heating, air-conditioning and equipment and lighting. The building structures and heating devices are similar to those described for the apartment buildings. So is the modelling methodology.

The ideal approach in modelling the industrial sector would be to consider the major industries separately. For each major industry, the model should include the processes that are being considered as options. This would require extensive interaction with the industries to develop the database and hence the model could take several man years. In the absence of the extensive resources required for such a task, the industrial sector has been divided broadly into five categories, namely, indirect heat, direct heat, electric drives, utilities and petroleum products. The indirect heat category is described by coal, natural gas and heavy oil boilers. Coal, gas, heavy oil and electricity describe the direct heat category. The utilities are served by natural gas and electricity. Petroleum products and propane flow into the petroleum products and petrochemical feedstock node. Interfuel substitution in this stage is only permitted for the indirect heat category. Each arc representing a boiler technology has an associated per unit cost (described earlier in this section) and the efficiency of conversion. The other categories are fixed by market share constraints which translate into input equality shares placed on the inflowing arcs, associated with the particular node assigned to the category.

The transportation sector is represented by seven categories, namely auto, light trucks and vans, bus, trucks, rail, marine,aircraft and electric street cars and subways. In addition to conventional petroleum fuels alternative fuels considered in appropriate categories include propane, CNG, LNG, liquid hydrogen, methanol, ethanol and electricity. Interfuel substitution is permitted in auto, light trucks and vans, bus and trucks categories. Each technology (arc) has an associated per unit cost and an efficiency. In addition, an input share constraint bounds the total demand that can be met by electric vehicles. This is because even if electric cars are cost effective, the limitations in driving range would probably permit its use only as a second car (for local travel) in a household. The rail, marine and aircraft categories have market share constraints in the form of input equality shares on the incoming arcs of the appropriate demand nodes.

The end-use demands translate as lower bounds on the appropriate arcs. These demands are specified either as a level of service (e.g. kilometres in a transportation sector) or as end-use energy demands. End-use energy demands are defined in terms of useful energy or in terms of fuel energy. The former refers ~~to~~ the energy after conversion from end-use device and is defined as the product of fuel (energy) times the efficiency of the end-use device. This measure of energy is independent of the type of fuel. This description applies to all demand categories where interfuel substitution is carried out in the end-use stage and in those categories where although only one fuel can satisfy the demand there is scope for efficiency improvement. The latter is defined in terms of fuel energy and applies to those categories where either there is only one possible fuel that could satisfy the demand with no efficiency improvements in the end-use utilisation device, or where market share constraints have been used to specify the shares of various fuels that satisfy the particular demand. As no end-use demand projections exist for the year 2021 in the form required by the model, these demands were estimated in the following way.

In the residential sector end-use demands are required for space heating, water heating, air-conditioning and appliances and lighting. Consider space heating demands. These need to be computed for each of the housing types. As the space heating demand per housing unit is known, then for each housing type, the product of the unit space heating demand and the number of households would determine the space heating demand. Let,

A = {R2000 house, IS house, OBC80 house, New apartments, Old apartments}

Dr_{ij} = the total end-use demand for category j (j = space heating) of housing type i ($i \in A$), in the year 2021

Hr_{ij} = the end-use demand j per housing type i,

Nr_i = the number of houses of type i in the year 2021,

then the space heating demands can be computed by,

$$Dr_{ij} = Hr_{ij} * Nr_i \qquad i \in A, \; j = \text{space heating} \qquad \ldots 4.15$$

The number of housing units that are of stock already built and still existing in 2021 can be computed from existing data. If the number of total housing units existing in 2021 can be estimated (Nr), then Nr_i can be determined from the following equations.

$$Nr_i = fre_i * Nre + frn_i * Nrn \qquad i \in A \qquad ...4.16$$

$$Nr = Nre + Nrn \qquad ...4.17$$

where,

Nre = the number of houses of existing stock in the year 2021,

fre_i = the fraction of existing stock in the year 2021 of type i,

Nrn = the number of houses of new stock in the year 2021,

frn_i = the fraction of houses of new stock in the year 2021 of type i.

No direct projections were available for the number of households in the year 2021. However projections did exist exist until the year 2006 (Statistics Canada, 1981). Using this data, a linear regression model was used to project the number of households for the year 2021.

The air-conditioning demands are disaggregated into demand by window air-conditioners and demand by central air-conditioning units. In addition to the above definitions, let,

B = window air-conditioners, central air-conditioners ,

fc = the fraction of households with air-conditioning,

Dr_j = the total end-use demand for category j,

then,

$$Dr_j = fc * \sum_{i \in A}(Hr_{ij} * Nr_i) \quad j \in B \qquad ...4.18$$

The demands for water heating and appliances and lighting are not a function of the type of housing units, these being given by,

$$Dr_j = Hr_j * Nr \quad j \in C \qquad ...4.19$$

where,

C = water heating, appliances and lighting ,

Hr_j = the end-use demand j per housing unit.

The commercial sector end-use demands to be computed are for space heating in old buildings, space heating in new buildings, water heating, air-conditioning, and for electrical equipment and lighting. Ideally, these demands could be computed as the product of the end-use demands per unit of floor space and the total floor space. As no projections could be found for the total floor space in 2021, this figure was approximated by escalating current floor space proportional to the projected population estimates and multiplying this estimate by a trend factor that accounts for all increases except for those due to population, e.g. a boom in office space due to an increasing trend of service industries, etc. The space heating demands are computed in the following way. Let,

D = {old buildings, new buildings}

Dc_{ij} = the end-use demand for building of type i ($i \in D$), for category j, (j = space heating),

Fc_{ij} = the end-use demand for building of type i, per unit of floor space for category j,

frc_i = the fraction of total commercial and institutional floor space of building type i,

Pc,Pp = the current population and projected population (2021) levels respectively,

FSc,FSp = the current commercial and institutional floor space and the projected (2021) levels respectively,

TF_c = the commercial and institutional trend factor that accounts for all increases except for that due to population increase,

then, the space heating demands are given by,

$$Dc_{ij} = Fc_{ij} * FSp * frc_i \qquad i \in D, \; j = \text{space heating} \qquad ...4.20$$

where FSp, the projected floor space is given by,

$$FSp = [FSc * (Pp/Pc) * TFc] \qquad ...4.21$$

The air-conditioning demand is the sum of the individual air-conditioning demands for both building types. Let, Dc_j be the end-use demand for category j, then the total air-conditioning demand is given by,

$$Dc_j = \sum_{i \in D} Fc_{ij} * FS_p * frc_i \quad j = \text{air-conditioning} \qquad ...4.22$$

The waterheating and equipment and lighting demands are given by,

$$Dc_j = Fc_j * FS_p \qquad j \in \{\text{water heating, equipment and lighting}\} \qquad \ldots 4.23$$

where, Fc_j is defined as the energy demand j per unit of floor space.

In the industrial sector demands need to be computed for the indirect heat category, direct heat category [demands for heavy oil, coal, natural gas and electricity (there is no interfuel substitution), electric drive, utilities, and petroleum products. These demands have been computed by escalating current consumption levels to projected productivity levels, the latter being estimated by multiplying the proportional increase in population with a trend factor that accounts for all increases except for population increase (similar to the commercial and institutional sector)

Let,

E = {indirect heat, heavy oil - direct heat, coal - direct heat, electricity - direct heat, natural gas - direct heat, electricity - electric drive, utilities (fuel), petroleum products and petrochemical feedstock},

Di_j = the industrial energy demand for category j, ($j \in E$), for the year 2021,

Pi_j = the present industrial energy demand for category j,

TFi = the industrial trend factor that accounts for all increases except for those due to population increase,

then,

$$Di_j = Pi_j * (Pp/Pc) * TFi \quad j \in E \qquad ..4.24$$

In the transportation sector, end-use demands need to be computed for passenger cars, light trucks and vans, buses, railways, marine, aircraft, street cars and subway, and medium and heavy trucks. Here again, current levels are escalated proportionally to population increases and multiplied with a trend factor that accounts for all increases excluding the increase due to population. As the average distance travelled by cars and light trucks and vans are available, the demands here are computed as a level of service, i.e. the distance that vehicles in these categories would need to travel, as this has a more direct interpretation of an end-use demand. For other categories the demands are either in the form of fuel or useful energy as in the earlier cases.

Let,

G = {cars, light trucks and vans},

H = {buses, railways, diesel-marine, heavy oil-marine, jet fuel-aircraft, aviation gas-aircraft, subway and street car, medium and heavy trucks}

Dt_j = the distance demand in the year 2021 for category j, ($j \in G$) or output energy demand in the year 2021 for category j, ($j \in H$),

Pt_j = the annual distance travelled per vehicle belonging to category j, ($j \in G$) or the output energy consumed currently by category j, ($j \in H$),

TFta = the transportation trend factor for cars and light trucks and vans that account for all increases except for that due to population increases,

then the distance demand for cars and light trucks and vans and the output energy demand for all other categories is given by,

$$Dt_j = Pt_j * Pp/Pc * TFTa \quad j \in G \cup H \qquad \ldots 4.25$$

Finally, to conclude the model description, both imports and exports of secondary fuels are permitted. Imports are represented by inflowing arcs and exports by outflowing arcs at the appropriate nodes. Because exports, in general, produce revenues, being a cost minimisation model, the model tries to export as much as possible. Thus an upper bound must be placed to avoid an unbounded solution.

CHAPTER V

DATA ASSUMPTIONS FOR THE BASE CASE

The base case describes a most likely scenario for the year 2021. Prices and available quantities of primary resources represent most likely values, costs of conversion and utilisation represent best possible estimates and end use demand quantities represent most likely demand. The data for each of the stages is described below.

5.1 Supply stage

The prices of primary resources (in 1985 dollars) assumed for the base case are given in Table 1. These prices include transportation to major points in Ontario but do not include distribution costs which are considered separately. The price of natural gas was arrived at by escalating the Toronto city gate 1985 price at an annual rate of 1.21%, the rate being derived from projections by MEO (1985) for the year 2000. The same annual rate was used to escalate the 1985 price for propane. The price of uranium reflects an average cost of $170-340 per kg reported in EMR (1983b) escalated to 1985 dollars. The prices for all other primary resources excluding crude oil

Table 1. Primary resource prices (1985 dollars) assumed for the base case (2021)

RESOURCE	PRICE
Natural Gas	$6.21 / Mcf
Western Coal	$128.00 / Tonne
US App. Coal	$97.00 / Tonne
Lignite	$71.00 / Tonne
Propane	$0.30 / Litre
Crude Oil	$49.00 / Barrel
Uranium	$297.00 / Kg
Wood	$82.00 / Odt
Wheat	$225.00 / Tonne
Barley	$191.00 / Tonne
Corn	$198.00 / Tonne

are arrived at by escalating 1985 prices at an annual rate of 1%. The instability in world crude oil prices for the last fifteen years or so makes it extremely difficult to project a price for oil. The figure of $49 per barrel reflects a 2% annual increase on a representative 1985 price of $24 per barrel.

Current annual supplies of indigenous Ontario natural gas from Southern Ontario gasfields are approximately 5.9 petajoules (PJ) per year. These gasfields supply approximately 2% of Ontario's annual natural gas requirement. Based on an estimate of 320 PJ of remaining supplies (MEO 1985a), and if production continues at the same level in the future, the indigenous Ontario natural gas supply has an upper bound of 5.9 PJ. In recent years, the share of Western coal supplies to Ontario is steadily increasing. Based on this trend, the shares of coal are assumed to change, with US coal contributing 70 % of the total, a decrease from a current share of 82%, the other 30% being supplied by Western Canadian sources, an increase from a current share of 18%.

5.2 Non-electric conversion stage

Data for all non-electric conversion technologies was adapted from EMR (1983a). A very detailed base case production cost worksheet was available for each process. From this worksheet, the capital cost was calculated as the sum of the total field, land, home office, catalyst and chemical inventory, working capital and start-up costs. The operating expenses were calculated as the sum cost of catalyst and chemicals, maintainence material and contract labour, direct labour, administration and support labour and other expenses (property tax, insurance, etc.). Annual by-product credits were the sum total of all non-energy products produced annually. Table 2 shows cost and technical data for all the processes.

Table 3 gives the conversion efficiency for each process and wherever applicable, the input and output share parameters. These were calculated from the base case production worksheets. The conversion efficiency in this context is defined as the ratio of the output energy produced to the input energy provided by the major energy input. As described in the previous chapter, this parameter is associated with the major energy input arc. The input share parameter, here associated with the minor energy input, is defined as the input energy provided by the minor energy input divided by the sum total of the minor and major energy inputs. Obviously, to achieve energy balance, the node loss parameter for each node must be specified as the same value as the input share parameter. The output share parameter for an outgoing energy flow is defined as the energy associated with the outgoing energy flow divided by the total energy output

Table 2. Cost and technical data for nonelectric conversion processes (excluding refinery), assumed for the base case (2021)

PROCESS OPTIONS	PILOT PLANT Capital Cost [Million Dollars (1982 $)]	Operating Expenses	Operating Credits	Plant Capacity GJ/day	EQUAL PLANT CAPACITY GJ/day	CAPACITY EXPONENT	UNCERTAINTY FACTOR	SERVICE FACTOR	LEAD TIME	PROJECT LIFETIME
GAS-GASOLINE (MOBIL)	1988.87	214.01	37.53	270199	250000	0.85	1.26	0.80	5	30
METHANOL-GASOLINE (MOBIL)	625.44	20.18	37.53	270199	250000	0.85	1.25	0.80	5	30
COAL-GASOLINE (MOBIL)	3280.78	194.89	39.76	270199	250000	0.81	1.33	0.80	5	30
COAL-GASOLINE (ZnCl2)	2635.46	197.45	28.35	307227	250000	0.82	2.09	0.80	5	30
COAL-GSL&DIESEL (SASOL)	3911.64	296.88	149.57	226503	250000	0.80	1.15	0.85	5	30
COAL-SYNCRUDE (SRCII-B)	1418.70	98.32	48.21	326760	250000	0.83	1.47	0.80	5	30
GAS-METHANOL	171.20	17.50	0	22717	250000	0.79	1.02	0.90	3	30
COAL-METHANOL	2816.45	187.88	2.18	308933	250000	0.85	1.17	0.85	5	30
WOOD-METHANOL	270.82	19.46	0	22696	250000	0.79	1.35	0.80	5	30
GAS-ETHANOL	410.45	64.79	15.34	32105	250000	0.76	1.40	0.90	3	30
COAL-ETHANOL	692.12	76.71	13.77	32105	250000	0.78	1.47	0.80	3	30
WOOD-ETHANOL	37.59	6.09	2.54	1591	250000	0.74	1.25	0.90	3	30
CORN-ETHANOL	116.23	16.41	7.47	13558	250000	0.83	1.04	0.90	3	30
BARLEY-ETHANOL	135.55	13.71	13.71	13558	250000	0.83	1.04	0.90	3	30
WHEAT-ETHANOL	124.26	17.01	9.90	13558	250000	0.83	1.04	0.90	3	30
GAS-LIQUID HYDROGEN	267.04	11.82	12.56	31848	40000	0.68	1.07	0.90	3	30
COAL-LIQUID HYDROGEN	448.02	26.29	1.05	31848	40000	0.72	1.18	0.90	3	30
ELECTRICITY-LIQUID HYDROGEN	648.53	26.36	13.09	32562	40000	0.85	1.04	0.90	3	30
COMPRESSED NATURAL GAS	0.56	0.11	0	156	40000	1	1	0.95	0.5	30
LIQUIFIED NATURAL GAS	5.81	1.56	0	1000	40000	1	1.01	0.95	1	30

adapted from EMR (1983a)

Table 3. Technical specifications for model parameters for nonelectric conversion processes (excluding refinery), assumed for the base case (2021)

PROCESS OPTIONS	INPUT FLOW DETAILS: ENERGY FLOWS	INPUT FLOW DETAILS: EFFICIENCY PARAMETER	INPUT FLOW DETAILS: EQUALITY SHARE PARAMETER	OUTPUT FLOW DETAILS: ENERGY FLOWS	OUTPUT FLOW DETAILS: EQUALITY SHARE PARAMETER
GAS-GASOLINE (MOBIL)	NATURAL GAS	0.4994	-	GASOLINE	-
	ELECTRICITY	-	0.0132	PROPANE	0.0543
METHANOL-GASOLINE (MOBIL)	METHANOL	0.8027	-	GASOLINE	-
	ELECTRICITY	-	0.0011	PROPANE	0.0543
COAL-GASOLINE (MOBIL)	COAL	0.3079	-	GASOLINE	-
	ELECTRICITY	-	0.0011	PROPANE	0.0543
COAL-GASOLINE (ZnCl2)	COAL	0.5659	-	GASOLINE	-
COAL-GSL&DIESEL (SASOL)	COAL	0.2593	-	GASOLINE	0.9139
				DIESEL	-
COAL-SYNCRUDE (SRCII-B)	COAL	0.5488	-	SYNCRUDE	-
GAS-METHANOL	NATURAL GAS	0.6222	-	METHANOL	-
	ELECTRICITY	-	0.0097		
COAL-METHANOL	COAL	0.3835	-	METHANOL	-
WOOD-METHANOL	WOOD	0.4189	-	METHANOL	-
GAS-ETHANOL	NATURAL GAS	0.4171	-	ETHANOL	-
	ELECTRICITY	-	0.0467		
COAL-ETHANOL	COAL	0.3352	-	ETHANOL	-
	GAS	-	0.1526		
	ELECTRIITY	-	0.0316		
WOOD-ETHANOL	WOOD	0.3351	-	ETHANOL	-
	ELECTRICITY	-	0.1583		
CORN-ETHANOL	CORN	0.6390	-	ETHANOL	-
	COAL	-	0.3506		
BARLEY-ETHANOL	BARLEY	0.5453	-	ETHANOL	-
	COAL	-	0.3860		
WHEAT-ETHANOL	WHEAT	0.5780	-	ETHANOL	-
	COAL	-	0.3774		
GAS-LIQUID HYDROGEN	NATURAL GAS	0.6326	-	LIQUID HYDROGEN	-
	ELECTRICITY	-	0.2300		
COAL-LIQUID HYDROGEN	COAL	0.4646	-	LIQUID HYDROGEN	-
	ELECTRICITY	-	0.2230		
ELECTRICITY-LIQUID HYDROGEN	ELECTRICITY	0.6008	-	LIQUID HYDROGEN	-
COMPRESSED NATURAL GAS	NATURAL GAS	1	-	COMPRESSED NATURAL GAS	-
	ELECTRICITY	-	0.0260		
LIQUIFIED NATURAL GAS	NATURAL GAS	1	-	LIQUIFIED NATURAL GAS	-
	ELECTRICITY	-	0.0571		

data adapted from EMR (1983a)

produced from the process, i.e. the sum of all outgoing flows.

Data for the refinery sector was calculated from Nelson (1974a,b,c,d). This was done by selecting an average sized refinery and identifying the processes that would make up the two kinds of refineries described in the previous chapter, i.e. a refinery with a smaller and with a larger share of lighter refined products. For each of the refineries, the complexity and capital cost was determined for each process. Table 4 gives details of refinery makeup and complexity. Operating expenses, amongst other factors are a function of complexity. This was calculated using the complexity figures described in Table 4 and the functions described in Nelson (1974e,f and 1975 a,b,c,d). The assumptions in calculating operating expenses were kept identical to the non-electric technologies described above. Table 5 gives overall cost details and the output range of products for both the refineries.

5.3 <u>Electric conversion stage</u>

Data for the electric sector was largely taken from Ontario Hydro (1985). Table 6 shows cost and technical details for new non-renewable generating options. Table 7 shows cost and technical details for new hydro options in the categories required in the model. Ontario Hydro (1985)

Table 4. Capacity assumptions and process complexity associated with processes for an average sized refinery assumed for the base case (2021)

Refinery capacity : 100,000 barrels/day

Refinery processes	capacity b/d	complexity
Crude distillation	100000	1.000
Vacuum processing	50000	0.790
Hydro-desulphurisation	45000	1.190
Sulphur recovery process	500	0.425
Hydrocracking and hydrogen man.	18000	5.240
Coking plants	14000	1.070
Viscosity breaking and alkylation	8400	1.000
Catalytic reforming	18000	1.190
Catalytic cracking	45000	2.740

N.B. 1. The refinery with a larger share of lighter refined products has all the above processes. The refinery complexity = 14.645

2. The refinery with a smaller share of refined products does not have catalytic cracking and hydrocracking facilities. The refinery complexity = 6.665

Table 5. Data for cost and percentage range of refined products associated with the low and high capacity refineries assumed for the base case (2021)

Refinery capacity : 100,000 barrels/day

Description	Low complexity refinery (6.665)		High complexity refinery (14.645)	
Cost[1] (1973$)				
Capital cost (M$)	135.49		236.79	
Operating cost (M$)	13.89		24.34	
Energy shares[2]	range in % share of output streams			
	lower	upper	lower	upper
Gasolines	0.1313	0.2120	0.3730	0.5232
Distillates	0.2071	0.2931	0.2654	0.4267
Heavy oils	0.5269	0.5318	0.1347	0.1374
Propane	0.0064	0.0065	0.0207	0.0281

1. Adapted from Nelson (1974a,b,c,d)
2. Adapted from Texaco Canada (1983)

Table 6. Technical and cost details for new fossil and nuclear based generation options assumed for the base case (2021)

New Generating Option	Station size MW	Capital cost (1985$) $/kW	Annual O&M cost (1985$) $/kW	Lead Time during constr. (years)	Plant Lifetime (years)	Availa-bility Factor	Conversion efficiency
Natural gas - subcritical	4 x 800	497	7	11	40	0.80	0.3400
Natural gas - supercritical	2 x 1300	555	8	11	40	0.80	0.3504
Light oil - CTU	10 x 25	788	2	5	40	0.80	0.2435
Heavy oil - Subcritical	4 x 500	944	13	11	40	0.80	0.3494
Coal - PFC subcritical	4 x 800	983	9	11	40	0.80	0.3545
Coal - PFC supercritical	2 x 1300	899	11	11	40	0.80	0.3641
Coal - AFBC conventional	4 x 200	1264	23	11	40	0.80	0.3500
Lignite - PFC subcritical	4 x 200	1732	24	11	40	0.80	0.3300
Uranium - Darlington NGS design	4 x 850	1594	22	14	40	0.85	-

N.B. 1. All data taken from Ontario Hydro (1985) excepting for conversion efficiency data, which has been calculated based on Ontario Hydro (1985) and U.S. Department of Energy (1982).

Table 7. Technical and cost data for new hydro options assumed for the base case (2021)

New Hydro option	Capacity (MW)	Energy (gWh/a)	Capital cost (1985 $) M$	Annual O&M cost (1985 $) M$/a	Annual water rental M$/a	Lead Time during constr. (years)	Plant Lifetime (years)	Availability Factor
New hydro (> 10 MW; dedicated peaking)	1723	1962.2	1640	1.261	1.751	8	70	0.8
New hydro (> 10 MW; all modes)	1904	4073.4	2638	3.186	3.491	8	70	0.8
New hydro (2-10 MW; all modes)	1234	628.1	427.7	2.032	0.550	5	70	0.8

adapted from Ontario Hydro (1985)

Table 8. Technical data for generating options of existing stock assumed for the base case (2021)

Existing option	Capacity (MW)	Energy (gWh/a)	Availability Factor
Existing hydro (dedicated peaking)	967	1516.3	0.80
Existing hydro (all modes)	4687	31605.1	0.80
Existing nuclear	8612	-	0.85

adapted from Ontario Hydro (1984)

gives details on each hydro site available for the 2 to 10-MW and greater than 10 MW categories. All plants that had capacity factors less than or equal to 0.2 were considered as dedicated peaking units. The data in Table 7 represents the sum of costs and technical parameters for all hydro options that make up a particular category. Table 8 shows technical details on generating options of existing stock. All hydro plants currently operating which have been built after 1945 are included in the hydro options. The nuclear options of existing stock includes the Pickering B, Bruce B, and the new Darlington plant.

Figure 3 shows the annual load duration curve for Ontario for the year 1985. The shape of the annual load curve is assumed to remain the same. The annual load curve is approximated by four strips such that the area under the approximated four-step load description is equal to the area under the load curve. The break points on the time axis were chosen at 200, 2000, 6000 and 8760 hours, these figures reflecting the practice in models that have been developed (Systems Control Inc., 1978 and Soyster and Eynon, 1979). The break point on the extreme end of the power axis was 100 %. The choice of the other three breakpoints was determined to be at 50.5%, 68% and 79%, such that the area under the load curve for each mode (specified by the above time breakpoints) is equal to the area of the corresponding strip. The energy shares

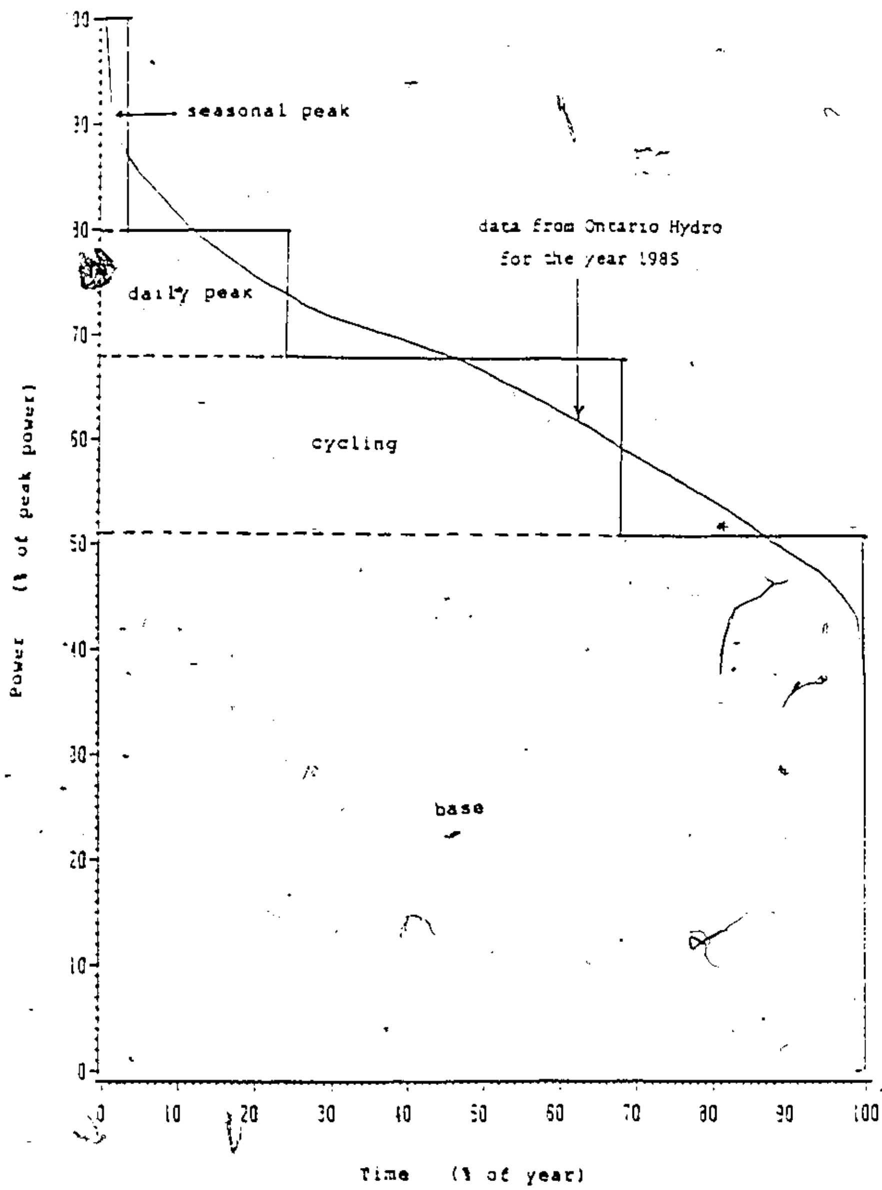


Figure 3. Four step approximation of the annual load duration curve.

corresponding to the above breakpoints are approximately 0.7% for seasonal peak, 3.8% for daily peak, 18.3% for cycling and 77.2% for base.

5.4 Transportation and distribution stage

The transportation and distribution costs for applicable fuels are shown in Table 9. For natural gas, the price in the supply stage, includes transportation to Toronto (city gate price), therefore at this stage the costs of transportation and distribution within Ontario are considered. The costs were arrived at by subtracting the 1985 Toronto city gate price from the average price to the end-use sectors, and escalating this cost at a rate of 2% for 36 years. Costs of liquid fuels include the cost of transportation to distribution outlets and the costs of distribution. Based on EMR (1983a), the transportation and distribution costs for gasoline was assumed to be $4.75 (1985 dollars) per litre. This figure has been escalated at 2% for 36 years for all petroleum fuels. For alcohols, the same cost as the above petroleum fuels has been assumed. This probably underestimates the costs, at least in the case of methanol, where there would be additional costs for replacement of existing storage systems (methanol has a corrosive effect on the materials that are currently being used for storage). However, with no data existing on the subject, the same cost has been assumed. LNG

Table 9. Costs associated with the transportation and distribution stage (1985 dollars) assumed for the base case (2021)

FUEL	COST Tran. & Dist. stage ($ / GJ)
Natural Gas	1.890
Gasoline	2.520
Diesel	2.495
Propane	3.785
Ethanol	4.176
Methanol	5.354
Aviation gas	2.890
Jet fuel	2.697
Light fuel oil	2.495
Heavy fuel oil	2.324
LNG	4.746
Liquid Hydrogen	5.763
Electricity	5.671
Wood	2.350

transportation and distribution costs, are higher than petroleum fuels, since they would require special cryogenic tanks and delivery outlets. EMR (1983a) report an additional cost of $1 per GJ (1982 dollars) of energy. The cost given in Table 9 was arrived at by escalating the cost at 2% for 36 years. No estimates exist for liquid hydrogen's transportation and distribution costs. However EMR (1983a) reports that costs would be extremely high due to its added storage volume which is approximately three times more than gasoline on an equal energy basis, and due to specially built cryogenic tank vehicles for transportation and specially built storage and pumping facilities. Both of these special facilities would need to be designed with safety features due to the fuel's low boiloff limits. The figure in Table 9 represents an estimate based on the above discussion. The transportation and distribution costs for wood are based on a cost of $17 (1981 dollars) per oven dried tonne (odt), reported in MEO (1981), escalated at 2% for 36 years. The transportation and distribution cost for electricity was estimated as 1 cent per kWh (1985 dollars), again escalated at 2% for 36 years.

For all liquid fuels a loss factor of 0.3% was taken. The loss factor for natural gas was taken as 8.4%. Electricity's loss factor was taken as 7.07%. These figures have been taken from Sullivan et. al (1980).

5.5 End-use utilisation stage

Data for the end-use stage was determined from various sources. Tables 10 and 11 show cost and technical details for space heating technologies for houses and apartments respectively. The figures in Table 10 apart from solar technology were based on MEO (1983) and Economic Council of Canada (1984). For active solar a system cost of $500 (1979$) per square metre of collector area was reported in Seymour (1979). The average heat energy supplied is 1200 MJ per square metre of collector area per year. Based on this, the R2000 house requires 13.5 square metres of collector area. Due to constraints such as structural strength of the roof or the land area required for the collectors, etc., the maximum collector area that could be installed on an average house is approximately 15 square metres. Based on the heating loads for the IS and OBC80 houses (see Table 16), both would require more than the maximum level. Considering the above limitation, both house categories have 15 square metres of collector area, active solar technology providing only a share of the total space heating requirement. Since 1979 however, there has been a decrease in costs as improvements have occured, therefore a system cost of $400 (1985$) per square metre per year has been used to calculate solar energy costs. The estimates on apartment heating costs (Table 11) were based on MEO (1983) and on discussions with various

Table 10. Cost and technical data for space heating options for different categories of houses assumed for the base case (2021)

TECHNOLOGY OPTION	Capital cost ($) R2000H (4 kW)	ISH (6 kW)	OBC80H (7.5 kW)	Operating cost ($)	Currency year	Device Efficiency	Device Lifetime (years)
Condensing gas furnace	1720	1980	2175	35	1981$	0.92	20
Induced gas furnace	1107	1306	1455	35	1981$	0.80	20
Light oil furnace	933	1100	1225	60	1981$	0.75	20
Electric baseboard	933	1100	1225	0	1981$	1	20
Electric heat pump	3100	3400	3700	70	1981$	1.90	20
Wood combination furnace	1550	1700	1927	85	1981$	0.65	20
Active solar - space heat	3900	7200	7200	60	1985$	-	20

N.B. 1. Data adapted from various sources. See text for details

2. R2000H : High insulation design house
ISH : Medium insulation design house
OBC80H : Low insulation design house

Table 11. Cost and technical data for space heating options for apartments assumed for the base case (2021)

TECHNOLOGY OPTION	Capital cost (1985$)	Operating cost (1985$)	Device Efficiency	Device Lifetime (years)	# of apartments serviced
Condensing gas boiler	6505	90	0.87	20	4
Induced gas boiler	4683	90	0.80	20	4
Light oil boiler	4107	180	0.75	20	4
Electric boiler	4107	38	1	20	4
Electric baseboard	933	0	1	20	1

N.B. 1. Data adapted from various sources. See text for details personnel connected with the supply and installation of apartment boilers. Table 12 shows cost and technical details for water heating and air-conditioning equipment. Details on water heating (excepting solar technology) and electrical air-conditioning equipment are market estimates. Solar water heating costs ranged from approximately \$6500 in 1978\$ (MEO, 1980), \$6000 in 1979\$ (Seymour, 1979), and \$4000 in 1983\$ (Andrews and Wilkins, 1983). These systems provide approximately 70% of the total water heating requirement for a household. Based on these figures and allowing for further cost decreases, a figure of \$3000 (1985\$) per system was used. No recent estimates on solar air-conditioning could be found. Middleton Associates (1976) reported an estimate of \$4000 (1976\$). In the absence of more recent estimates and allowing for improvements, a figure of \$3000 in 1985\$ was assumed for the cost of solar air-conditioning. In the absence of data for water heating costs in apartment buildings, the data for houses was used. Although the costs would represent a higher estimate, as economies of scale would decrease costs in the case of apartments, it is assumed that the relative relationship in costs between technologies would still remain the same.

The heat pump is assumed to provide 70% of the total heating load as heat pumps do not operate during very cold days. Wood furnaces are assumed to provide 90% of the

Table 12. Cost and technical data for water heating and air-conditioning options for houses assumed for the base case (2021)

TECHNOLOGY OPTION	Device Capacity	Capital cost (1985$)	Operating cost (1985$)	Device Efficiency	Device Lifetime (years)
Standard gas water heater	30 gallons	265	-	0.8	20
Flueless gas water heater	30 gallons	475	-	0.8	20
Electric gas water heater	30 gallons	215	-	1	20
Active solar water heater	30 gallons	4000	60	-	20
Electric window air-conditioner	5000 Btu	400	-	3	20
Electric central air-conditioner	3 ton	1625	20	3	20
Solar central air-conditioner	3 ton	4000	20	0.8	20

N.B. 1. Data adapted from various sources. See text for details

Table 13. Cost and technical data for industrial boilers assumed for the base case (2021)

TECHNOLOGY OPTION	Boiler size lb/hr steam	Capital cost (1979$)	Operating cost (1979$)	Device Efficiency	Device Lifetime (years)
Industrial gas boiler	100000	2260	235	0.80	20
Industrial heavy oil boiler	100000	3200	310	0.75	20
Industrial coal boiler	100000	7500	640	0.80	20

Data source: Canadian Energy Research Institute (1979) heating load as these need constant refuelling and need to be attended regularly, in the absence of which (roughly 10% of the time), these would not work. The solar space heating technologies, based on the maximum collector size and the heating loads provide 92% of the heating load for IS houses and 48% of the heating load for the OBC80 houses. Also, approximately 10% of the heat energy supplied is required in the form of electricity to run the active solar technology. This translates to an input equality share of 0.0909. Solar water heating technology is assumed to provide 70% of the total water heating demand as mentioned earlier in this section. The heat pump has an output share of approximately 84% for space heating and 16% for air-conditioning. These figures are based on heating and air-conditioning loads (see Table 16). The shares of heating loads for each house and apartment category are dependent on the number of houses of each type and the individual heating loads; both of these are described later in this section.

For the commercial and institutional sector, data for apartment buildings were used.

Costs and technical specifications for various industrial boilers are shown in Table 13. These costs were taken from Canadian Energy Research Institute (1979). For the utility subsector in the industrial sector, it is assumed that natural gas would supply 65% of the total energy, the other 35% being supplied by electricity. In the direct heat category, the shares of gas and heavy oil are assumed at an 8% level each, coal at 83% and electricity at 1%; these figures represent 1985 levels.

Table 14 shows cost and technical data for the auto and light trucks and vans categories of the transportation sector. The costs were based on figures reported in EMR (1983a). The end-use utilisation energy efficiency for these two subcategories is defined as millions of kilometres per peta joule of input energy. For gasoline cars, the efficiency figure in Table 14 corresponds to a fleet average efficiency of 8.5 litres per 100 kilometres. The end-use utilisation energy efficiency is the same for alcohol blends and liquid hydrogen. For diesel, alcohols, propane, CNG and LNG, a 10% improvement in energy efficiency has been assumed. This efficiency improvement is due to higher compression ratios associated with engines running on these fuels. For electric cars the efficiency figure corresponds to 0.5 kWh per mile reported by Hedley et al. (1976). For light trucks and vans running on gasoline, the figure corresponds to 11.4 litres per 100 kilometers, the average efficiency figure for this category in 1985. All other efficiencies have been relatively scaled. Table 15 shows cost and technical features for all the other remaining categories in the transportation sector. The cost categories are defined for those sectors

Table 14. Cost and technical data for auto and light truck and van categories assumed for the base case (2021)

TECHNOLOGY OPTION	Incremental Capital cost per vehicle (1982$)	Device Efficiency Mkm / PJ	Device Lifetime (years)
Propane - auto	500	386.08	10
Methanol - auto	500	386.08	10
Ethanol - auto	500	386.08	10
CNG - auto	500	386.08	10
LNG - auto	500	386.08	10
Gasoline - auto	0	350.98	10
Diesel - auto	0	386.08	10
Methanol-gasoline - auto	120	350.98	10
Ethanol-gasoline - auto	120	350.98	10
Liquid hydrogen - auto	5000	350.98	10
Electric - auto	1500	555.60	10
Propane - light trucks & vans	500	287.86	10
Methanol - light trucks & vans	500	287.86	10
Ethanol - light trucks & vans	500	287.86	10
CNG - auto & light trucks & vans	500	287.86	10
LNG - light trucks & vans	500	287.86	10
Gasoline - light trucks & vans	0	261.69	10
Diesel - light trucks & vans	0	287.86	10
Methanol-gasoline - light trucks & vans	120	261.69	10
Ethanol-gasoline - light trucks & vans	120	261.69	10
Liquid hydrogen - light trucks & vans	5000	261.69	10
Electric - light trucks & vans	1500	414.40	10

N.B. For data sources see text

Table 15. Cost and technical data for bus and truck categories assumed for the base case (2021)

TECHNOLOGY OPTION	Incremental Capital cost per vehicle (1982$)	Device Efficiency	Device Lifetime (years)
Propane - bus	1500	0.24	7
CNG - bus	1500	0.24	7
LNG - bus	1500	0.24	7
Methanol - bus	1500	0.24	7
Ethanol - bus	1500	0.24	7
Liquid Hydrogen - bus	15000	0.22	7
Diesel - truck	0	0.26	7
Propane - truck	3750	0.24	7
CNG - truck	3750	0.24	7
LNG - truck	3750	0.24	7
Methanol - truck	3750	0.24	7
Ethanol - truck	3750	0.24	7
Liquid Hydrogen - truck	37500	0.22	7

N.B. For data sources see text

where interfuel substitution is permitted. For the others, the shares of fuels are fixed, thus no cost estimations have been done. For the buses and trucks category, the costs represent roughly half the percentage increase in the cars category, since the cost for the changes, i.e. for engine, fuel system, etc., in proportion to the parts that do not change, drive trains, suspension systems, etc., would be less for buses and trucks than for the cars. The efficiency term here is defined in the standard way i.e. ratio of output energy to input.

Market penetration for electric vehicles has an upper bound of 20%. This figure reflects the technology limitation in driving range. Thus even if electric cars are cost effective, they perhaps would only compete as a second car in a household. Other shares include, 0.4% share of aviation gas to the total aircraft energy requirement, the rest being provided by jet fuel, and a 47% input share of diesel for marine category, the rest being provided by heavy oil. These values represent actual shares in 1984.

Houses, apartments and commercial and institutional buildings built after the year 1950 are assumed to exist in the year 2021. For the residential sector this amounts to a total of 1,869,261 household units that would be existing in the year 2021 out of the household units currently existing (Statistics Canada, 1987). The ratio of houses to apartments for the existing stock was taken as 61:39 (MEO, 1985b) with 99% of the houses belonging to the OBC80 (houses with insulation levels described by 1980 building code) and 1% belonging to the IS (houses with insulation levels inbetween OBC80 and R2000 houses) category. As no data were available to estimate the number of commercial and institutional buildings, based on residential data, 34% of all buildings in this category existing in 2021 was assumed as existing stock.

The values of parameters used to determine certain shares (mentioned earlier) and end-use demands are shown in Table 16. As described in the previous chapter, the end-use parameters are defined in terms of useful energy or in terms of fuel energy. The space heating loads for different houses was taken from EMR (1983c). Space heating for old apartments, water heating and appliances and lighting loads per household are reported in terms of fuels in MEO(1985b). These were translated into useful energy demands by multiplying the fuel demands by their device efficiencies. New apartments were assumed to be 30% more efficient than old apartments, the figure obtained from MEO (1985b). Air-conditioning loads for OBC80 house category was taken from Middleton Associates (1976). For the commercial sector, the parameters were again available in the form of fuel demands (MEO, 1985b). These too were translated into useful energy demands by multiplying the fuel demands by their device efficiencies. New commercial

TABLE 16. Specifications of technical parameters of the end-use stage assumed for the base case (2021)

CATEGORY	TYPE	END-USE DEMANDS/SERVICES PER YEAR	
RESIDENTIAL[1]			
Space heat R2000 house	Useful	16.20	GJ/unit
Space heat IS house	Useful	39.10	GJ/unit
Space heat OBC80 house	Useful	74.41	GJ/unit
Space heat New apartments	Useful	12.60	GJ/unit
Space heat Old apartments	Useful	18.00	GJ/unit
Water heating	Useful	20.41	GJ/unit
Window a/c units-OBC80 house	Useful	2.70	GJ/unit
Central a/c house-OBC80 house	Useful	7.20	GJ/unit
Appliances & lighting	Fuel	20.61	GJ/unit
COMMERCIAL[2]			
Space heat New buildings	Useful	0.66	GJ/m^2
Space heat Old buildings	Useful	0.94	GJ/m^2
Water heating	Useful	0.04	GJ/m^2
Air conditioning - Old bgs.	Useful	0.18	GJ/m^2
Equipment and lighting	Fuel	0.28	GJ/m^2
INDUSTRIAL[3] (1984 demands)			
Indirect heat	Useful	268	PJ
Direct heat - coal	Fuel	211	PJ
Direct heat - heavy oil	Fuel	40	PJ
Direct heat - natural gas	Fuel	40	PJ
Direct heat - electricity	Fuel	3	PJ
Electric drive.	Fuel	119	PJ
Utilities	Fuel	71	PJ
Pet. prods. & Pet.ch. fstk.	Fuel	204	PJ
TRANSPORTATION[4] (1984 demands)			
Average distance per car	Useful	16210	km
Average distance per van/l.t.	Useful	16890	km
Buses	Useful	7.43	PJ
Rail	Useful	21.60	PJ
Marine - diesel	Useful	7.29	PJ
Marine - heavy oil	Useful	12.50	PJ
Aircraft - aviation gasoline	Useful	0.26	PJ
Aircraft - turbo jet fuel	Useful	42.38	PJ
Truck	Useful	15.77	PJ
Subway and St. cars	Fuel	1.37	PJ

1. Data for space heating loads for houses taken from EMR (1983c). Data for space heating in apartments, water heating, and appliances andlighting have been adapted from MEO (1985b).
2. Data adapted from MEO (1985b)
3. Data for distance travelled for cars and lt.trucks and vans taken from SC (1985). For all other categories data adapted from SC (1986).

buildings are also assumed to be 30% more efficient than existing buildings. 1984 figures for the industrial sector were taken from MEO (1985b). The average distance travelled by a car and a light truck and van were taken from Statistics Canada (SC, 1985a). The 1984 fuel consumptions were reported in SC (1985b). Wherever required, these have been translated to useful energy in the manner described earlier.

The values assigned to certain additional parameters that the model uses to determine end-use demands are given in Table 17. Population projections for both Canada as a whole and the provinces exist, starting with a base year of 1983 and extending up to the year 2006 (SC, 1985). The projections for total Canadian population further extend up to the year 2031 in steps of five years, Starting with a medium growth projection series the projected fraction of Ontario's population to total Canadian population from the year 1983 to 2006 was used as data for construction of a linear regression model. The fraction obtained from the time series model for the year 2021 multiplied with the projected value for the total Canadian population for the year 2021 produced the estimate for Ontario's population for the year 2021. In a similar manner a linear regression model for determining the number of households in the year 2021 was based on medium growth projected data given in SC (1981). All other values given in the table were based on

Table 17. Values of parameters for projection of end-use demands for the base case (2021)

PARAMETER	VALUE
Population (millions)	10.4764
Housing units (millions)	5.5979
Fraction of housing units that are houses	0.39
Fraction of houses of the R2000 type	0.45
Fraction of houses of the IS type	0.5
Fraction of houses of the OBC80 type	0.05
Fraction of housing units with a/c	0.8
Fractional improvement in heating loads of of new apartments and C&I buildings over existing buildings	0.30
C&I floor space trend	2.51
Industrial production trend	1.82
Transportation trend (all categories excluding auto and light trucks & vans	1.00
Auto & light trucks & vans trend	1.55

TABLE 18. End-use demand projections for the base case (2021)

CATEGORY	TYPE	END-USE DEMANDS/SERVICES
RESIDENTIAL		
Space heat R2000 house	Useful	16.1 PJ
Space heat IS house	Useful	43.65 PJ
Space heat OBC80 house	Useful	97.04 PJ
Space heat New apartments	Useful	19.14 PJ
Space heat Old apartments	Useful	11.94 PJ
Water heating	Useful	114.23 PJ
Window air-cond. units	Useful	15.94 PJ
Central air-cond. units	Useful	21.54 PJ
Appliances & lighting	Fuel	115.37 PJ
COMMERCIAL		
Space heat New buildings	Useful	194.32 PJ
Space heat Old buildings	Useful	60.78 PJ
Water heating	Useful	14.40 PJ
Air conditioning	Useful	47.49 PJ
Equipment and lighting	Fuel	100.80 PJ
INDUSTRIAL		
Indirect heat	Useful	571.37 PJ
Direct heat	Fuel	542.59 PJ
Electric drive	Fuel	253.71 PJ
Utilities	Fuel	151.37 PJ
Pet. prod. & Pet.ch. fstk.	Fuel	434.92 PJ
TRANSPORTATION		
Auto	Useful	121.16 Gkm.
Light Trucks & Vans	Useful	21.08 Gkm
Buses	Useful	2.27 PJ
Rail	Useful	6.60 PJ
Marine	Useful	2.75 PJ
Aircraft	Useful	14.99 PJ
Truck	Useful	18.53 PJ
Subway and St. cars	Fuel	1.61 PJ

trends reported in MEO (1985b,1986). Based on these values the end-use demands for each category are shown in Table 18.

A discount rate of 8% was used to amortise all capital costs for production (with the exception of electrical generation plants) and end-use technologies over their respective lifetimes. A discount rate of 3% was used for electrical generation plants, the 3% figure being the actual rate used by Ontario Hydro.

Imports or exports for refined products were not permitted for the base case. For electricity, exports were permitted upto a level of 50 PJ and were priced at 4.533 c/kWh (1985$). The price figure represents 1985 export price escalated at an annual rate of 1% over 36 years and the upper bound reflects current export levels.

Lastly, WATEMS permits data input in terms of natural units. However, a conversion factor defined as the number of basic units per natural unit must be specified (defined in 3.1.2.4). The basic unit for the model is the peta joule. The conversion factors for various resources where natural units have been used are given in Table 19. The conversion unit for uranium converts directly to petajoules of electricity.

The above data was entered into spreadsheets. Details on data input along with the input spreadsheets are given in Appendix A. The model has 419 variables and 242

Table 19. Conversion factors for primary energy resources and fuels

RESOURCE / FUEL	NATURAL UNITS	NUMBER OF BASIC UNITS PER NATURAL UNIT
Natural Gas	10^3 Mcf	0.00107
Western Coal	10^3 Tonnes	0.02933
US App. Coal	10^3 Tonnes	0.02999
Lignite	10^3 Tonnes	0.01534
Crude Oil	10^3 Barrels	0.00610
Wood	10^3 Tonnes	0.02000
Uranium	Tonnes	0.18054
Wheat	10^3 Tonnes	0.01420
Barley	10^3 Tonnes	0.01420
Corn	10^3 Tonnes	0.01420
Propane	10^6 Litres	0.02560
Electricity	gWh	0.00360

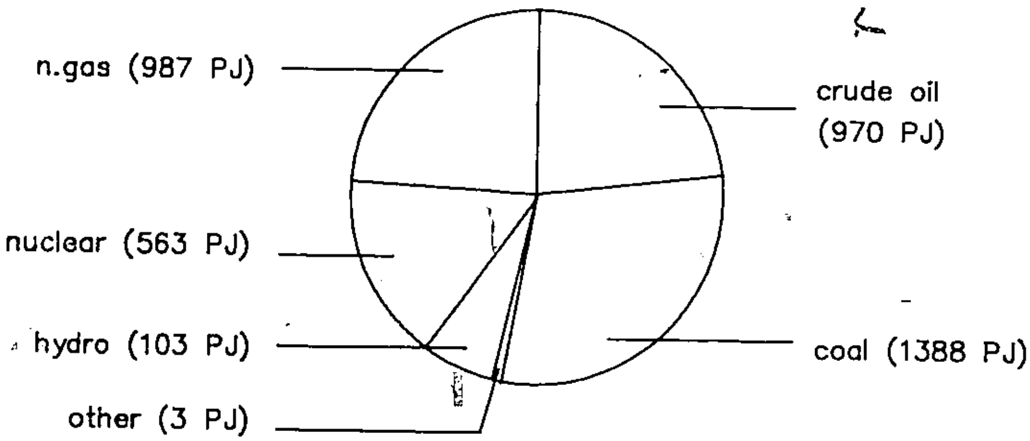
Note: The basic unit is the peta joule (10^{15} joules) constraints. Results of the base case are analysed in the following chapter.

CHAPTER VI

RESULTS FOR THE BASE CASE

Figure 4 shows primary energy consumption for the year 2021 as calculated by the model for the base case. The primary energy consumption increases from 2830 PJ in 1984 to 4014 PJ in 2021. There is a significant change in the primary mix with a substantial decline in the share of oil and substantial increases in the share of nuclear electricity and coal (Figure 5).

The end-use fuel consumptions are shown in Figure 6. In particular the share of coal in the total fuel mix increases sharply (Figure 7). This increase is due to coal substitution in the indirect heat category in the industrial sector, despite higher capital costs of coal boilers relative to gas and oil fired boilers. As mentioned earlier, the model does not distinguish between different industries, the indirect heat category represents an average of cost and efficiency parameters for the entire range of boilers used in industry. The increase in coal share therefore represents an upper limit on the possible increase. In reality, the cost effectiveness would only hold for some industries. There is a decrease in the share



Total primary energy consumption (base case, 2021) = 4014 PJ

[Total primary energy consumption (1984) = 3432 PJ*
Average % increase per year = 0.42]
* MEO (1985b)

Figure 4. Primary energy consumption (base case, 2021)

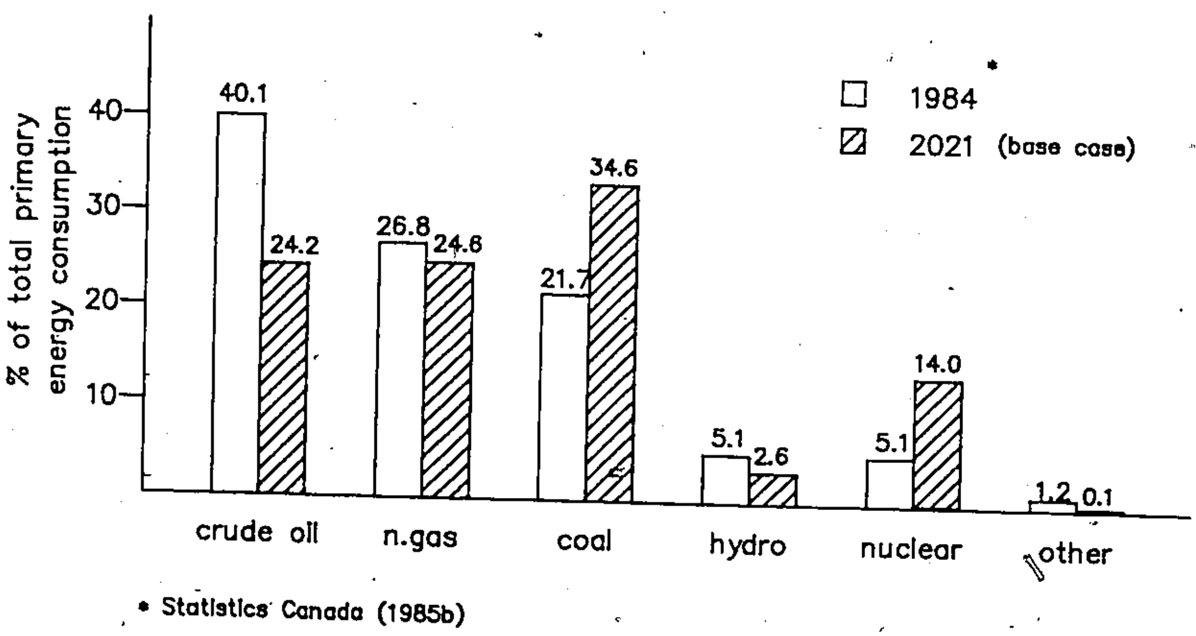
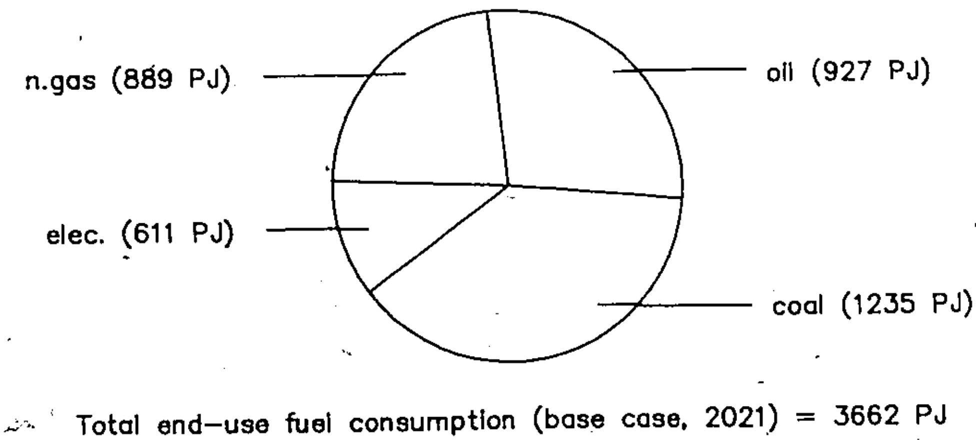


Figure 5. Primary energy shares (base case, 2021)



[Total end-use energy consumption (1984) = 2404 PJ*
Average % increase per year = 1.14]
* MEO (1985b)

Figure 6. End-use fuel consumption (base case, 2021)

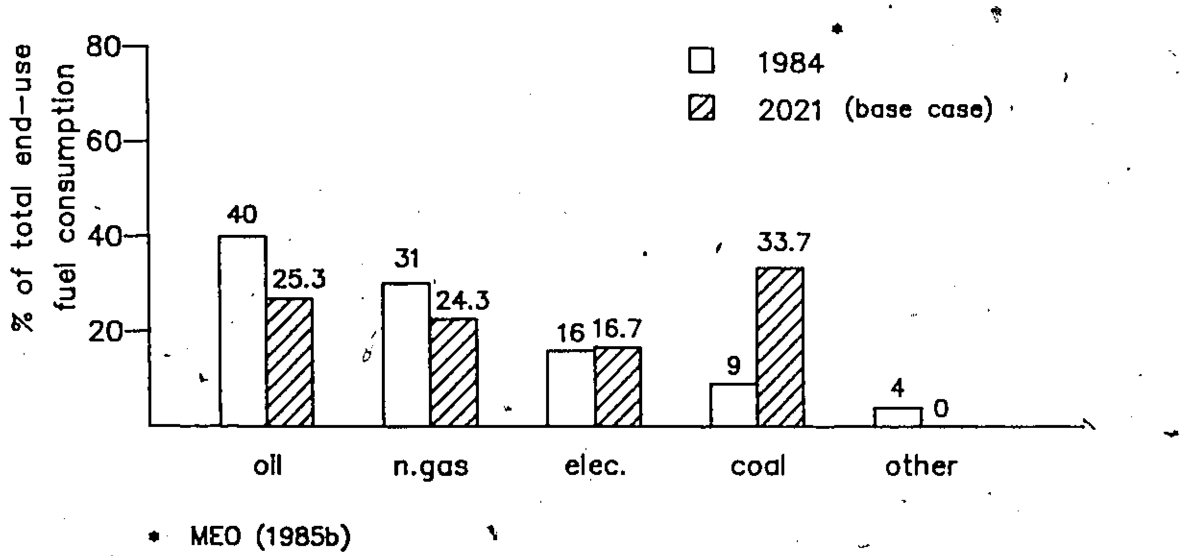
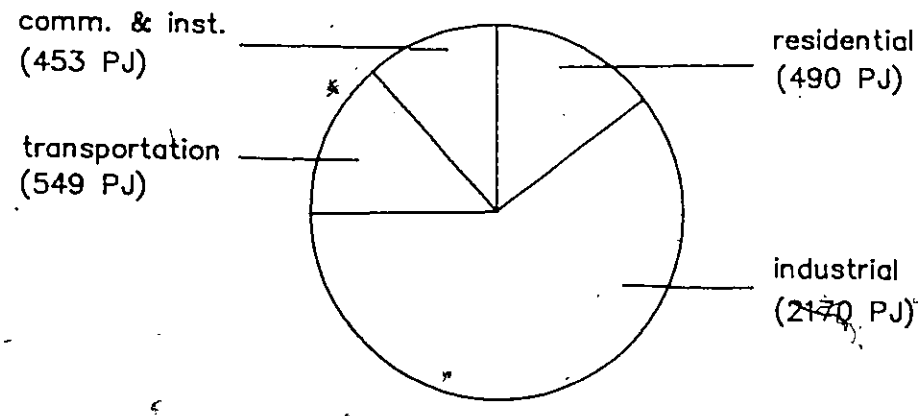


Figure 7. End-use fuel shares (base case, 2021)

of oil. In the residential and commercial sectors oil consumption is nil (since other technologies are more cost effective). The share of oil decreases both in the industrial as well as transportation sectors.

Results showing market shares are shown in Figures 8 and 9. The decrease in the share for the residential sector is mainly due to better designed energy efficient buildings and heating devices. The relative increase in the share of the industrial sector to a high level (approximately 59%), reflects to some extent the inflexibility of the "under-modelled" industrial sector. Despite higher capital costs, better efficiency of electric vehicles leads to low operating costs which makes electric vehicles cost effective relative to other technologies in the Auto and Light truck categories. Market penetration is at the maximum allowable level of 20 %. As electric vehicles have nearly twice the end-use energy efficiency in comparison with gasoline vehicles, this is reflected in the decrease in the transportation market share.

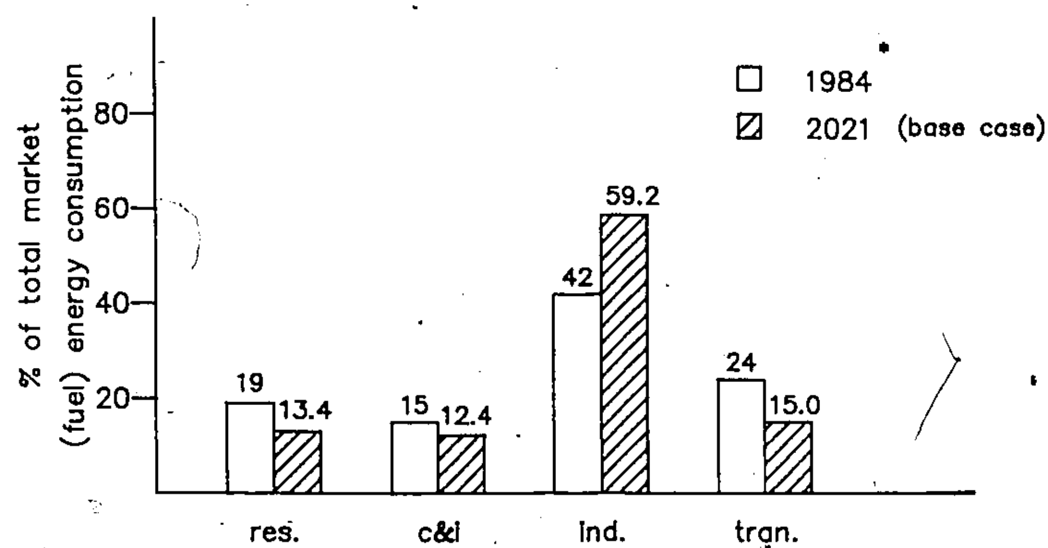
The share of electricity in the total end-use fuel energy remains nearly at the same level as 1984. There is an increase in electric energy generation, with nuclear generation having the largest share (78%), followed by hydro (14%), fossil (8%) and a very small fraction by municipal refuse. The above least cost generation mix is



Total market energy (fuel) consumption (base case) = 3662 PJ

[Total market energy consumption (1984) = 2404 PJ*
Average % increase per year = 1.14]
* MEO (1985b)

Figure 8. Market energy consumption (base case, 2021)



* MEO (1985b)

Figure 9. Market shares of end-use sectors
(base case, 2021)

in accordance with the expected trend of an increased share of nuclear generation. Ontario Hydro estimates that by 1993, the year by which all current commitments are completed, the generation mix would consist of nuclear power with a share of 70%, followed by hydro (24%) and fossil generation (6%). Figure 10 gives the power and energy produced from the type of plant and mode of operation. The base load is entirely provided by nuclear power. The cyclic or intermediate load is nearly entirely met by hydro and coal generation, and a very small fraction by the reconditioned municipal refuse plant at Hearn. The daily peak mode is met by hydro and coal generation. The seasonal peak by hydro and gas generation. The total peak power load is approximately 43 GW.

Figure 11 shows end-use energy consumption for the residential sector. For houses, the induced gas furnace is the preferred option for the R2000 and the Intermediate Solar house, and the condensing gas furnace for the OBC80 house. The reason for induced gas heating in R2000 and the Intermediate Solar house over the condensing gas furnace is that the induced gas heating has a lower capital cost than the condensing gas furnace and as the energy requirement for both these houses is low, capital costs dominate making this option more cost effective. However, with energy requirements per household increasing for the OBC80 house, the better efficiency of condensing gas furnaces reduces

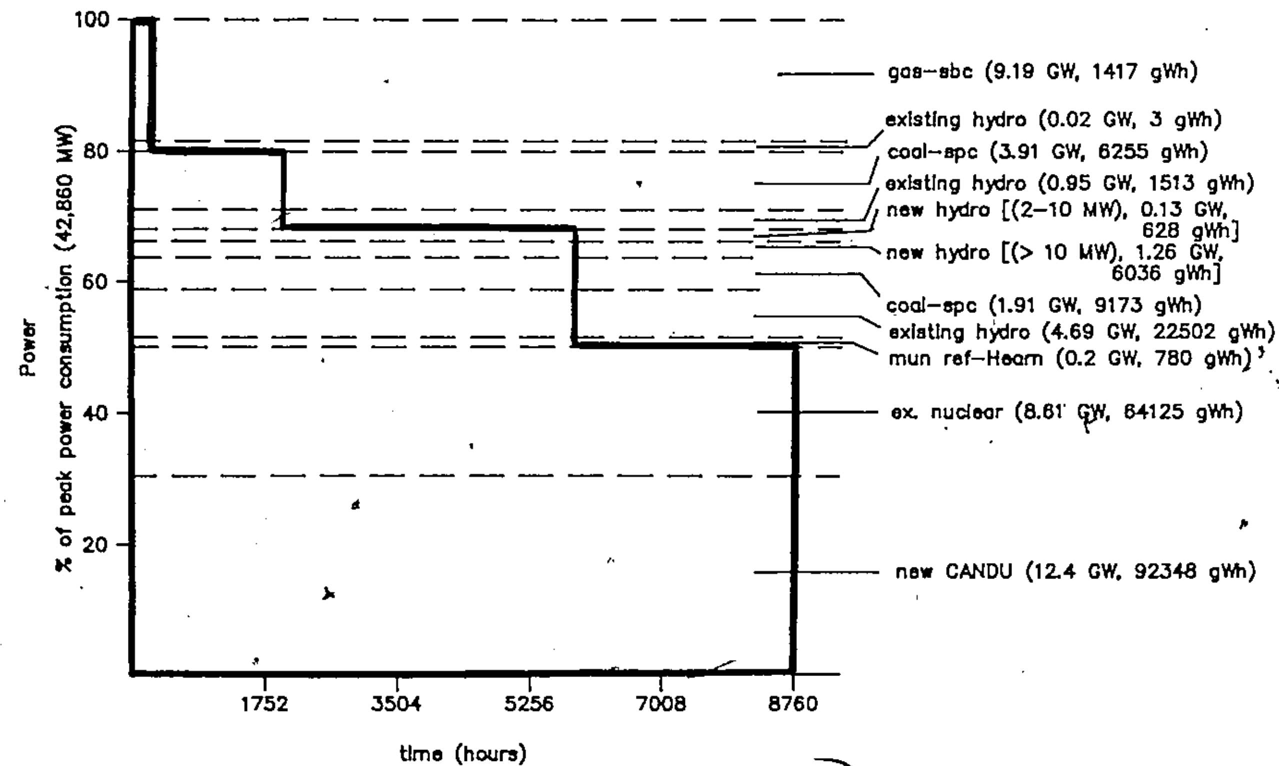
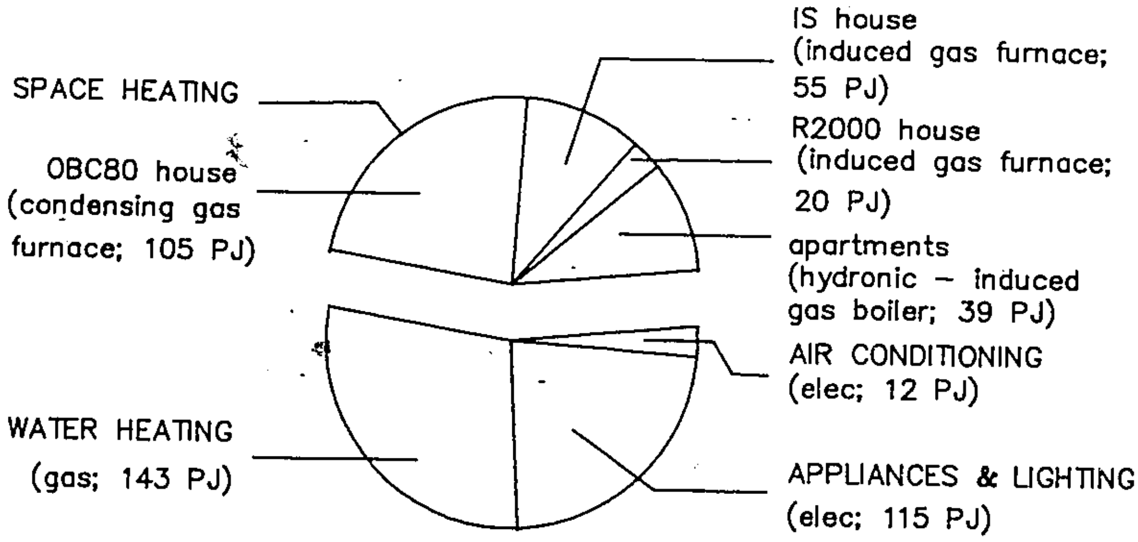


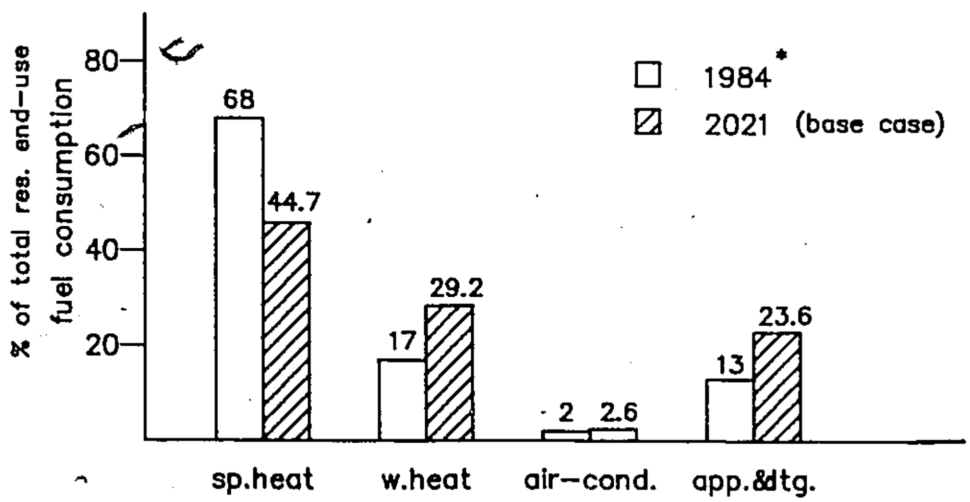
Figure 10. Linear approximated load duration curve for the base case (2021) showing electrical energy generation and mode of operation for supply sources.



Total residential energy consumption (base case, 2021) = 490 PJ

[Total residential energy consumption (1984) = 448 PJ*
Average % increase per year = 0.24]
* MEO (1985b)

Figure 11. Residential energy consumption by end-use (base case, 2021)



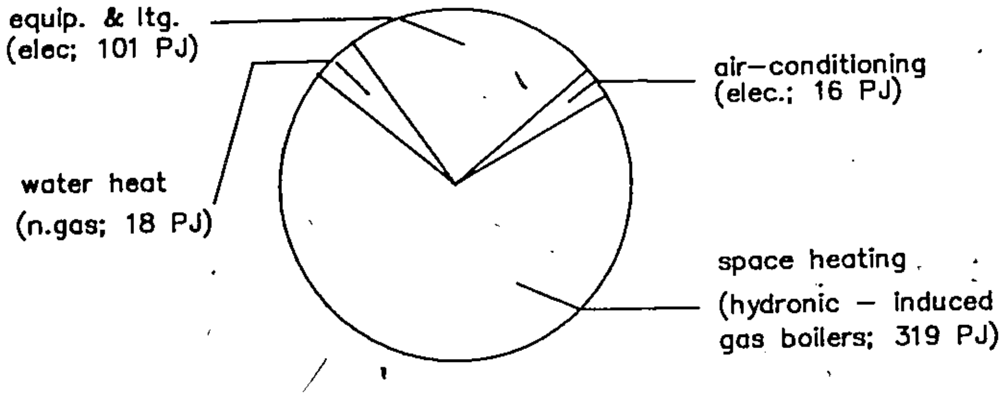
* MEO (1985b)

Figure 12. Shares of residential end-use sectors (base case, 2021)

operating costs and compensates for the higher capital cost. For apartment buildings, hydronic heating with induced gas boilers is the most cost effective amongst the technologies considered. Water heating by natural gas is more cost effective than electric. It is worth noting that this is so in spite of the fact that the capital cost for the flueless gas water heater (the type considered here) is double that of an electric water heater. Solar space and water heating do not appear in the solution. Solar air-conditioning does not either. Heat pumps, despite their dual purpose of air-conditioning and heating, do not enter the solution. This is probably due to additional capital cost for back-up heating equipment as heat pumps are not effective on very cold days.

Residential shares of end-use sectors are shown in Figure 12. As mentioned earlier, the sharp decrease in the share of space heating can be attributed to better designed buildings and heating devices. In fact, space heat consumption levels decrease from 305 PJ in 1984 to 219 PJ in 2021 despite increases in the number of household units.

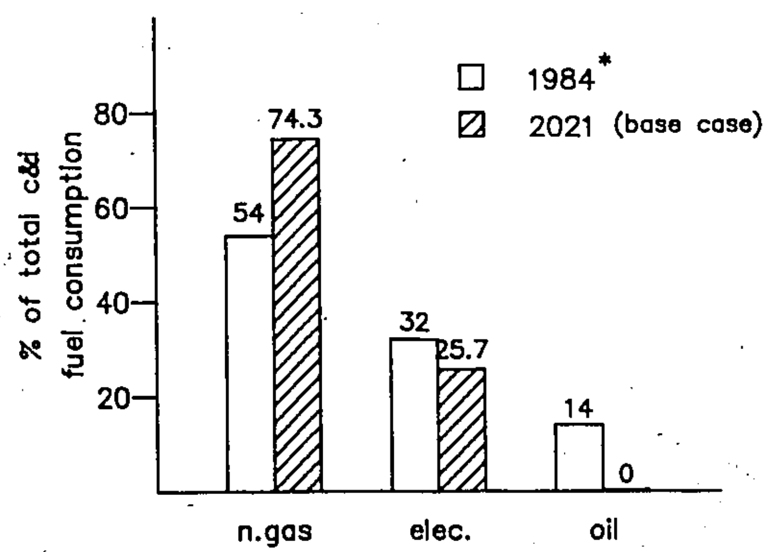
Figure 13 gives the energy consumption for the commercial and institutional sector. Amongst the technologies considered, hydronic heating with induced gas boilers is the preferred option. Water heating is by gas. Figure 14 shows the fuel shares for the Commercial and Institutional sector.



Total comm. & inst. energy consumption (base case, 2021) = 453 PJ

[Total comm. & inst. energy consumption (1984) = 367 PJ*
Average % increase per year = 0.57]
* MEO (1985b)

Figure 13. Comm. & Inst. energy consumption by end-use (base case, 2021)

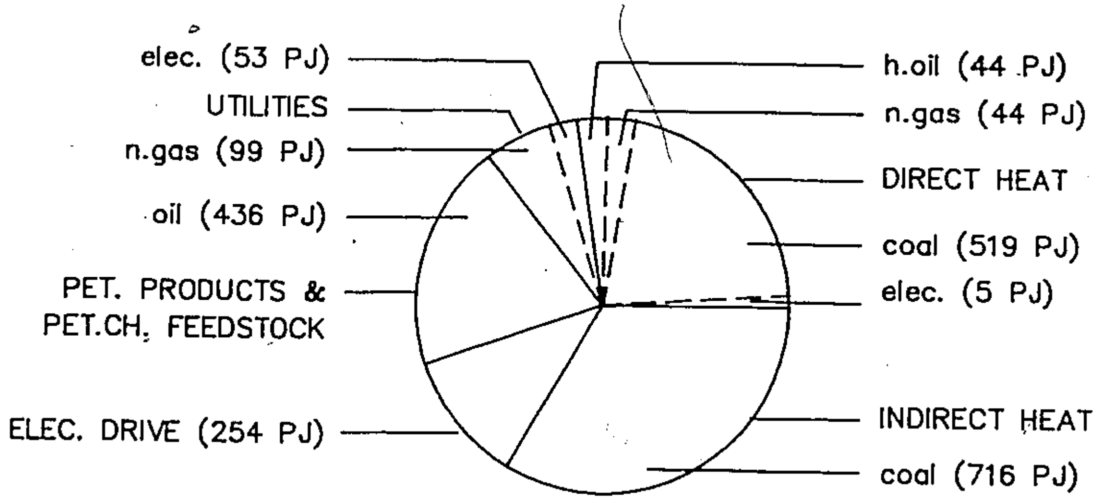


* MEO (1985b)

Figure 14. Comm. & Inst. fuel shares (base case, 2021)

Results for the industrial sector are shown in Figures 15 and 16. Interfuel substitution is only permitted for the indirect category. For all other categories, market shares based on historic levels were fixed. As mentioned earlier in this section, coal is most cost effective for indirect heat. The major shift is due to the penetration of coal for boiler fuel.

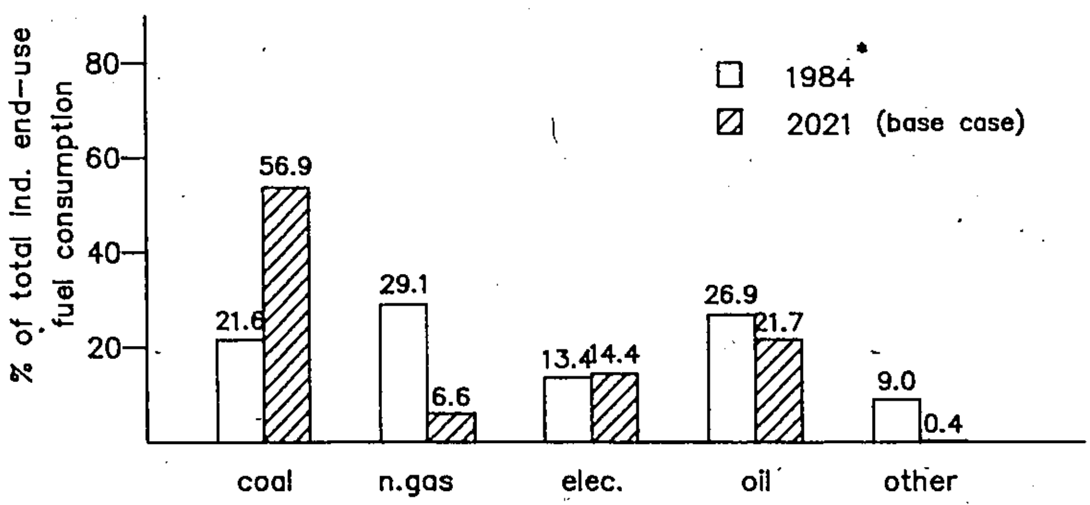
Figure 17 and 18 show consumption in the transportation sector. For cars, from a predominantly gasoline market, there is a significant shift towards diesel and CNG fuelled cars with small percentages of electric and propane fuelled cars. The shift away from gasoline becomes immediately obvious when looked at from the refinery point of view. A reduction in gasoline and an increase in diesel permits refineries of lower complexity to operate, thus reducing costs. Worth noting is the fact that despite higher capital costs by approximately $600 per car for CNG fuelled cars over gasoline powered cars, it is more cost effective to produce CNG cars than produce the extra gasoline from a higher complexity refinery. Also, despite higher capital costs of approximately $1700 per car for electric cars over gasoline fuelled cars, they too appear in the optimal solution. The small percentage of propane cars is due to the fact that only propane produced from the refinery as a by-product is cost effective. Propane imported from other regions is not cost effective.



Total industrial energy consumption (base case, 2021) = 2170 PJ

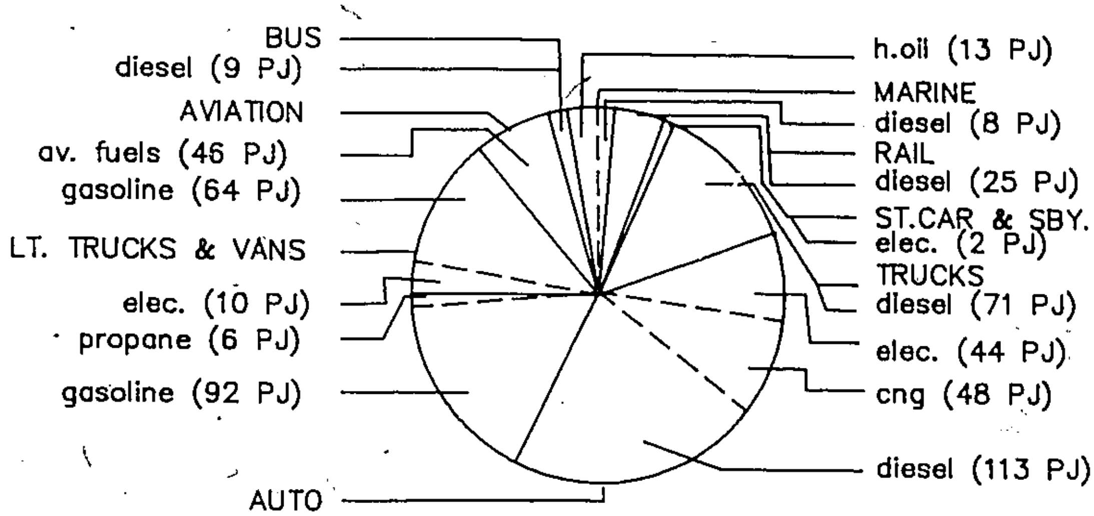
[Total industrial energy consumption (1984) = 1018 PJ*
Average % increase per year = 2.07]
* MEO (1985b)

Figure 15. Industrial energy consumption by end-use (base case, 2021)



* Statistics Canada (1985b)

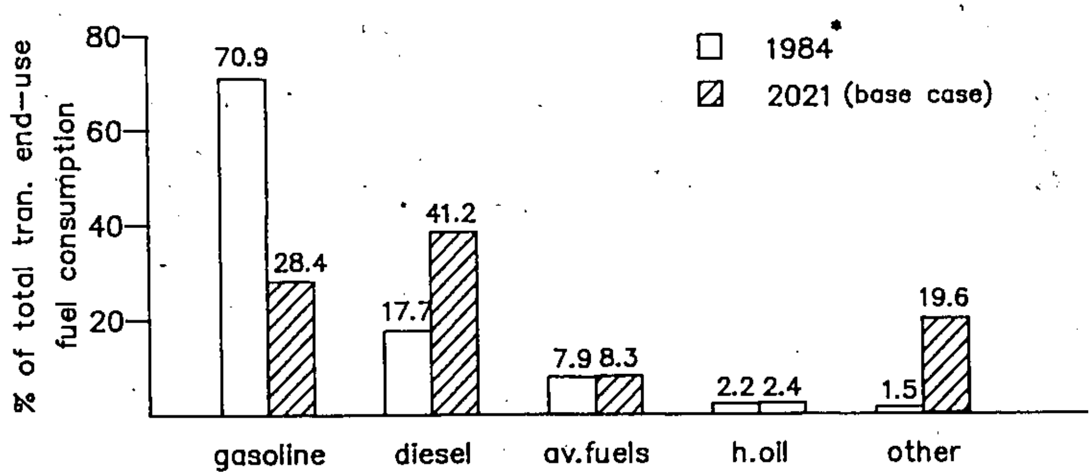
Figure 16. Industrial fuel shares (base case, 2021)



Total transportation energy consumption (base case, 2021) = 549 PJ

[Total transportation energy consumption (1984) = 571 PJ*
Average % increase per year = -0.11]
* MEO (1985b)

Figure 17. Transportation energy consumption by end-use (base case, 2021)



* Statistics Canada (1985b)

Figure 18. Transportation fuel shares (base case, 2021)

Detailed results for the base case are given in Appendix B. To account for the uncertainty that exists in examining the future the model has been run for two additional scenarios, namely, the low energy demand and the high energy demand scenarios. Creation of the two scenarios along with model results are presented in the following chapter.

CHAPTER VII

ASSUMPTIONS AND RESULTS FOR THE LOW AND HIGH ENERGY DEMAND CASES

7.1 Assumptions

The base demand represents the most likely scenario. As mentioned at the end of the previous chapter, in view of the uncertainty that exists when dealing with the future, the model has been run for two additional scenarios, the low and the high energy demand scenarios.

The low energy demand scenario can be a result of various factors such as lower population levels, high energy prices, etc. that combine together to reduce energy consumption. On the other hand, the high energy demand scenario reflects a situation where factors such as high population, low energy prices, etc. increase the energy demand.

The prices of primary energy assumed for both the scenarios are shown in Table 20 along with the base case for comparison purposes. The prices for the low demand case generally represent an escalation of all primary resource prices by approximately 25% over the base case. Conversely, for the high demand case the prices represent a

Table 20. Primary resource prices (1985 dollars) assumed for the low, base and high energy demand scenarios (2021)

RESOURCE	UNITS	PRICE low	base	high
Natural Gas	$/Mcf	7.64	6.21	4.64
Western Coal	$/Tonne	160.00	128.00	96.00
US App. Coal	$/Tonne	121.00	97.00	73.00
Lignite	$/Tonne	89.00	71.00	53.00
Propane	$/Litre	0.38	0.30	0.22
Crude Oil	$/Barrel	62.00	49.00	36.00
Uranium	$/Kg	371.00	297.00	233.00
Wood	$/Odt	103.00	82.00	62.00
Wheat	$/Tonne	281.00	225.00	169.00
Barley	$/Tonne	239.00	191.00	143.00
Corn	$/Tonne	248.00	198.00	149.00

Table 21. Values of parameters for projection of end-use demands for the low, base and high energy demand scenarios (2021)

PARAMETER	VALUE low	base	high
Population (millions)	9.5809	10.4764	12.1306
Housing units (millions)	5.1732	5.5979	6.3478
Fr. of housing units of houses	0.61	0.61	0.61
Fr. of new houses of R2000 type	0.60	0.45	0.30
Fr. of new houses of IS type	0.38	0.50	0.62
Fr. of new houses of OBC80 type	0.02	0.05	0.08
Fr. of housing units with a/c	0.70	0.80	0.90
Fr. improvement in heating loads of new apartments and C&I buildings over existing buildings	0.35	0.30	0.25
C&I floor space trend	2.01	2.51	3.01
Industrial production trend	1.46	1.82	2.18
Transportation trend (all categories excluding auto and light trks.& vans)	0.80	1.00	1.20
Auto & light trucks & vans trend	1.24	1.55	1.86

reduction by the same figure over the base case.

The values assumed for certain parameters that determine end-use demands are shown in Table 21 (see previous page). The population figure was obtained by a procedure similar to that used for the base case, using low and high growth projection series for total Canadian population (Statistics Canada, 1985). Similarly, low and high growth household projections were used to determine the number of households (Statistics Canada, 1981). It was also assumed that higher energy prices would have an increasing effect on the average insulation level of a houshold unit, i.e. there would be, say, more R2000 houses in comparison with the base case, which in turn would result in lower energy demands. The converse is assumed to exist for lower energy prices. It was also assumed that higher energy prices would reduce economic growth, thus depressing energy demand, while lower energy prices would have a converse effect. This is reflected in the trend factors. All other values such as costs of conversion, share fractions, etc., are kept the same as in the base case. End-use demand projections are shown in Table 22.

7.2 Results

Starting with the results for the low case, there are certain differences in comparison with the base case in the pattern of energy consumption, i.e. in the type of fuel and

TABLE 22. End-use demand projections for the low, base and high energy demand scenarios (2021)

CATEGORY	TYPE	END-USE DEMANDS/SERVICES low	base	high	UNITS
RESIDENTIAL					
Space heat R2000 house	Useful	14.22	16.10	19.44	PJ
Space heat IS house	Useful	38.59	43.65	52.60	PJ
Space heat OBC80 house	Useful	96.07	97.04	98.74	PJ
Space heat New apartments	Useful	17.06	19.14	22.83	PJ
Space heat Old apartments	Useful	11.94	11.94	11.94	PJ
Water heating	Useful	105.57	114.23	129.54	PJ
Window air-cond. units	Useful	12.89	15.94	20.33	PJ
Central air-cond. units	Useful	17.42	21.54	27.49	PJ
Appliances & lighting	Fuel	106.63	115.37	130.84	PJ
COMMERCIAL					
Space heat New buildings	Useful	121.44	194.32	306.54	PJ
Space heat Old buildings	Useful	60.78	60.78	60.78	PJ
Water heating	Useful	10.54	14.40	19.98	PJ
Air conditioning	Useful	33.92	47.49	68.32	PJ
Equipment and lighting	Fuel	73.76	100.80	139.85	PJ
INDUSTRIAL					
Indirect heat	Useful	420.33	571.37	794.63	PJ
Direct heat	Fuel	399.15	542.59	754.61	PJ
Electric drive	Fuel	186.69	253.71	352.84	PJ
Utilities	Fuel	111.36	151.37	210.52	PJ
Pet. prod. & Pet.ch. fstk.	Fuel	319.95	434.92	604.87	PJ
TRANSPORTATION					
Auto	Useful	88.59	121.16	168.24	Gkm
Light Trucks & Vans	Useful	15.41	21.08	29.28	Gkm
Buses	Useful	1.66	2.27	3.15	PJ
Rail	Useful	4.83	6.60	9.17	PJ
Marine	Useful	2.01	2.75	3.83	PJ
Aircraft	Useful	10.97	14.99	20.83	PJ
Trucks	Useful	13.56	18.53	25.74	PJ
Subway and St. cars	Fuel	1.18	1.61	2.24	PJ

end-use technology used to satisfy end-use demands. For R2000 houses, electric space heating replaces the induced gas furnace as the preferred option. As this scenario is associated with higher energy prices for fossil fuels, there is a relative decrease in the cost of electricity generation in comparison with fossil fuels, thus causing the above substitution. There is a slight change in the transportation sector with propane fuelled cars not appearing in the optimal solution. This difference is not very significant as propane fuelled cars were having approximately 1% share of the auto market in the base case, the propane being obtained from refineries as a by-product.

All other patterns of consumption for all end-use sectors remains the same as in the base case with lower levels of consumption. The net reduction in electrical energy demand causes a reduction in the share of fossil-fuel generation. This is understandable as this scenario is associated with higher fossil fuel prices in comparison with hydro. The results for the low energy demand scenario are shown in Figures 19 to 33.

The results for the high energy demand scenario reveal the following changes. With lower fossil fuel prices, the induced gas furnace becomes more cost effective than the condensing gas furnace for the OBC80 house category. Also, there is a significant shift in the transportation sector. For cars, in the base case demand was met by electric,

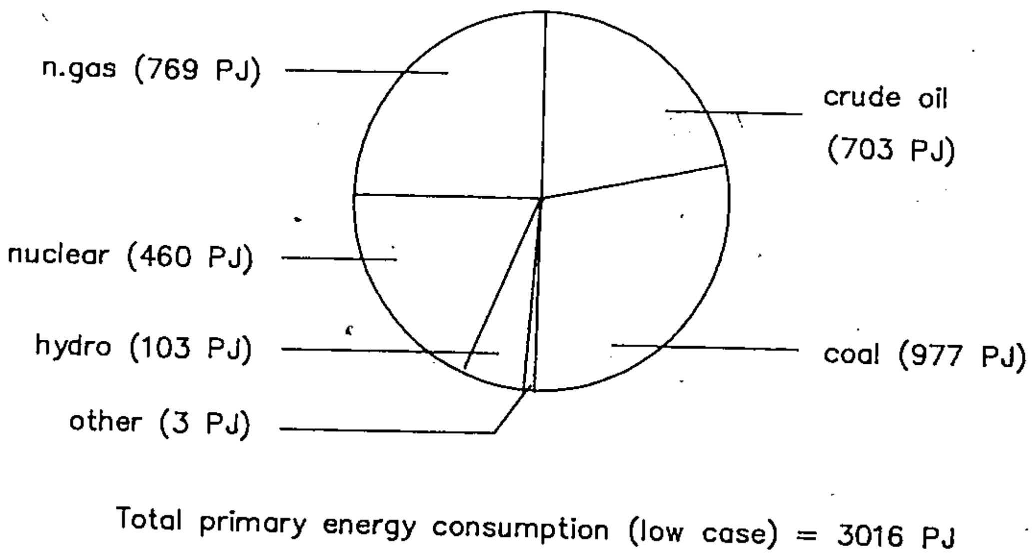


Figure 19. Primary energy consumption (low case, 2021)

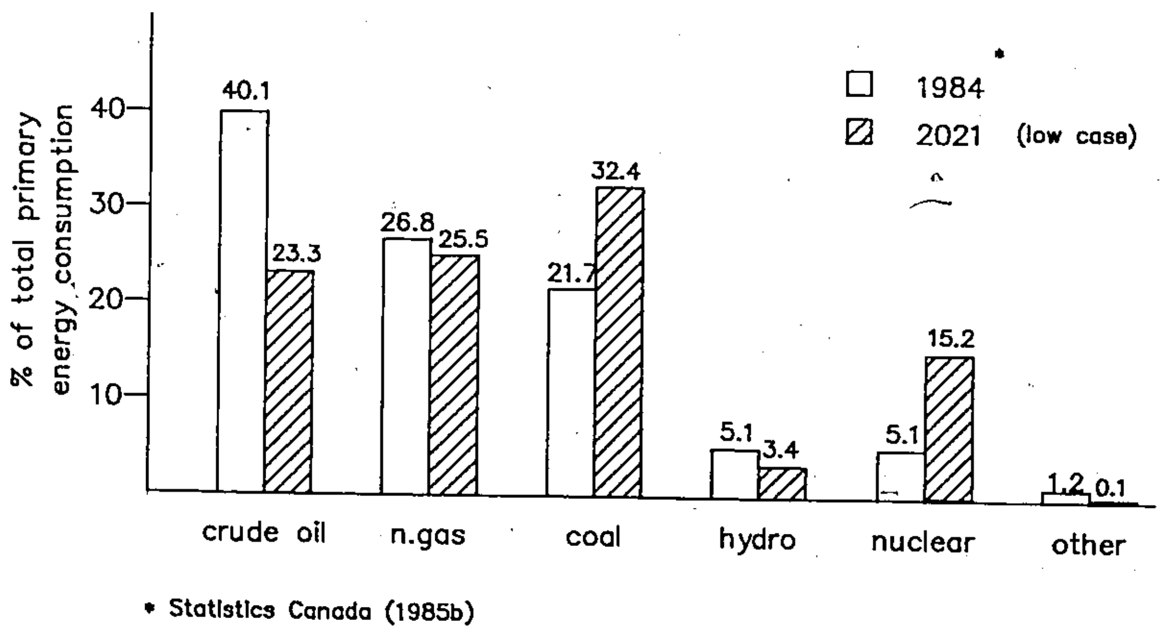


Figure 20. Primary energy shares (low case, 2021)

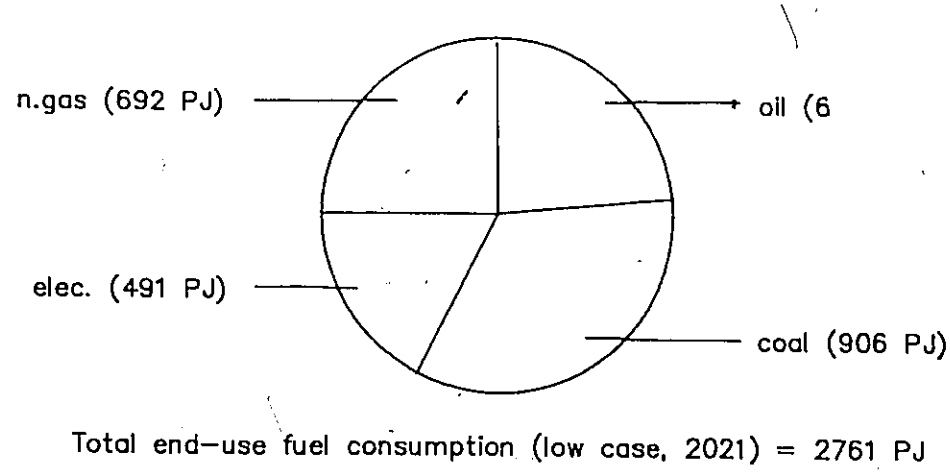


Figure 21. End-use fuel consumption (base case, 2021)

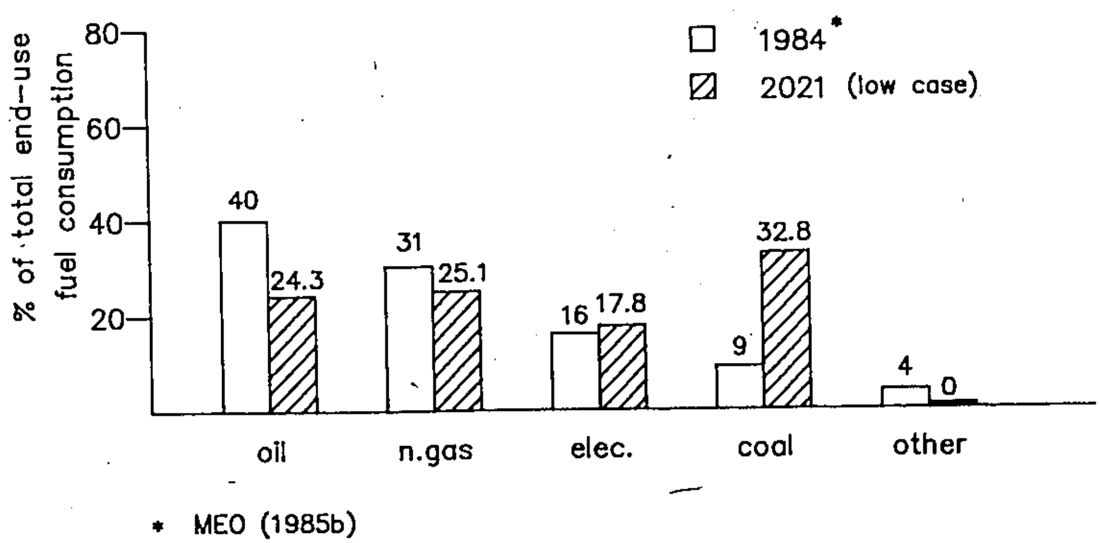
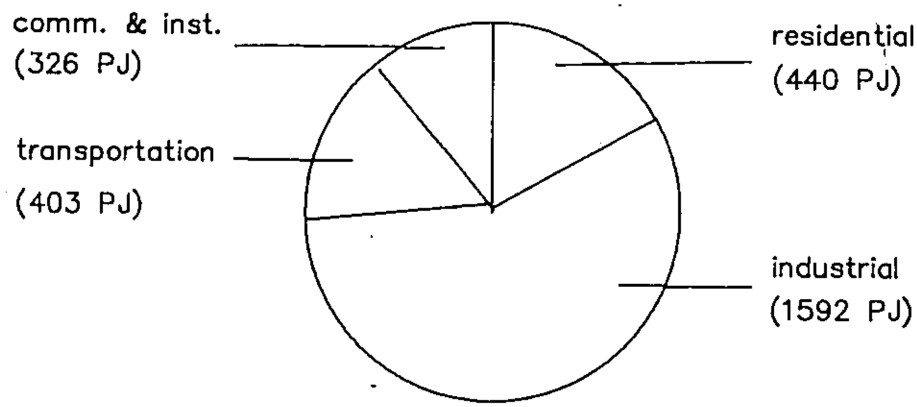


Figure 22. End-use fuel shares (low case, 2021)



Total market energy (fuel) consumption (low case, 2021) = 2761 PJ

Figure 23. Market energy consumption (low case, 2021)

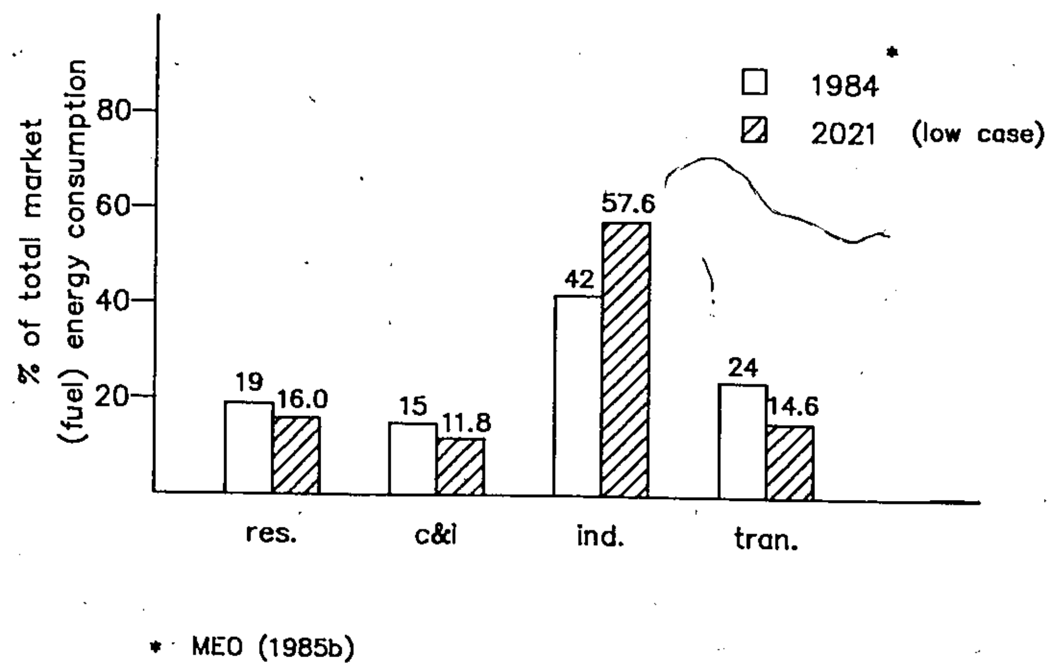


Figure 24. Market shares of end-use sectors (low case, 2021)

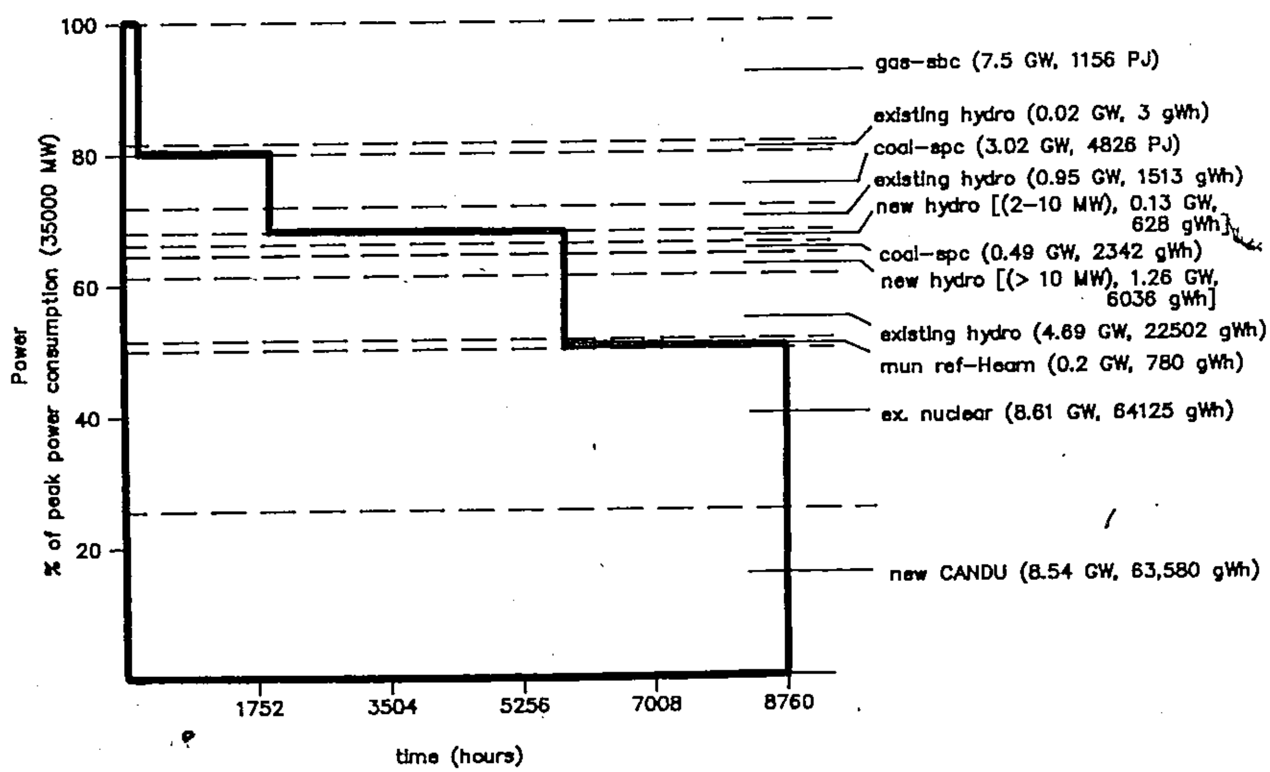
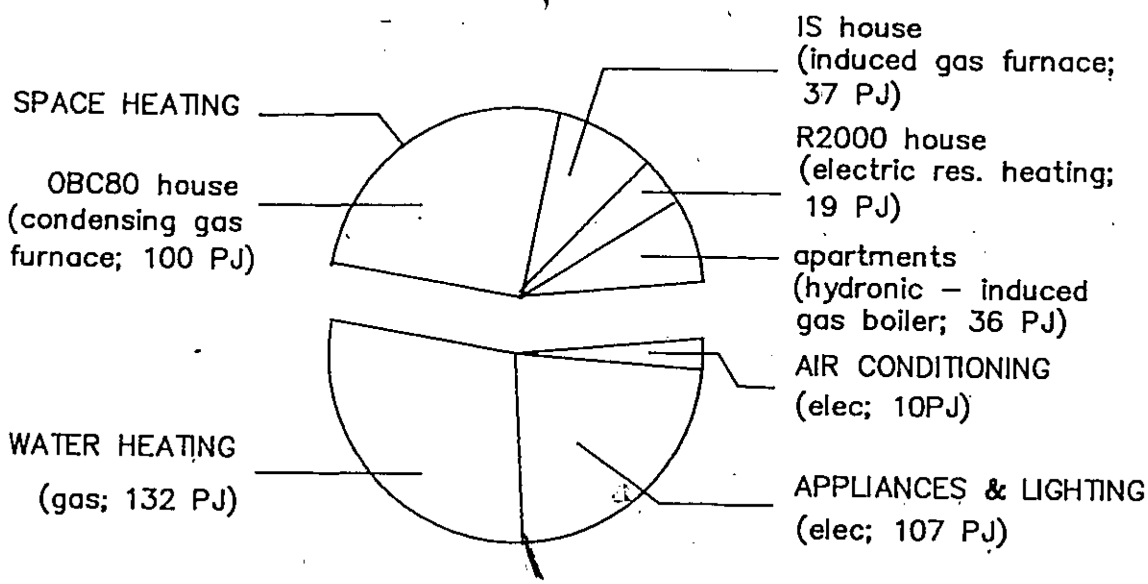


Figure 25. Linear approximated load duration curve for the low case (2021) showing electrical energy generation and mode of operation for supply sources.



Total residential energy consumption (low case, 2021) = 440 PJ

Figure 26. Residential energy consumption by end-use (low case, 2021)

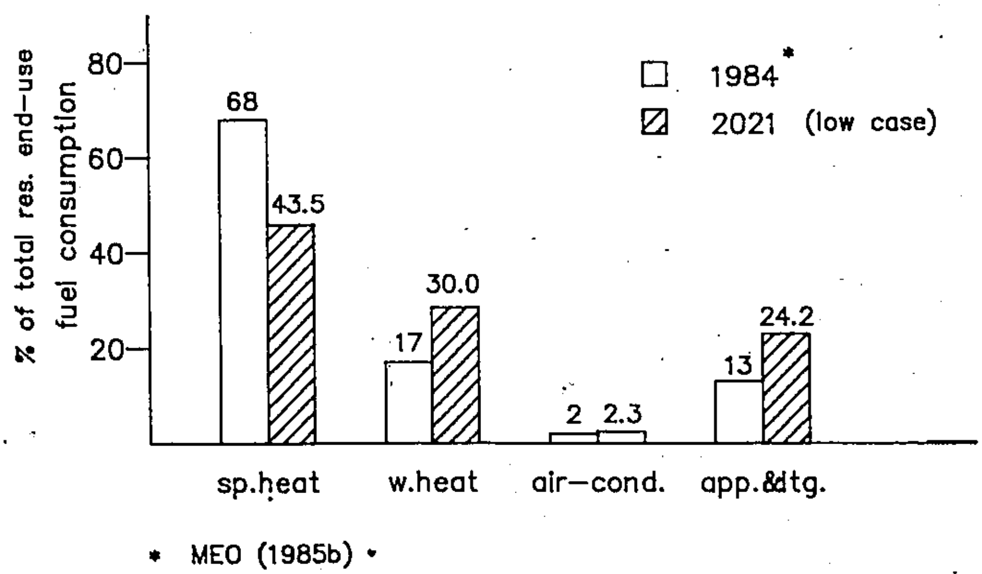
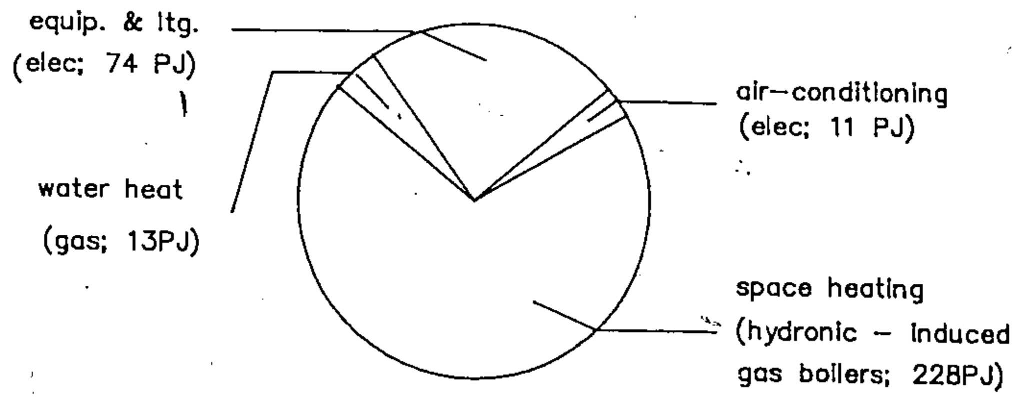


Figure 27. Shares of residential end-use sectors (low case, 2021)



Total comm. & inst. energy consumption (low case, 2021) = 326 PJ

Figure 28. Comm. & Inst. energy consumption by end-use (low case, 2021)

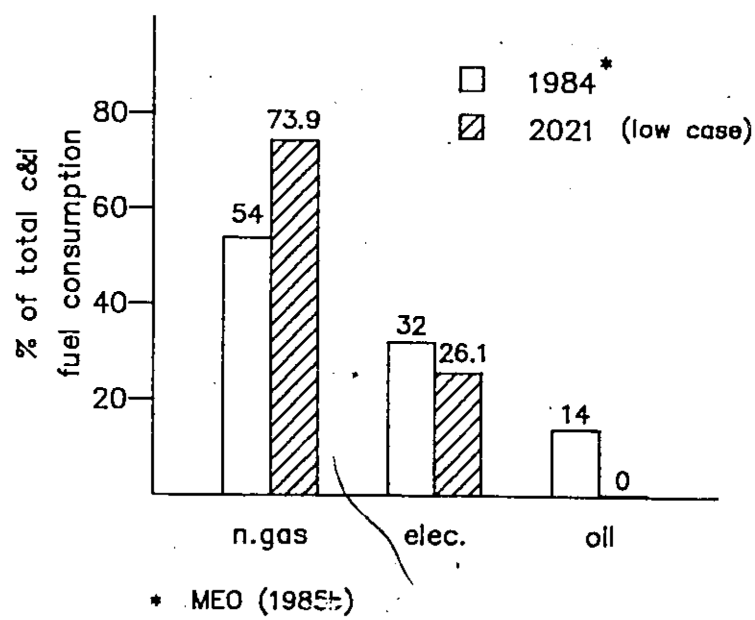


Figure 29. Comm. & Inst. fuel shares (low case, 2021)

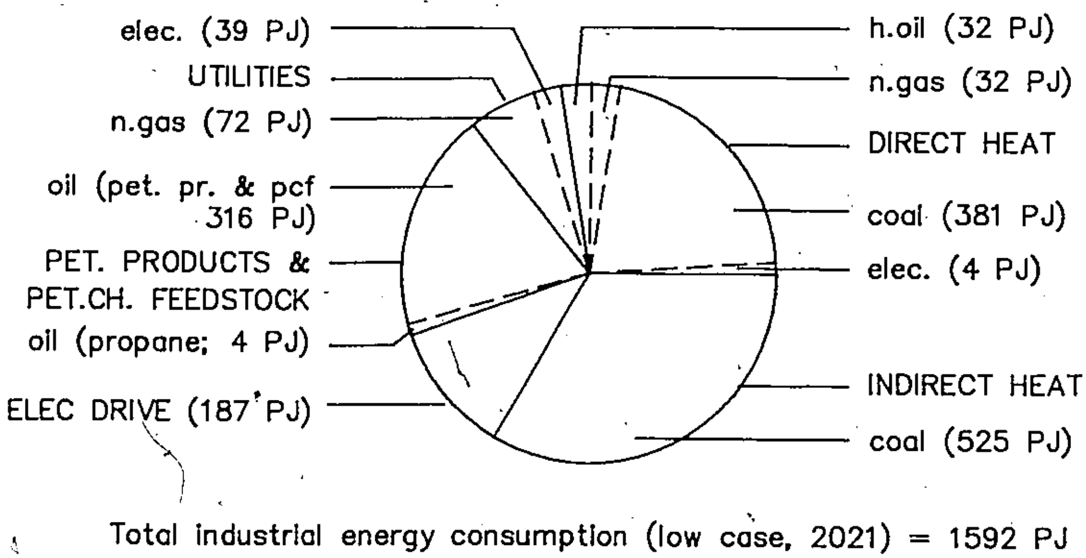


Figure 30. Industrial energy consumption by end-use (low case, 2021)

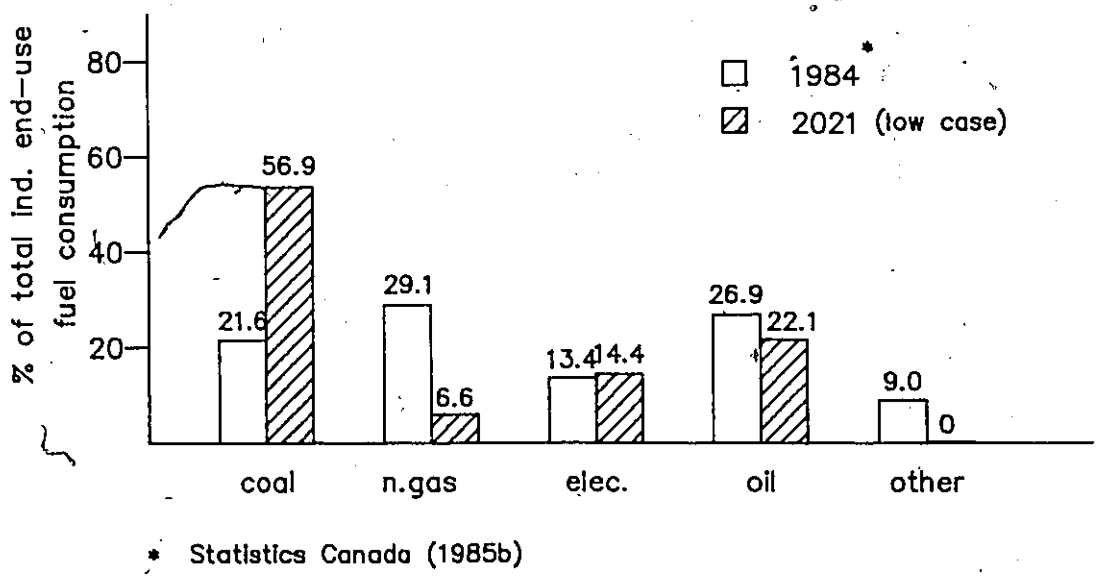


Figure 31. Industrial fuel shares (low case, 2021)

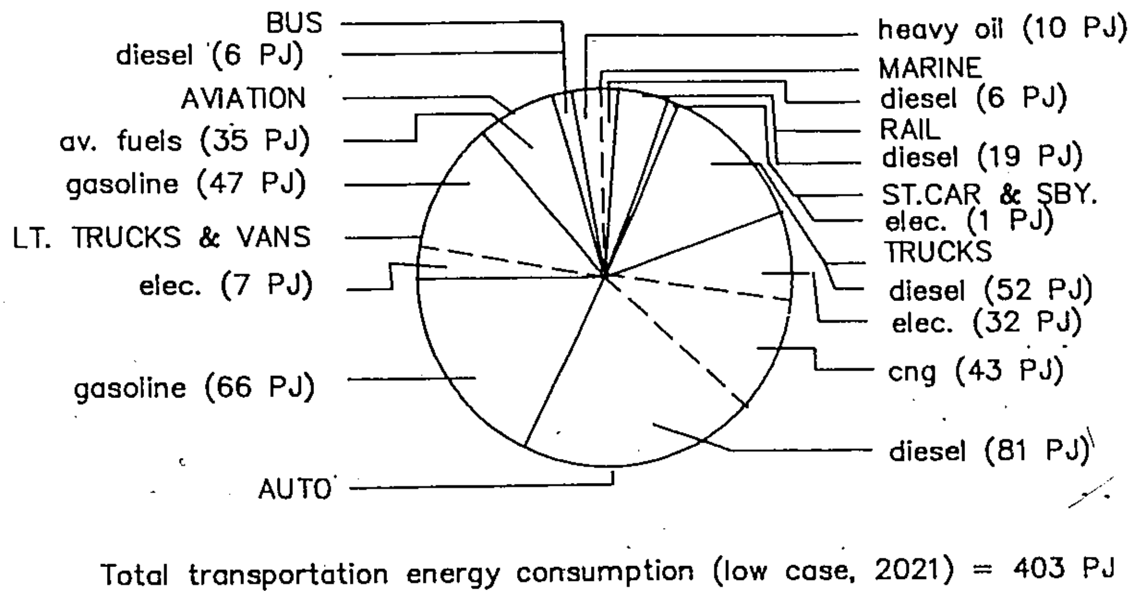


Figure 32. Transportation energy consumption by end-use (low case, 2021)

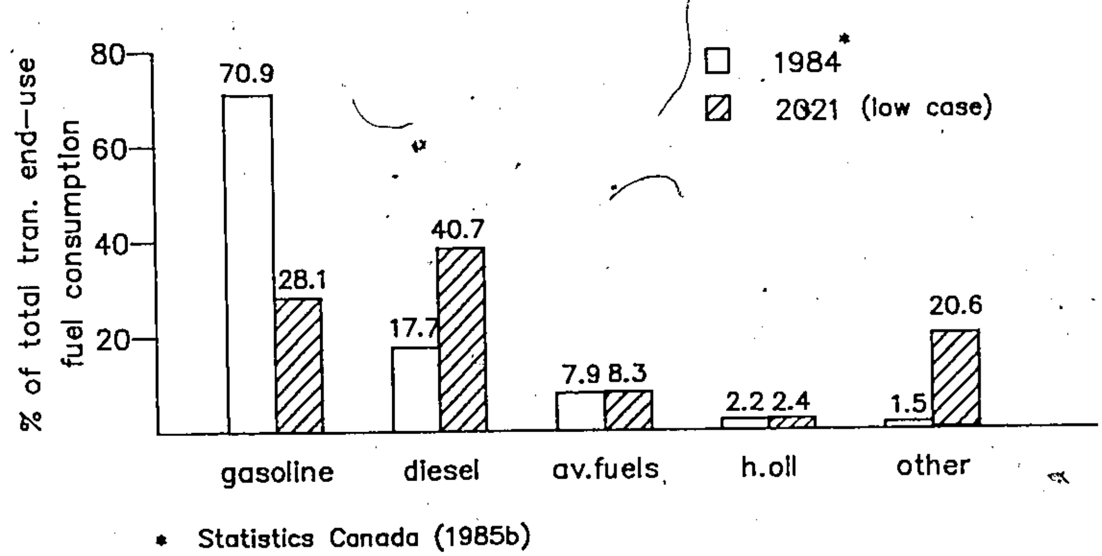
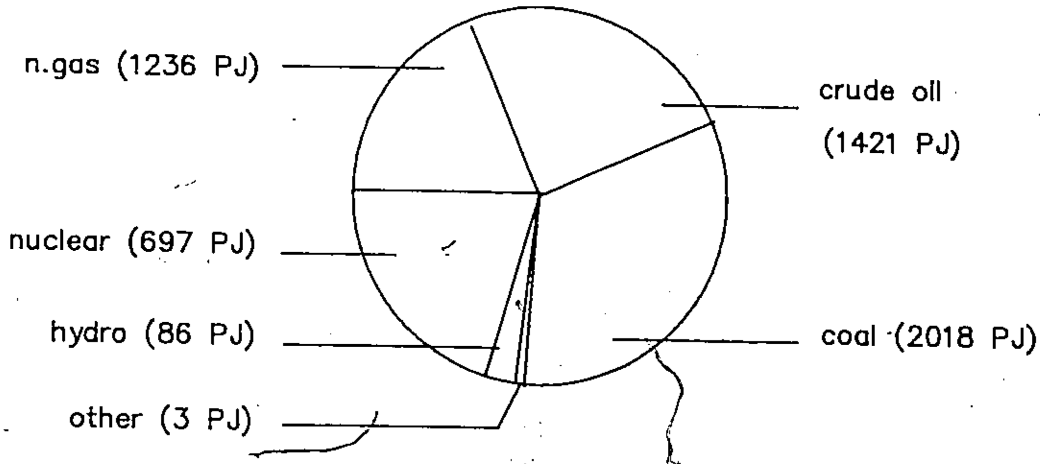


Figure 33. Transportation fuel shares (low case, 2021)

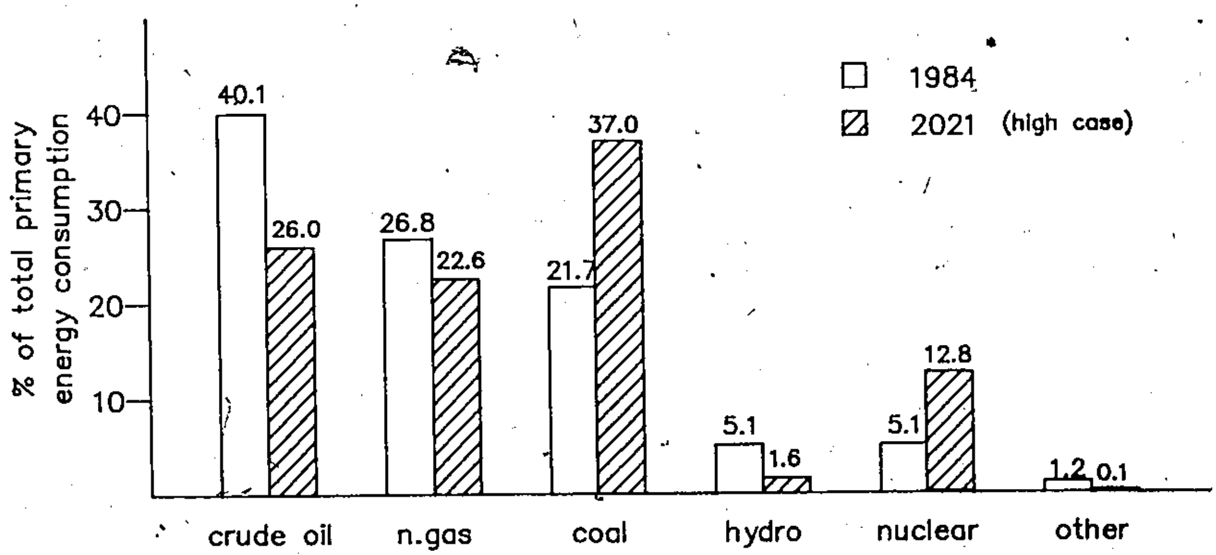
gasoline and diesel from lower complexity refineries and the slack left over by CNG fuelled cars. In the high case, the above pattern of electric, and gasoline and diesel from lower complexity refineries remains the same, however the slack is met by gasoline and diesel from higher complexity refineries rather than CNG. The mix of low and high complexity refineries in the solution does not necessarily imply the existence of just the low and high complexity refineries but perhaps a range of refineries with in between degrees of complexity. This in turn implies a range of refineries with varying degrees of catalytic cracking and hydro cracking facilities. The mean complexity in this case was 7.136 in comparison to 6.665 (low complexity refinery) for the low and base cases. All other patterns of energy consumption remain the same as in the base case except with higher consumption patterns.

With increasing electrical energy demand there is an increase in coal, gas and nuclear generation. However, there is a decrease in hydro energy, with no new hydro (greater than 10 MW and 2-10 MW) appearing in the solution. This can be understood in light of the fact that this scenario was associated with lower primary energy resource prices that applied to coal, gas and nuclear, thus making these options more cost effective. Peak power demanded is approximately 53 GW. The results for the high energy demand scenario are shown in Figures 34 to 48.



Total primary energy consumption (high case, 2021) = 5461 PJ

Figure 34. Primary energy consumption (high case, 2021)



* Statistics Canada (1985b)

Figure 35. Primary energy shares (high case, 2021)

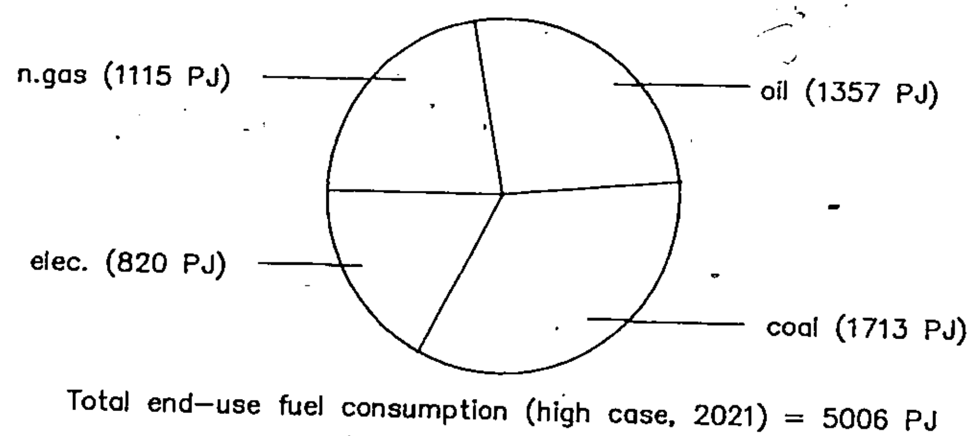


Figure 36. End-use fuel consumption (high case, 2021)

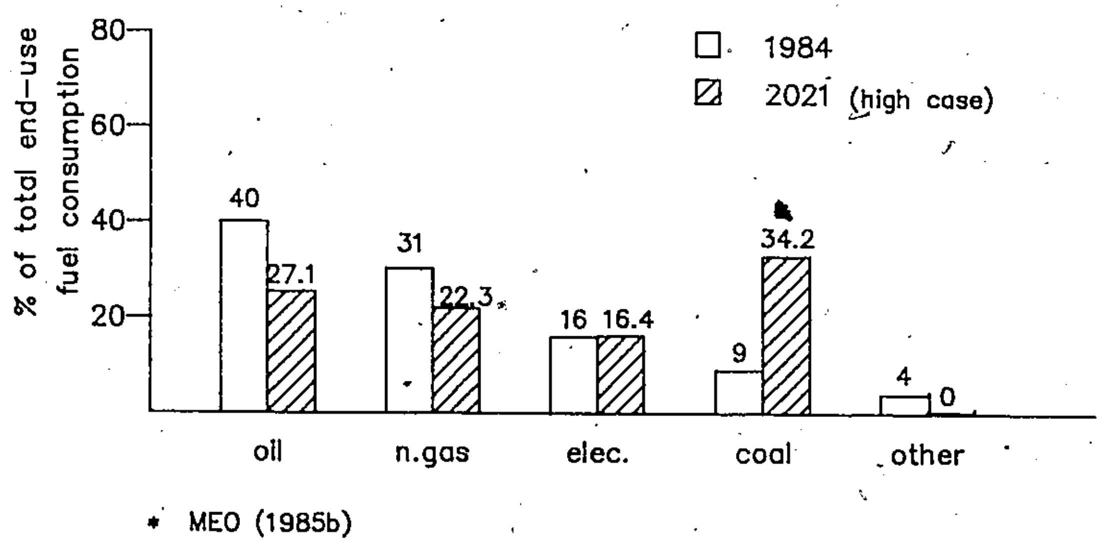
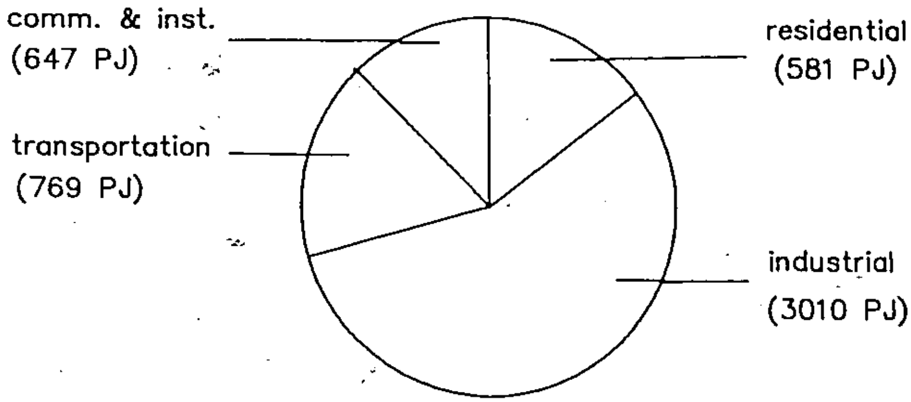


Figure 37. End-use fuel shares (high case, 2021)



Total market energy (fuel) consumption (high case, 2021) = 5006 PJ

Figure 38. Market energy consumption (high case, 2021)

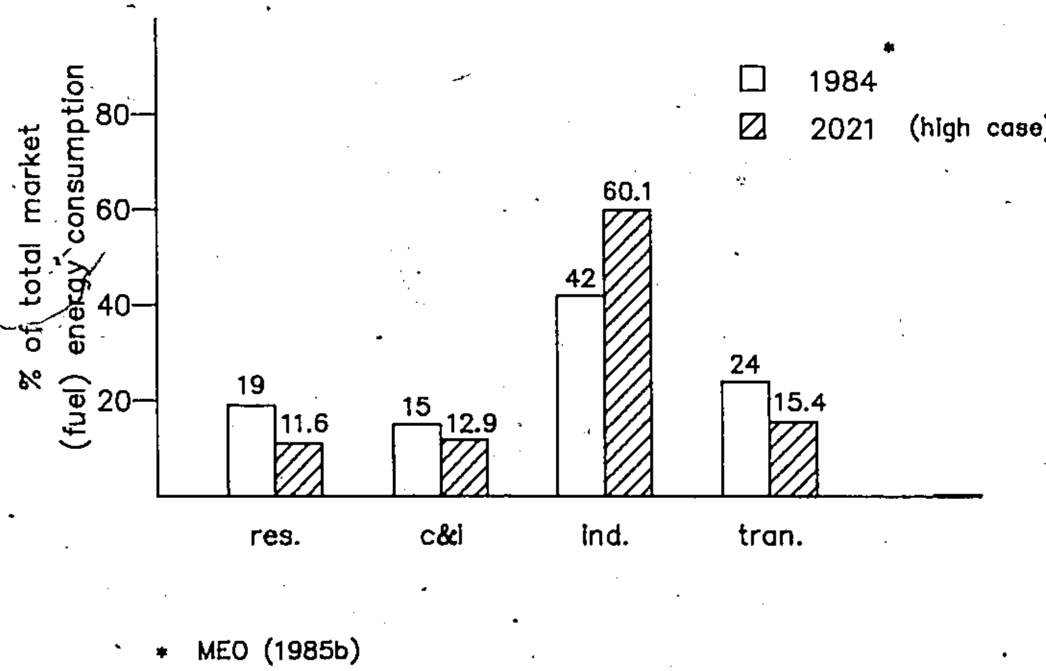


Figure 39. Market shares of end-use sectors (high case, 2021)

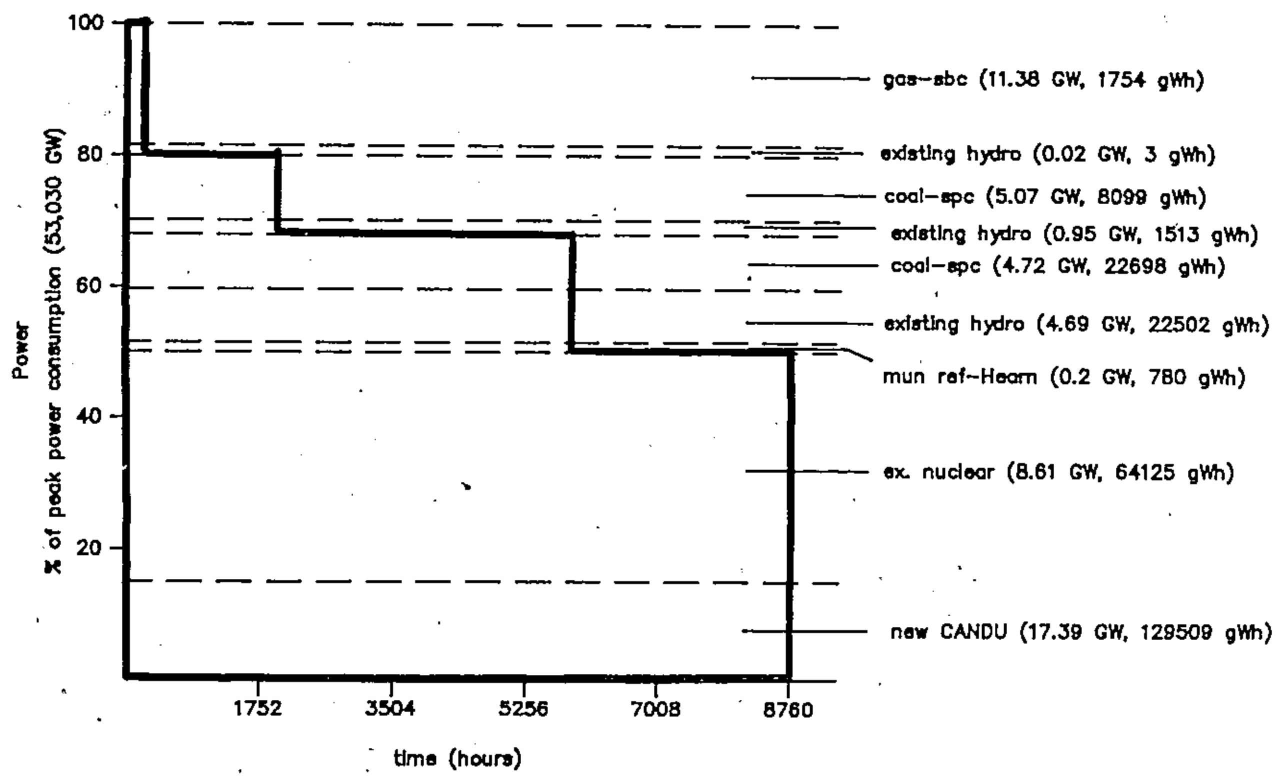


Figure 40. Linear approximated load duration curve for the high case (2021) showing electrical energy generation and mode of operation for supply sources.

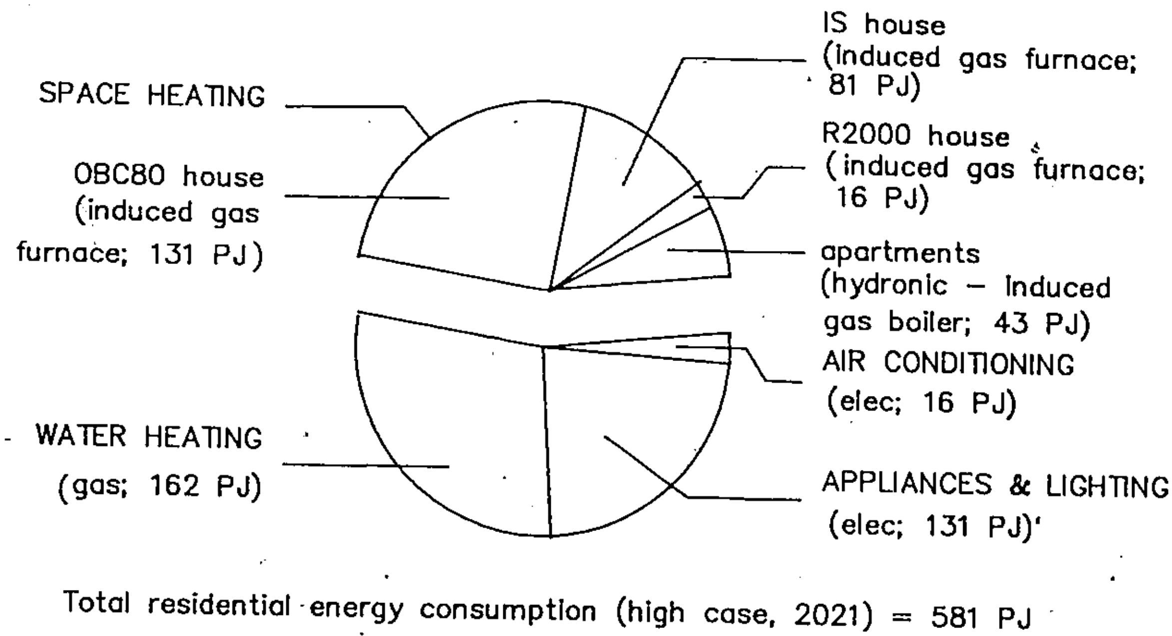


Figure 41. Residential energy consumption by end-use (high case, 2021)

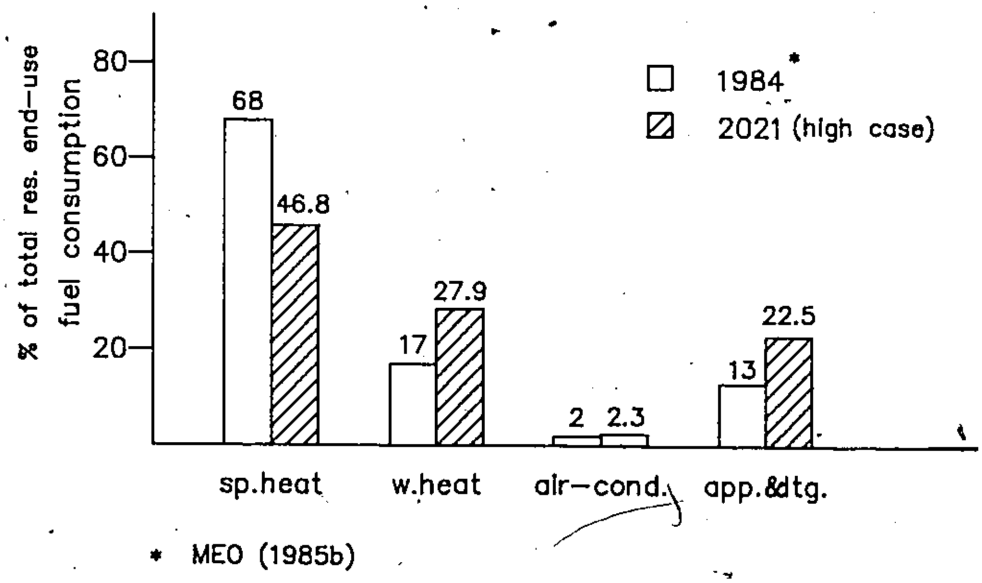
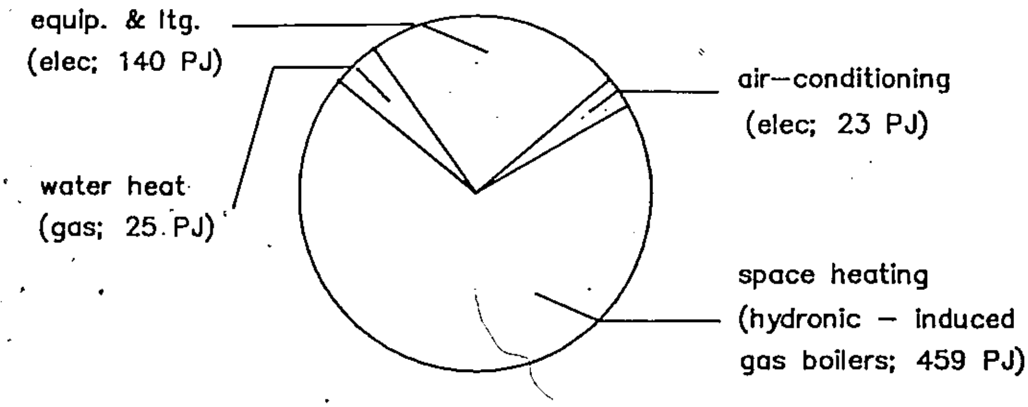
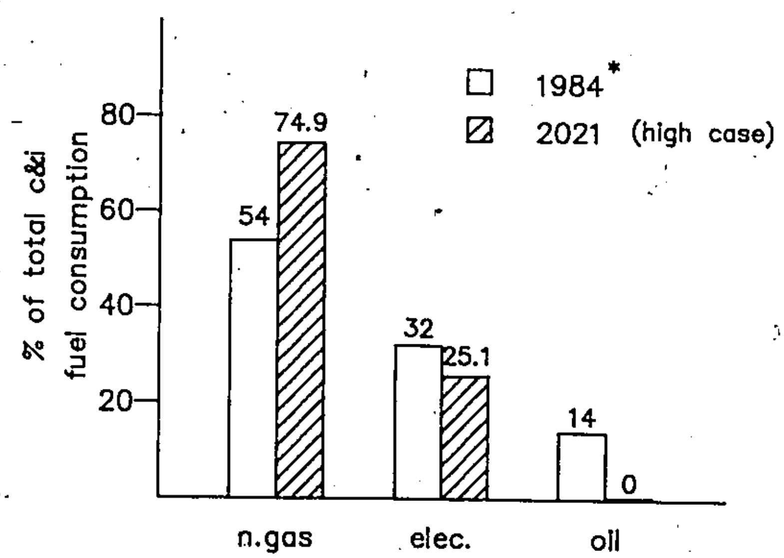


Figure 42. Shares of residential end-use sectors (high case, 2021)



Total comm & inst. energy consumption (high case, 2021) = 647 PJ

Figure 43. Comm. & Inst. energy consumption by end-use (high case, 2021)



* MEO (1985b)

Figure 44. Comm. & Inst. fuel shares (high case, 2021)

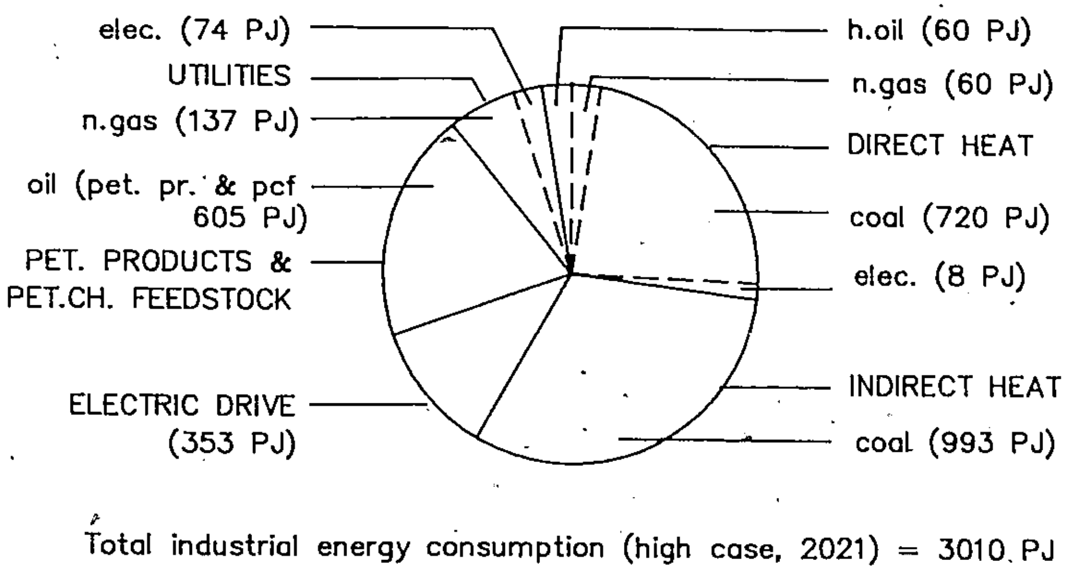


Figure 45. Industrial energy consumption by end-use (high case, 2021)

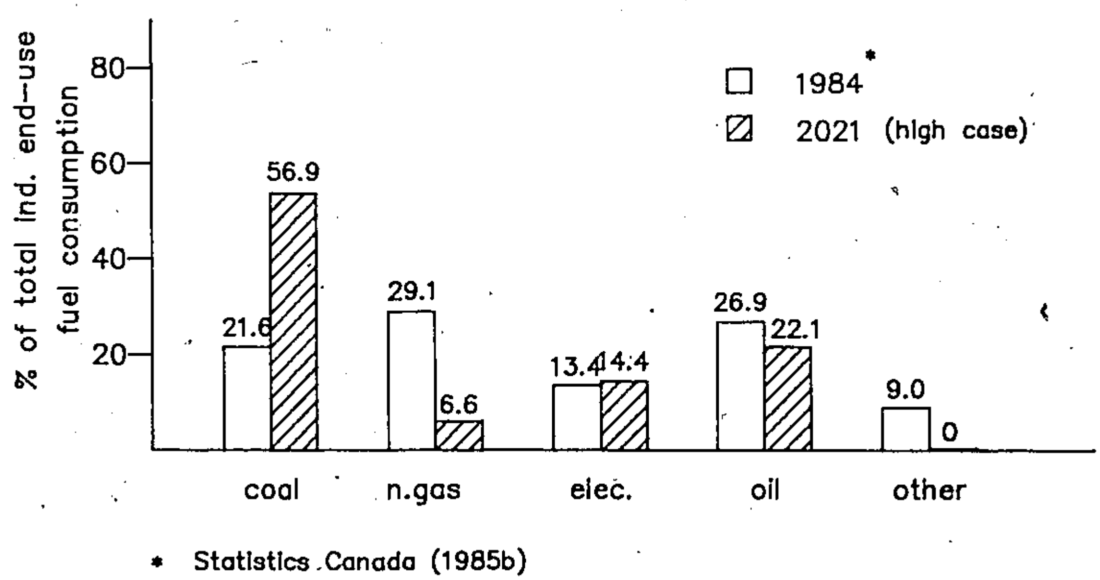


Figure 46. Industrial fuel shares (high case, 2021)

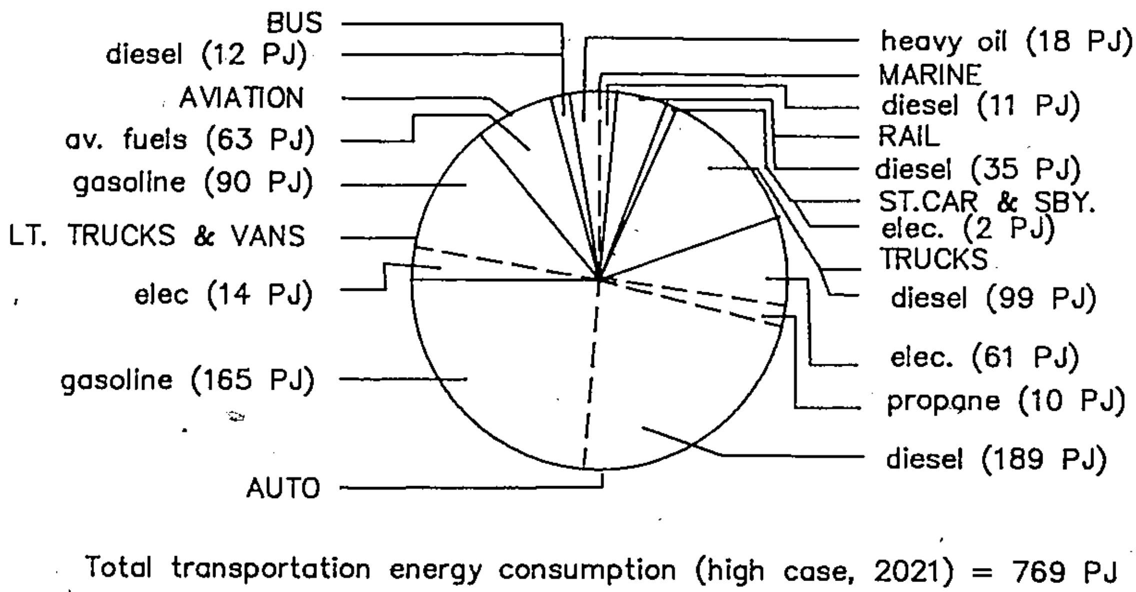


Figure 47. Transportation energy consumption by end-use (high case, 2021)

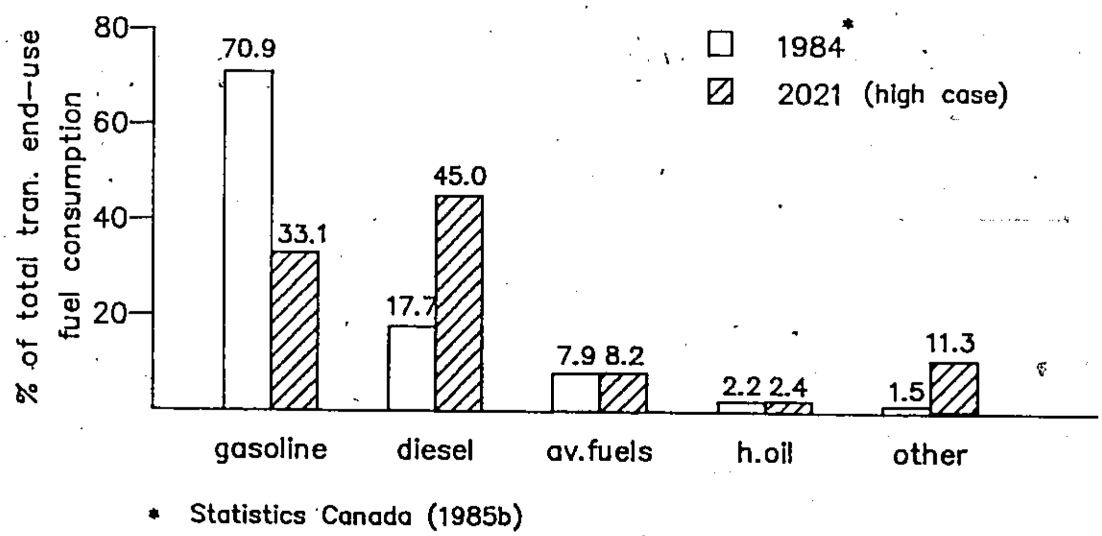


Figure 48. Transportation fuel shares (high case, 2021)

The results of the low, base and high scenarios provide a range of possible solutions in response to changes in population, trends in economic growth, etc. A study of the end-use energy consumption pattern for the three scenarios leads to the following conclusions. For the R2000 house, two technologies emerge as the most cost effective, namely, electric resistance heating for the low energy demand scenario and the induced gas furnace for the base and high energy demand scenarios. Looking at it from an overall point of view the induced gas furnace can be considered as an optimal technology for this catgory. This conclusion can be described as fairly robust. For the IS house, the induced gas furnace is the optimal technology under all the three scenarios, therefore this result is robust. For the OBC80 house category, the condensing gas furnace is the optimal technology under the low and base case, with the induced gas furnace for the high scenario. The conclusion that the condensing gas furnace is the optimal technology for this category can be considered as fairly robust. On similar lines, gas water heating (flueless) and electric air-conditioning for houses are robust conclusions. For apartments and commercial and institutional buildings, space heating by gas (hydronic), water heating by gas and electric airconditioning are again robust conclusions. In the transportation sector, medium and heavy trucks are diesel fuelled, a major percentage of light trucks and vans are gasoline fuelled and a small percentage being electric are robust conclusions. For the Auto category, a robust conclusion is that the major share of cars would largely consist of gasoline and diesel fuelled vehicles with a small but significant share of electric vehicles. The gasoline and diesel are produced from low complexity refineries. The debate then centres about the left over share of approximately 20%, which in the base and the low energy demand scenarios is satisfied by CNG, while in the high scenario is met by gasoline and diesel produced from higher complexity refineries. Based on the above, the use of CNG vehicles for the above 20% can be considered as a fairly robust conclusion.

Electric generation shares are fairly consistent under all three scenarios. In addition, the shares of primary energy and end-use energy are also fairly consistent for the three scenarios. These shares can be considered as robust.

These three scenarios therefore provide an environment from which one can draw reasonably robust conclusions. The next chapter demonstrates the use of the model in examining policy issues.

CHAPTER VIII

SOME ENERGY POLICY QUESTIONS ADDRESSED BY THE MODEL

8.1 No new nuclear generation

The model has been used to study the impact of a no new nuclear policy. The existing nuclear facilities were permitted to operate. However, no further expansion of new nuclear plants was permitted. The simplest way to achieve this in the model was to assign a very high cost to electrical production by new nuclear generation, thus ensuring that it would not enter the optimal solution. All other conditions were similar to the base case. All dollar values are in terms of 1985 dollars.

The objective function value increases from 33.65974 billion dollars to 34.94242 billion dollars, an increase of approximately 1.28 billion dollars. This figure represents an increase that is spread over all sectors. Dividing this total to the various sectors in proportion to the energy consumed by each sector, produces the following. In the residential sector, an increase of $2.55 per month per household for utilities. In the commercial and institutional sector, an increase of 4 cents per square metre per month for utilities. In the industrial and transportation sectors there is an increase of 35 cents per GJ of input fuel energy used. These figures represent an increase of 3.81% over the base case. They also can be looked upon as a "cost of insurance" against (new) nuclear hazards since the existing nuclear facilities are permitted to operate (which is also why the percentage cost increase is low).

Because of the increased cost in the generation of electricity, the results indicated a change in the end-use utilisation pattern. In the transportation sector, electric autos as well as electric vans price themselves out of the optimal solution, producing the following changes. There is an increase in gasoline fuelled light trucks and vans, the entire category now being met by gasoline, and a corresponding decrease in gasoline fuelled cars. This decrease, in addition to the demand that was earlier serviced by electric autos, is made up by CNG fuelled cars. Diesel consumption remains at the same level. Worth noting is the fact that there is no increase in overall crude oil consumption, the refinery with a lower complexity remaining in the optimal solution. Details are shown in Figure 49.

The substitution of electricity from end-use sectors results in a lower demand for electricity. The total peak power demanded reduces by approximately 5 GW. The place of new nuclear generation is largely replaced by coal based

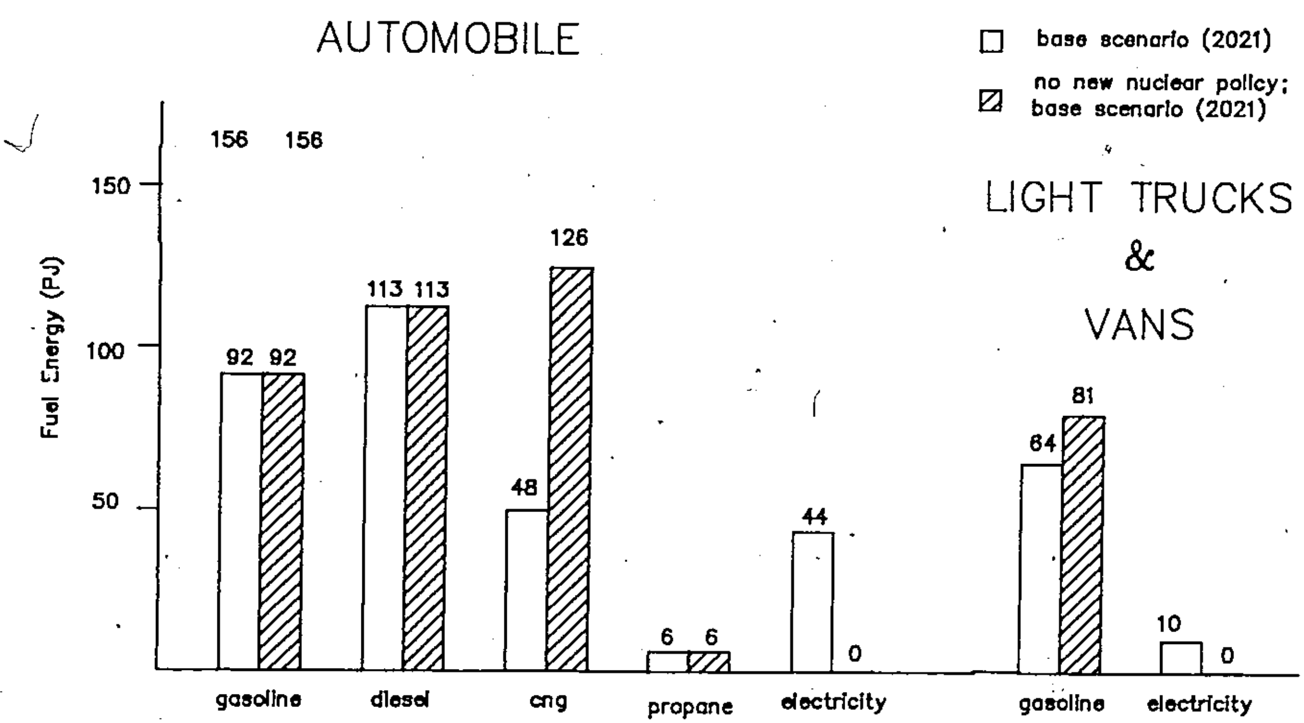


Figure 49. Auto and Light Trucks and Vans end-use fuel consumption (base case and base case with no new nuclear policy, 2021)

power plants. All new capacity of hydro in both the large and small capacity, is exploited to its maximum. There is a shift in the mode of operation. Base load is met by all categories of hydro, refuse generation, the existing nuclear facilities and coal generation. The cyclic load is met by coal. The daily peak load is met by coal and existing hydro and the seasonal peak load by gas generation and existing hydro. Details are shown in Figure 50.

Figure 51 shows the change in primary energy consumption. There are significant increases for coal and natural gas. The former increase is entirely for electricity generation while the latter is for substitution for electricity in end-use demands. The increase in total primary energy is essentially a reflection of the way it is measured. Nuclear energy is measured in terms of electric energy, while any substitution of it by fossil fired electricity is measured by fossil fuel energy. Thus substitution of one unit of primary nuclear energy by fossil fired electricity would mean an approximate increase of three units of primary fossil energy.

From an environmental viewpoint the no new nuclear policy is a tradeoff between less nuclear and more air pollution, the latter due to the increase in coal based electricity generation.

The no new nuclear case was also run for the low and high demand scenarios. In all cases, electric autos and

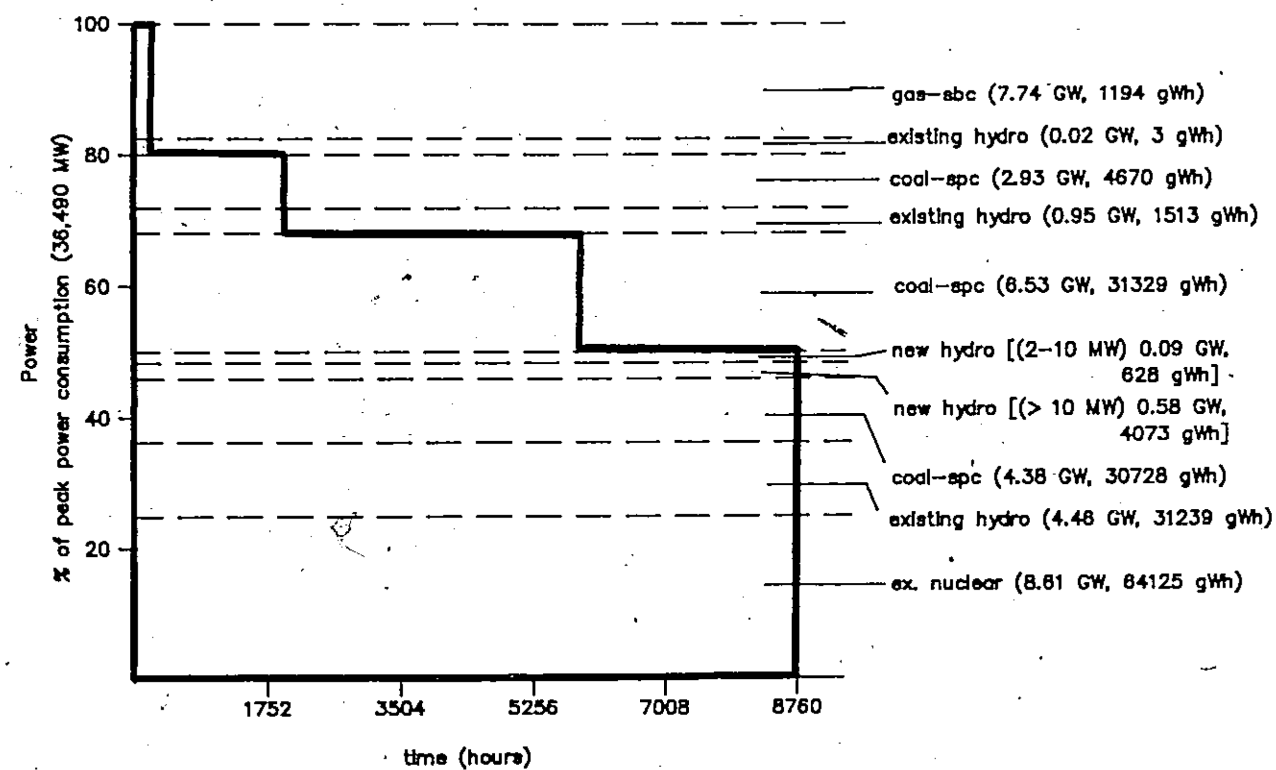


Figure 50. Linear approximated load duration curve for the base case (2021) for the no new nuclear policy, showing electrical power requirement, energy generation and mode of operation for supply sources, as given by the model's output.

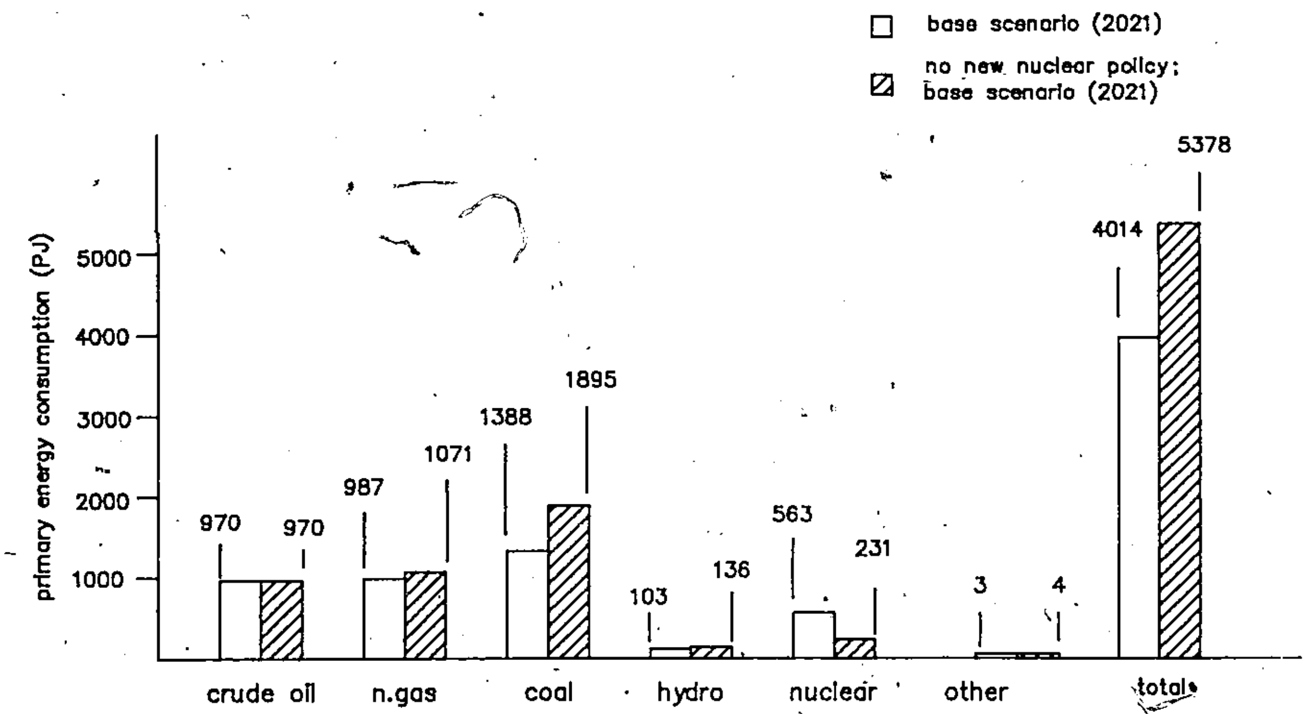


Figure 51. Primary fuel consumption (base case and base case with no new nuclear policy (2021)

vans price themselves out of the optimal solution. The additional costs were approximately 0.93 and 1.43 billion dollars when comparing the objective functions for the low and high energy demand scenarios. The results are shown in Tables 23 and 24.

8.2 Increasing Electrical exports to the U.S.A.

Increasing electricity exports increases revenues. However an increase in generation requires additional investment for building more power plants. When the return on this additional investment depends solely on a foreign market coupled with the fact that power plants have lifetimes upwards of 30 years, there is an element of "vulnerability" on the investment. Therefore although increasing exports increases revenues, it also increases the risk.

The model was used to address this issue. Exports were bounded at 0, 100, 200, 300, 400 and 500 PJ which represents 0, 16, 33, 49, 66 and 82 percent of domestic consumption respectively. The export price was 4.533 cents/kWh, the price arrived at by escalating the 1985 price by 1%. The solution, for each of the cases went to the bounds. For each case, the additional power requirement by each of the power plant types was determined from the output results of the export and no-export base case, along with the additional revenues. The additional power requirement was translated further into additional

Table 23. Primary energy consumption for the low, base and high scenarios (2021) for the no new nuclear policy

ENERGY SOURCES	CONSUMPTION (PJ) low	base	high
Natural Gas	856.31	1071.09	1234.31
Crude Oil	703.28	970.42	1539.46
Coal	1186.27	1895.00	2933.83
Hydro	136.16	136.16	136.16
Nuclear	230.85	230.85	230.85
Other	4.10	4.10	4.10
TOTAL	3116.97	4307.62	6078.71

Table 24. End-use fuel consumption for the low, base and high scenarios (2021) for the no new nuclear policy

FUELS	CONSUMPTION (PJ) low	base	high
Natural Gas	772.77	966.20	1115.17
Oil	671.73	926.89	1469.65
Coal	906.21	1235.25	1713.20
Electricity	432.62	557.38	745.72
TOTAL	2782.73	3685.72	5043.74

investment. The vulnerability of the additional investment can be looked at the following way. At low export levels, the additional investment has low vulnerability in the sense that in case the export market collapses, the surplus capacity has a good probability that it could be used within the future domestic supply framework as domestic demand is increasing every year. However, with higher export levels this flexibility is lost, and in case of a collapsed export market, the investment then is a loss. Therefore, vulnerability of additional investment increases with increased export levels. The aim here was not to define explicitly a measure for vulnerability but to identify the possible loss of investment funds in relation with the possible gain in revenues. Details obtained are shown in Tables 25, 26 and 27.

Additional investment ranges from 7.5 billion dollars to 37.4 billion dollars for export levels of 100 PJ (approximately 16% of domestic consumption) to 500 PJ (82% of domestic consumption) with annualised system wide savings (decrease in the objective function value) ranging from 0.06 billion dollars to 0.31 billion dollars respectively (dollars are defined in 1985 dollars). The vulnerability can be described as ranging from low to very high for the above range of exports.

Table 25. Additional capacity required for different types of power plants for increasing electrical exports for the base case (2021)

EXPORTS (PJ)	GAS	COAL	CANDU	TOTAL
	Incremental Capacity (GW)			
0	0	0	0	0
100	1.39	1.90	3.18	6.47
200	2.79	3.81	6.37	12.97
300	4.19	5.72	9.55	19.46
400	5.58	7.63	12.73	25.94
500	6.98	9.54	15.92	32.44

Table 26. Incremental investment required for different types of power plants for increasing electrical exports for the base case (2021)

EXPORTS (PJ)	GAS	COAL	CANDU	TOTAL
	Incremental Investment [million dollars (1985)]			
0	0	0	0	0
100	690.83	1708.10	5068.92	7467.85
200	1386.63	3425.19	10153.78	14965.60
300	2082.43	5142.28	15222.70	22447.41
400	2773.26	6859.37	20291.62	29924.25
500	3469.06	8576.46	25376.49	37422.01

Table 27. Investment and annual revenues (1985 billion dollars) associated with increasing electrical exports for base case (2021)

EXPORTS (PJ)	TOTAL INCREMENTAL INVESTMENT	ANNUAL SAVINGS	VULNERABILITY
	Billion Dollars (1985)		
0	0	0	
100	7.47	0.061	LOW
200	14.97	0.122	↓
300	22.45	0.183	
400	29.92	0.244	
500	37.42	0.305	HIGH

8.3 Sensitivity to Oil Prices

This study is of much interest since in the last five years MEO has actively been promoting alternative fuels for transportation. Obviously, the key feature governing the substitution of petroleum based fuels for vehicles is oil price. The model was run for different oil prices ranging from ±30% of the base price of $49 per barrel in steps of approximately 10%, i.e., starting with $34 per barrel to $64 per barrel in steps of $5 per barrel.

For the above range of oil prices, the end-use consumption pattern did not change for the residential, commercial and institutional, and the industrial sectors. These results were the same as in the base case. It is worth noting that even when oil prices are low, space heating by natural gas is still cost effective. However, in the transportation sector, in particular the auto and light trucks and vans category, there were significant changes in end-use consumption patterns. Figure 52 shows the details on end-use energy consumption for cars and light trucks and vans. At $34 per barrel, the above categories were entirely met by refined petroleum fuels, i.e. gasoline, diesel and propane (produced from the refinery). The supply was from both the low and high complexity refineries (mean complexity being 7.915), with gasoline having the largest share, followed by diesel and a small fraction of propane. At $39 per barrel, electric

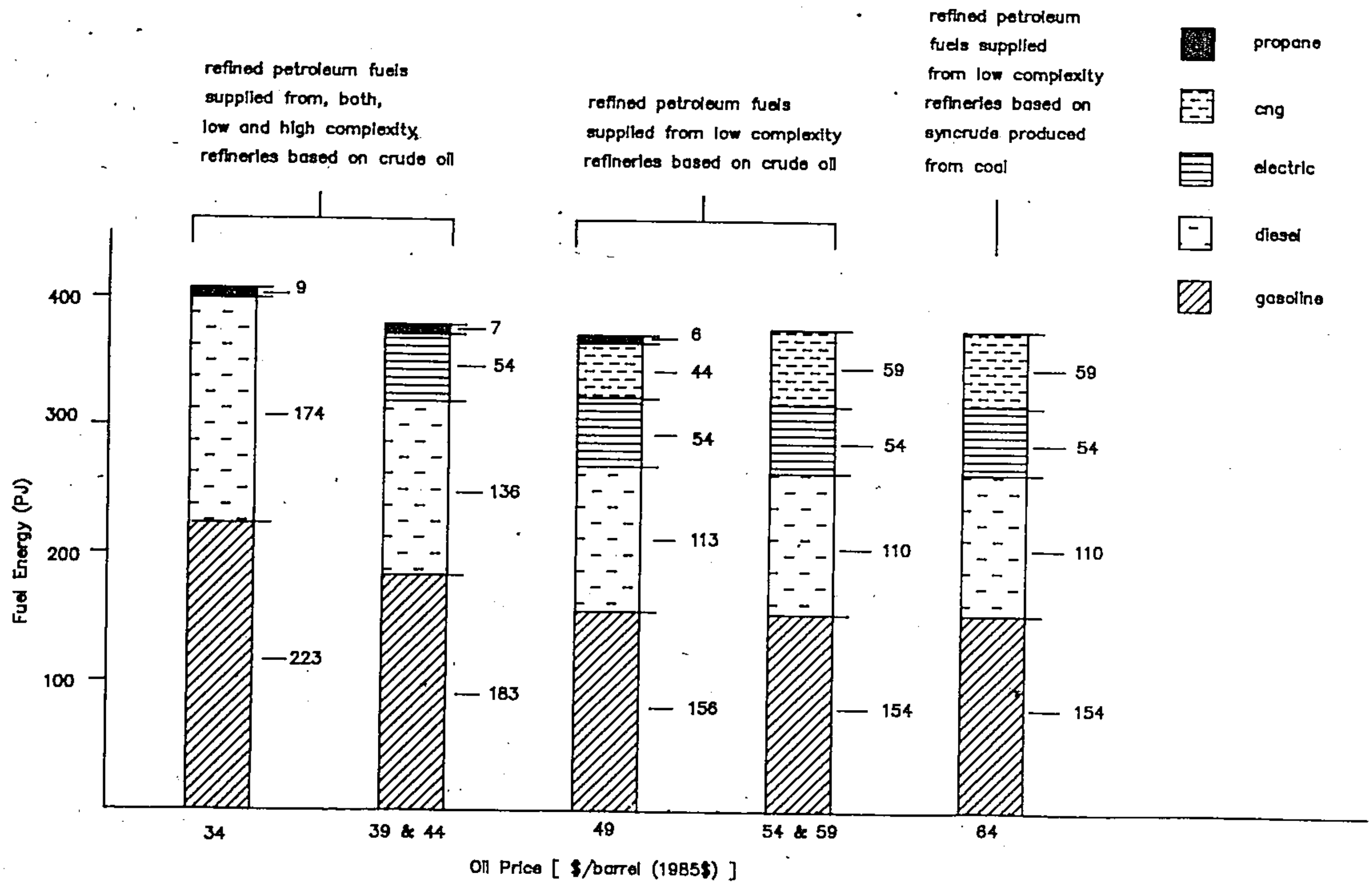


Figure 52. Changes in end-use energy utilisation patterns for auto & light truck and van categories (base case, 2021) in response to changes in oil prices

vehicles become cost effective, and satisfy the allowable 20% of demand. The subsequent decrease in refined fuels decreases the share from the high complexity refineries. This is understandable since the high complexity refinery has a higher cost of production than the low complexity refinery. Still, the supply is from both the types of refineries, with the mean refinery complexity reducing to 7.127. At $44 per barrel the consumption pattern remains the same as in the previous $39 per barrel case. At $49 per barrel, the high complexity refinery is priced out; its share of refined fuels is replaced by CNG. Thus, at this stage there is a further decline in the share of refinery fuelled vehicles. With just the low refineries operating, the mean complexity further reduces to 6.665. At $54 per barrel, the small share of propane based vehicles also price themselves out (the propane was refinery produced), its share being taken by an increasing share of CNG vehicles. This pattern remains the same at $59 per barrel. However, at $64 per barrel, although the end-use pattern remains the same, the refined fuels are based on syncrude produced from coal, the syncrude being more cost effective than crude oil. Figure 53 shows the corresponding primary energy consumption associated with the above range of oil prices. The slight increases in consumption of gas, coal, and nuclear at an oil price of $39 per barrel, reflect the increase for electricity

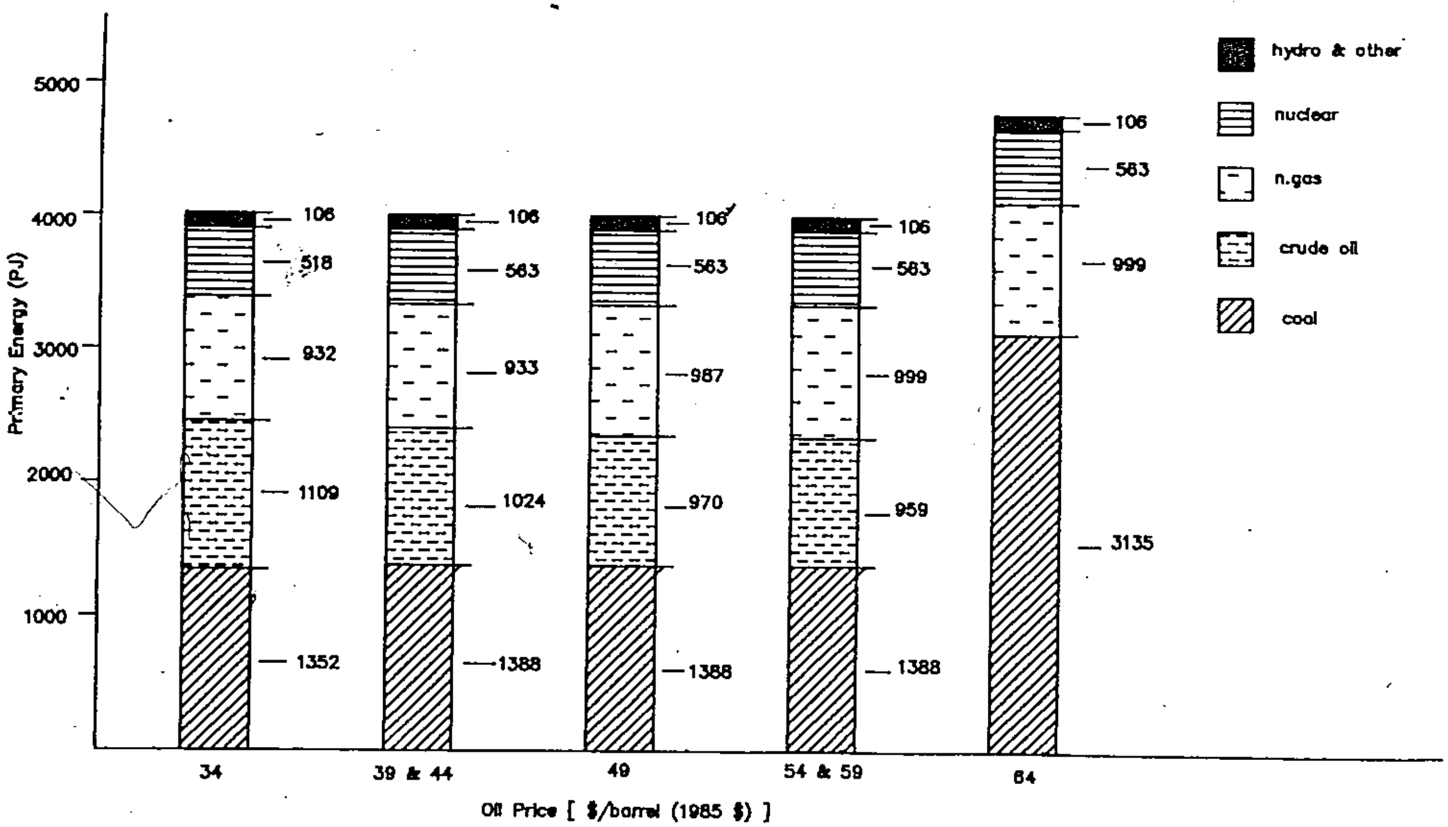


Figure 53. Changes in primary energy consumption patterns (base case, 2021) in response to changes in oil prices

generation, the demand created by electric cars. Note the decrease in crude oil consumption as oil prices increase. The sharp increase in coal consumption at an oil price of $64 per barrel reflects the coal demand for syncrude production. Figure 54 shows the corresponding end-use consumption.

Worth noting is the fact that vehicles based on alcohols, propane [as an imported primary resource (natural gas liquids)], liquid hydrogen, LNG, gasoline from MOBIL, Zinc Chloride, SASOL, and diesel from SASOL are not in the solution even for a high price of $64 per barrel. Further, even at this price, the low complexity refinery is in the solution, thus suggesting that alternative fuels should only penetrate a small portion of the automobile and light trucks and vans market, the other sectors being serviced by the traditional refined fuels.

8.4 Soft energy strategies

With increasing industrialisation, energy demands have grown year after year. However, conventional energy resources are finite and depleting, and coupled with a growing awareness of increasing environmental problems, in recent years "soft energy paths" have been advocated by many, such as Lovins (1977), and Brooks, Robinson and Torrie (1983). Briefly, soft energy paths stress reducing energy demand through conservation, and meeting these

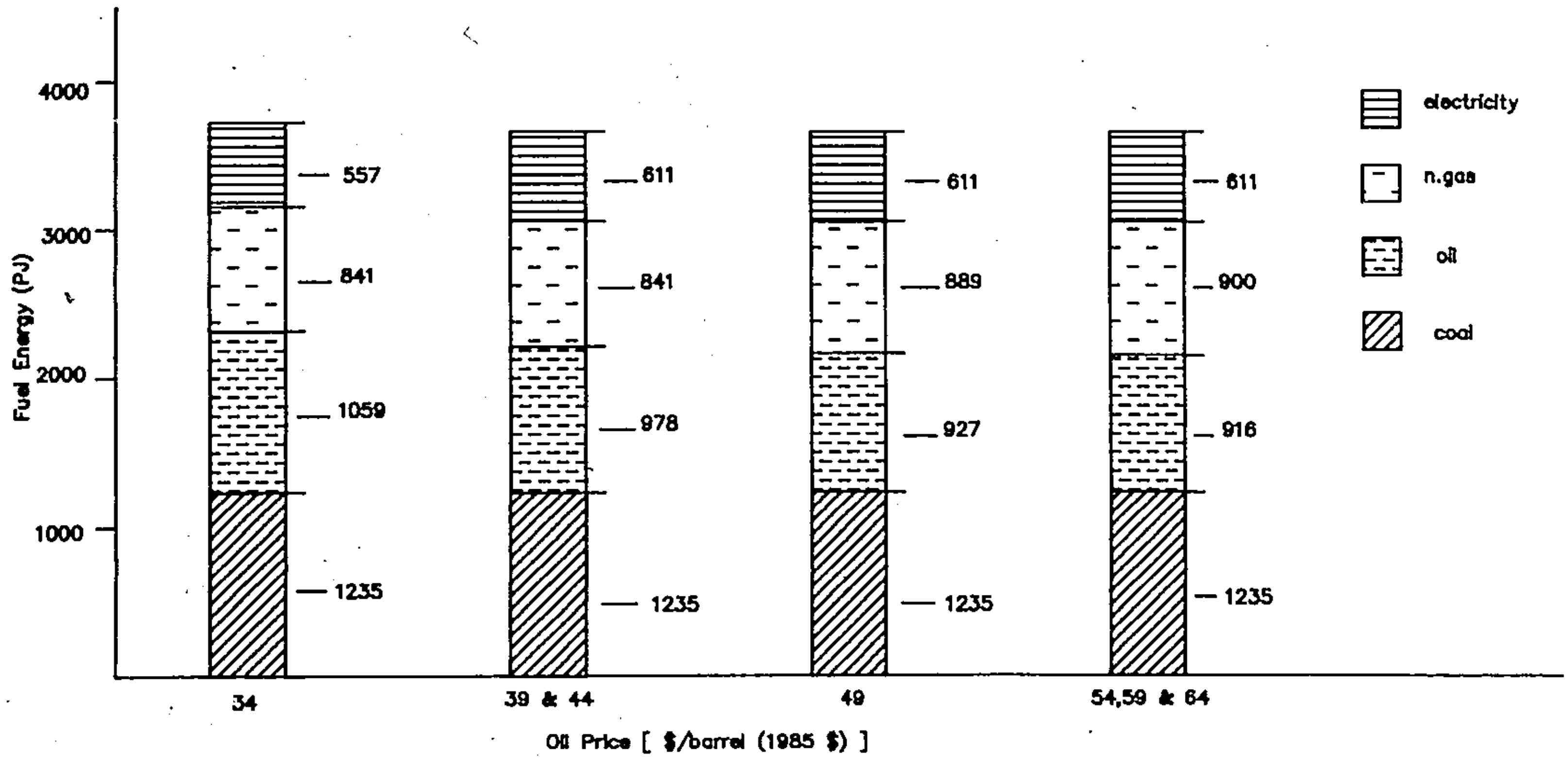


Figure 54. Changes in end-use fuel consumption patterns (base case, 2021) in response to changes in oil prices

demands by diverse, small-scale, renewable energy supplies with a high efficiency of energy use. In comparison, the more traditional "hard energy paths" emphasise increasing energy supplies by exploiting non-renewable sources by increasing scale and centralization of energy production. Energy policy in Ontario, athough predominantly leaning towards the "hard" path, has some elements of the "soft" approach, such as the reduction of space heating demands by energy conservation.

The study here examined two soft strategies for space heating in houses. The first soft strategy for the residential sector was to study the economics of energy conservation in houses. In the model houses have been categorised as three types, the R2000, the IS, and the OBC80. To study energy conservation, five energy conservation scenarios have been described as low, medium low, medium, medium high and high, depending upon the number and type of houses existing in 2021. For example, the high conservation scenario is categorised by all new stock of houses are of the R2000 type, thus representing the highest overall level of insulated houses, while in the low conservation scenario, none of the new houses built are of the R2000 type, 80% of them being the Intermediate Solar type and 20% are of the OBC80 type, representing the lowest level of overall insulation. The other conservation scenarios are between the two above mentioned insulation ranges (the base case insulation levels correspond to the medium conservation scenario). The existing stock of houses is assumed to be made up of 99% OBC80 and 1% IS (same as in the base case). The fractional makeup of houses for each energy conservation scenario is shown in Table 28. This range of insulation levels or the scale of conservation has been based on current trends in conservation. The model was run for each of the conservation scenarios with all other data being the same as the base case data. Based on base case incremental construction costs of 5% and 2.5% ($5250 and $2625), for the R2000 house and IS house over the OBC80 house, there was a decreasing trend in the objective function as the average level of conservation increased. As this decrease was solely due to changes in the overall level of insulation, the incremental decrease from the lowest insulation level divided by the total number of houses, gives the average annual savings in space conditioning (mainly heating, as energy for cooling is a very small fraction of energy for heating) for a house in the corresponding scenario. The average incremental savings (shown in Table 28) over the lowest conservation scenario ranged from approximately $34 for the medium low to $202 for the highest conservation scenario. Based on these results one can conclude that conservation is economically cost effective with R2000 houses providing the most savings

Table 28. Description of energy conservation scenarios and corresponding annual savings in space conditioning costs as determined by the model results.

conservation scenario description	fraction of houses of new stock R2000	IS	OBC80	objective function value (billion $)	average annual savings in space conditioning costs per house ($)
low	0	0.80	0.20	33.94672	0
medium low	0.20	0.70	0.10	33.83225	33.53
medium (base)	0.45	0.50	0.05	33.65974	84.05
medium high	0.70	0.30	0	33.48745	134.52
high	1	0	0	33.25794	201.72

All monetary figures are in 1985$.

in costs of heating and cooling.

Figure 55 shows the space heating energy consumption for houses for each of the conservation scenarios. For every conservation scenario, the induced gas furnace for the R2000 and IS house was the best technology, while the condensing gas furnace was the optimal technology for the OBC80 house. For the high conservation scenario there is a decrease of approximately 36% in end-use consumption for houses, over the low conservation scenario. The primary energy consumption remains the same for all energy sources as in the base case apart from natural gas. Figure 56 shows the details. There is a change of approximately ± 4.3% in primary consumption of natural gas over the base case (also corresponding to the medium conservation scenario).

The above study had no restrictions on the supply side. Looking on the supply side, a soft approach for space heating would allow only renewable energy based technologies. The second soft strategy therefore permitted only wood and solar technologies to satisfy the space heating demand. However, both these technologies require backups. For these there were no restrictions, i.e. the backups could be based on any technology. The above policy was implemented by placing input share constraints with a value of 0 at the appropriate space heating node for all technologies that were not permitted. The model was run

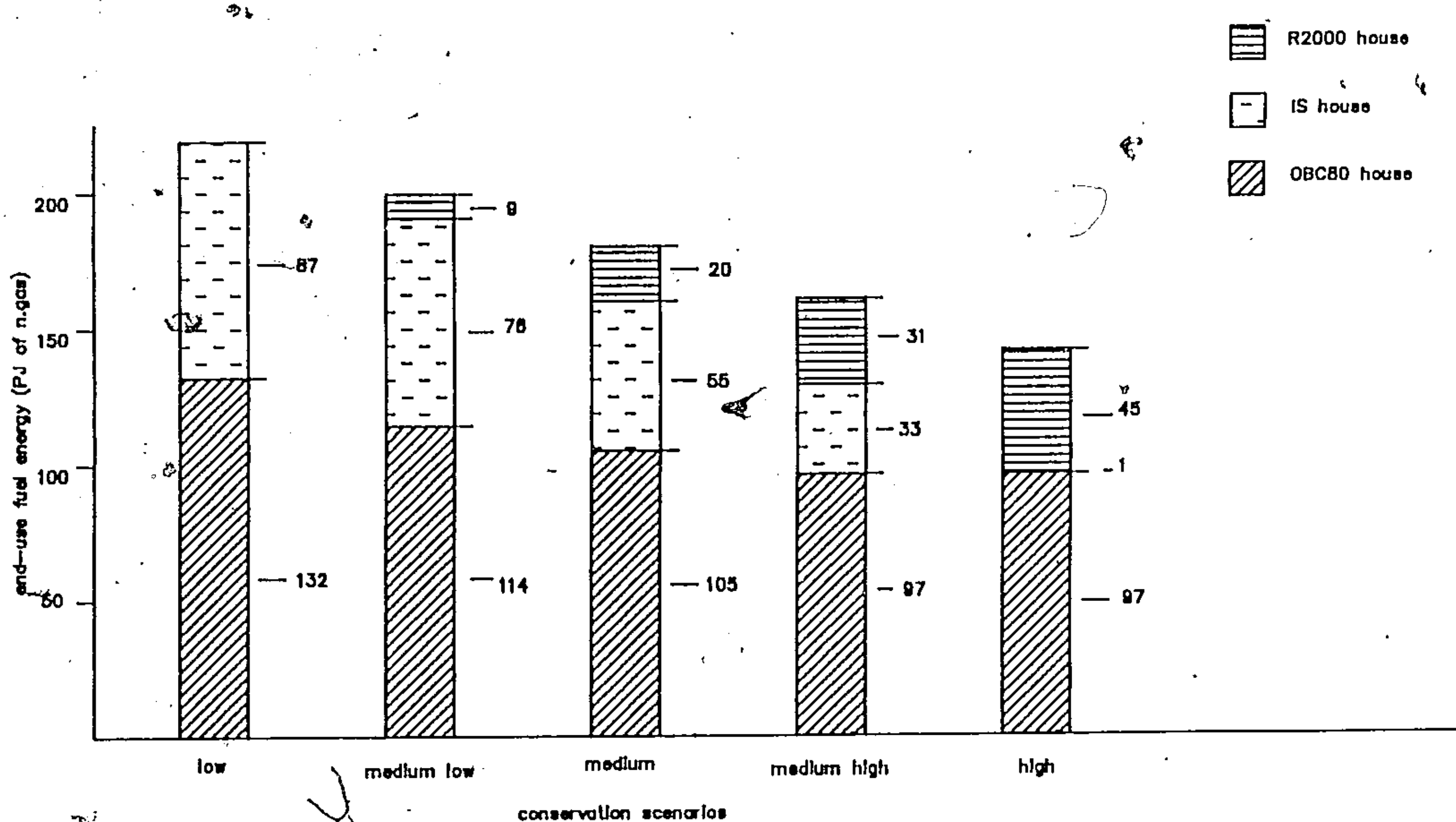


Figure 55. Space heating energy consumptions for each of the housing categories for different conservation scenarios (base case, 2021)

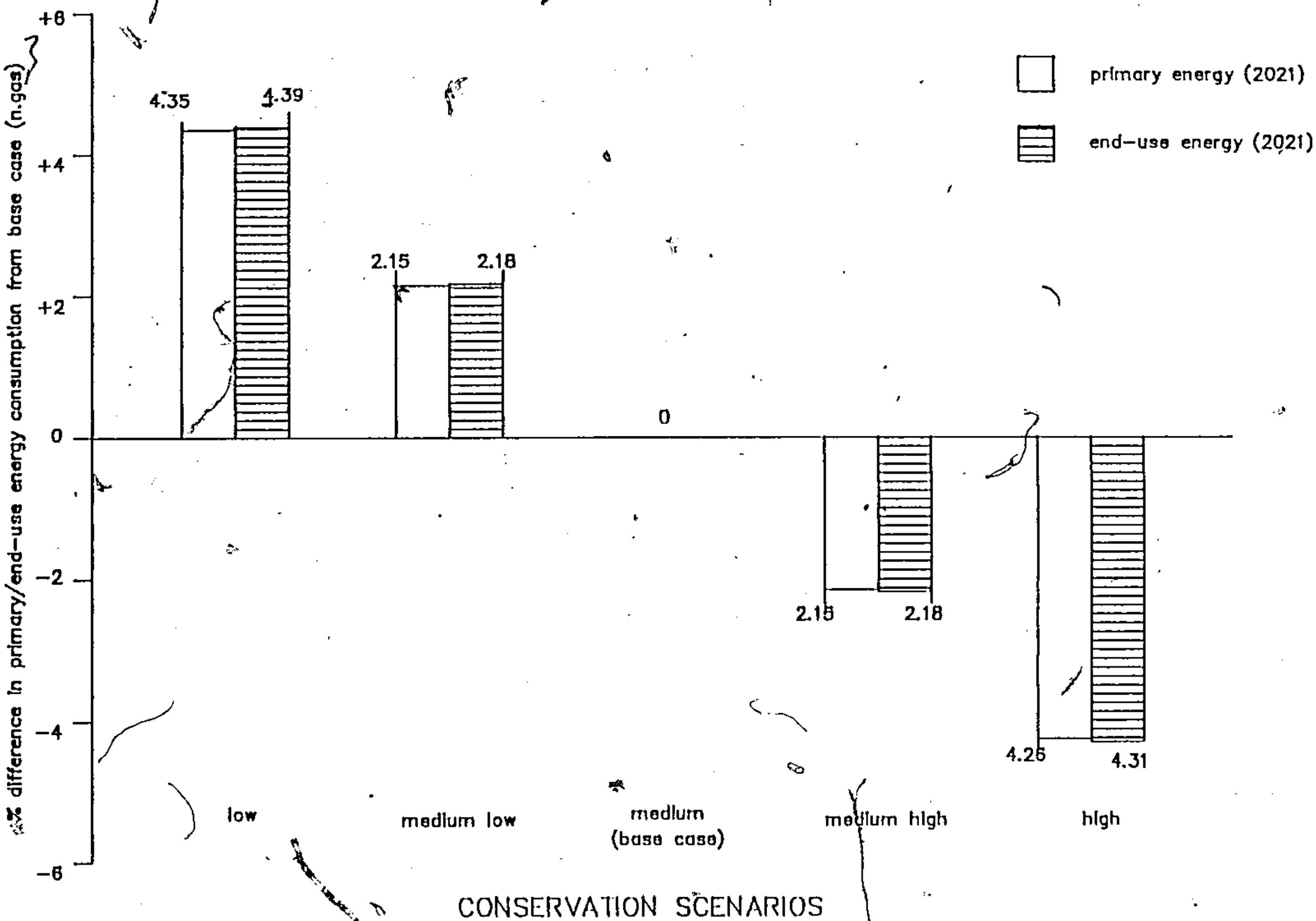


Figure 56. Percentage difference in primary and end-use energy consumption (natural gas) for different conservation scenarios (base case, 2021).

for the same conditions as for the unrestricted supply case, i.e. for all five energy conservation scenarios.

The results indicated wood combination furnace with gas backup to be the optimal technology for all conservation scenarios. Table 29 shows the additional cost for space heating by wood combination furnace for all energy conservation scenarios over the unrestricted supply case. The costs range from approximately $105 for the high energy conservation scenario to $110 for the low conservation scenario. The slight increase in the additional annual costs can be explained in the following way. The additional annual costs for each conservation scenario is the additional annualised capital cost for wood combination furnace and the additional cost of supply of gas and wood over the unrestricted supply case. In the latter case, as the percentage increase of end-use consumption is dependent only upon the efficiency of the wood combination furnace, this increase is the same for all conservation scenarios. However, there is slight difference in the total annualised capital cost for the wood combination furnace for each scenario due to the difference in requirements for the total number of furnaces required of different capacities. For example, the high conservation scenario, with the largest number of R2000 houses require the largest number of the relatively smaller furnaces, while the low conservation scenario requires the largest number of the

Table 29. Additional annual costs for space heating in houses using optimal renewable energy based technology (wood combination furnace with gas backup) for energy conservation scenarios, as determined by the model results.

conservation scenario description	objective function value (billion $)	additional costs for space heating per house using wood combination furnace with gas backup ($)
low	34.32195	0
medium low	34.20022	109.89
medium (base)	34.02330	107.76
medium high	33.84662	106.47
high	33.61562	104.75

All monetary figures are in 1985$

relatively larger size furnaces. Hence the slightly increasing costs from the highest to the lowest conservation level. A point to note here is that these figures are based on a base case price of wood of $82 per oven dried tonne, which is a very low price in relation to the enormous amount of wood that would be needed. To get an idea of the magnitude of wood involved, in 1980 approximately 3% of the total residential energy consumption was supplied by wood, in comparison to approximately 40% for the year 2021 (base case), an increase of approximately 13 times over the 1980 level (MEO has a target of 8% of residential energy consumption to be supplied by wood for the year 1995). The relevant results showing residential space heating consumption in houses and the primary consumption of wood and natural gas (all other primary resource consumptions remain the same as in the base case) are shown in Figures 57 and 58 respectively.

The above studies demonstrates the use of the model for policy analysis. The model can be used to study a wide range of policy studies.

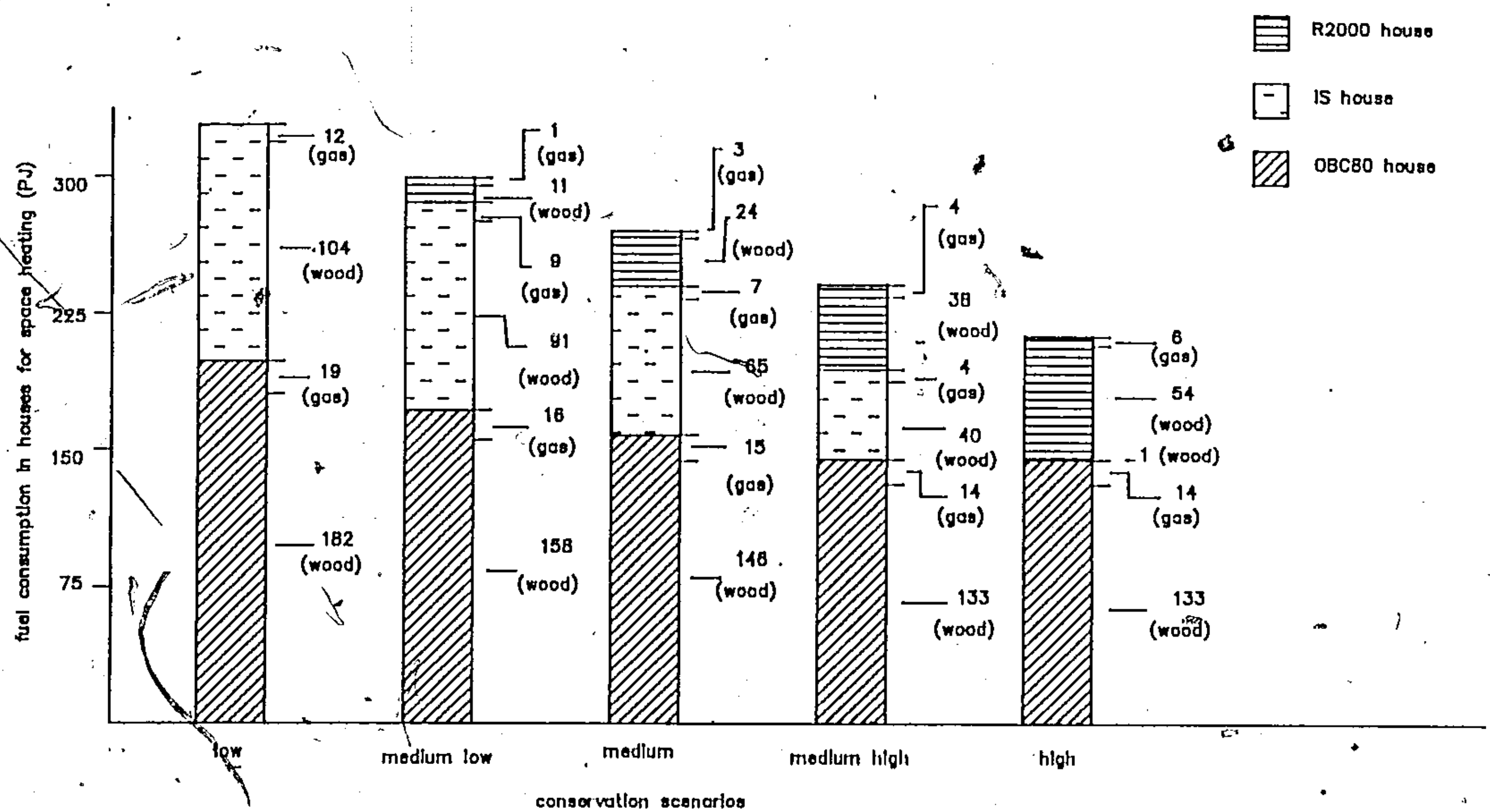


Figure 57. Space heating consumption pattern for houses (renewable policy base case, 2021) for different conservation scenarios)

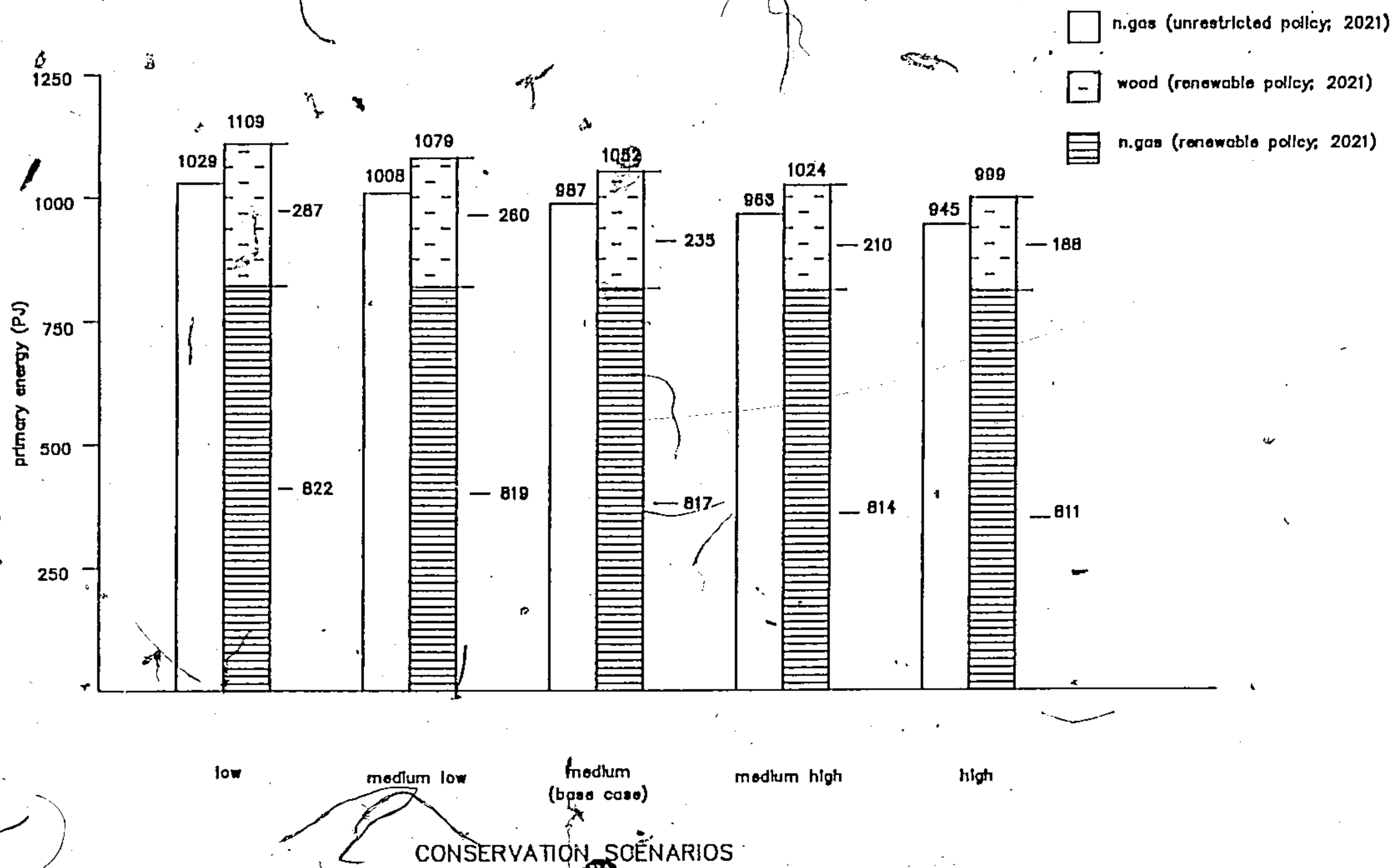


Figure 58. Primary energy consumption of natural gas (unrestricted policy, 2021) and natural gas and wood (renewable policy, 2021) for different conservation scenarios.

CHAPTER IX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This dissertation describes an energy planning model for the province of Ontario. The model is a single period model with a target year of 2021 and uses linear programming to minimise the total discounted annual costs of meeting a set of exogenous end-use demands subject to techno-economic constraints that describe the energy system of the province of Ontario. The model is detailed. It includes a comprehensive description of fuels and technologies of secondary conversion and end-use. The process approach used to model the energy system extends up to the end-use stage. As space heating and transportation sectors have been the target of policy debates and actions in Ontario, both these sectors have a high level of detail. Other features include modelling of the petroleum refinery sector and the electric sector. A major practical advantage is the creation of the model using WATEMS, which provides a very simple and user-friendly environment for data entry, changes to the structure and in running different scenarios.

Obviously, this detail in structure is supported by an extensive data base. Irrespective of any modelling technique, an energy model is only as good as the data base it supports. Most of the data for this model can be described as "solid", most of it being obtained from Ontario Hydro and from federal and provincial energy related government departments. Naturally, a major portion of the time has been spent on data collection and structural development. Also, being a large model, a fair amount of time was spent in debugging and checking model responses to a wide range of varying inputs.

Three scenarios, namely, base, low and high energy demand were developed. The results of the three scenarios provide a basis to draw robust conclusions. Also to demonstrate the use of the model in addressing policy issues, the model was used to address four policy questions. These were, no new nuclear power plants, increasing electric exports to the U.S., sensitivity to oil prices, and "soft" strategies for space heating in houses.

Some important conclusions drawn from the results are the following. Energy conservation brought about by better designed houses is definitely cost effective. This holds true for all categories of better designed houses, the better the insulation capability, the more savings in cost that can be realised. Space heating by natural gas is the most cost effective, with the induced gas furnace for better designed (high insulation) houses and the condensing gas furnace for houses of low insulation capability, such as those with the 1980 building code standards. Worth noting is the fact that electric resistance heating is not cost effective (only cost effective for the low energy demand scenario and that too only for the R2000 house), nor are electric heat pumps, wood furnaces or active solar. Water heating by natural gas is also more cost effective than electricity, despite the fact that the initial cost of an electric water heater is nearly half that of the flueless gas water heater. For apartment and commercial and institutional buildings, natural gas is again the most optimal fuel for space and water heating, out of the options considered. Solar air-conditioners are not cost effective.

There is an increase in coal demand in the industrial sector. This is due to coal being the most cost effective boiler fuel.

For cars and light trucks and vans it is definitely cost effective to reduce the current dominance by gasoline. This reduces the demand for "top of the barrel" oil products, thereby permitting refineries of lower complexity to operate. This reduction is substituted by electric cars and CNG cars. Worth noting is that the initial cost of an electric and a CNG vehicle is approximately $1700 and $600 (1985 dollars) respectively more than a gasoline vehicle.

Also, increasing gasoline production by more complex refineries, any of the MOBIL processes, the Zinc Chloride process or the SASOL process, is not cost effective. Alcohol-run vehicles are not cost effective. Cars run on propane are only cost effective when the propane is a by-product of refineries. Propane imported from other regions (natural gas liquids) is not cost effective. Cars run on liquid hydrogen are definitely not cost effective. All other forms of transportation remain the same. Worth pointing out is the fact that heavy trucks run on alcohols or any other alternative fuels are not cost effective.

For electrical production, nuclear power is the optimal technology for base load. The cyclic load is met by coal and hydro. So is the daily peak load. Seasonal peak is met by natural gas and hydro. In the absence of new nuclear plants, coal appears to be the next optimal technology.

It is virtually impossible to exactly compare the model response with existing models, since no model exists with this type of detail and for the year 2021. However, certain comparisons can be made with existing trends and with certain studies that have been conducted in Ontario, not for the year 2021, but for the nearer future. For example, the current drive for better built buildings is in accordance with the model results. In the transportation sector, current incentives exist to reduce gasoline consumption for cars. Both propane and CNG are actively being promoted. As mentioned above, nearly the same trend is observed from the model results. The increase in the share of nuclear power plants is again in accordance with Ontario Hydro, as is the increase in coal use [recent discussions with Ontario Hydro and MEO personnel (Duda et al., 1987)]. Also, results from the sensitivity to oil price study shows that the modelling of the refinery seems to be responding well, i.e., with lower oil prices, there is a mix of lower and higher complexity refineries supplying the entire auto demand. As oil prices increase, the higher complexity refinery is no more cost effective, its share being replaced with alternative fuels. Overall, the model appears to be performing well.

Future research can be in several directions. The modelling of the industrial sector was limited because of the data base available. Ideally, the industrial sector should be described by major industries, such as iron and steel, pulp and paper, cement, aluminum, etc., each industry being represented in detail with alternative technologies for processes that are under consideration. Although, this would be a task that would involve a large amount of resources, this is essential since the industrial sector has the largest share of energy consumption. Work has started on one industry. Currently, Ontario Hydro is involved in the development of a process model for the pulp and paper industry.

The model can be extended to a multiperiod dynamic model that would encompass a time horizon of about 40 years in the future in steps of five years or so. This would permit the study of the evolution of the energy system for the above mentioned time span.

The model can also be extended to include the accounting of total environmental emissions associated with the energy system. This would be useful as an accounting tool as well as a measure in comparing alternative production as well as end-use technologies. This would also add to the capability of the model to include certain environmental aspects in addressing energy issues.

A major area of future work could involve the linking of this model with MEO's energy demand models and a model of Ontario's economy. This would provide a comprehensive framework for energy planning for Ontario.

Another very major area could involve the development of a multiregional model for Canada. This model, together with the model developed for Quebec, provide a major step in this direction. Not only would the multiregional model be useful from a national point of view, but would also be an excellent tool for regional energy planning, since it would represent inter-regional energy flows endogenously.

APPENDIX A

DATA ENTRY INTO SPREADSHEETS

Data entry for the model is in two spreadsheets, namely, the main spreadsheet, that contains the major data description of the model, and the scenario spreadsheet that contains information related with the creation of scenarios. The descriptions and the spreadsheets follow below.

A.1 Main spreadsheet

The description here is in two segments. The first section describes data entry into that portion of the spreadsheet that is read by the WATEMS processor along with a few other details such as variable names etc. The second segment describes data entry in the "unused" portion of the spreadsheet. This data is not directly read by the WATEMS processor, but is used for determining values that are entered in the first segment.

A.1.1 First Segment

This segment consists of three sections, namely, general information of the model, node information and variable information. In general, WATEMS, has an area of the spreadsheet allocated for this information. The major portion of this area which has numerical information is uploaded to the main frame. In this area all cells must contain numerical information. The technique in WATEMS is to insert zeros in all unused cells. As mentioned in Chapter 3, certain features of WATEMS have not been used, or were not applicable in the context of the model developed here. In some cases, the WATEMS processor has been modified thereby eliminating the need of inserting zeros in their respective cells. However, in other cases zeros have to be inserted.

The first four rows contain no data. In row 5, columns A and B refer to the number of nodes and variables respectively. Columns C and D give the number of time periods and the period length. Columns E and F refer to the annual discount rate and the year zero, both of which are not applicable here.

Node information is described from rows 6 to 159. Column A gives the names of the nodes. Column B is a switch, that is either 0 or 1; 0 means $\beta_{mt} = 0$, and 1 means it is a constant given in column C. Columns D,E,F contain zeros. Columns G and H refer to the description of units. For the model here nodal information (marginal costs) are in basic energy units, i.e. \$/PJ, the conversion factor, described in column G is therefore 1.

Variable information is decribed in rows 160 to 578. The bulk of the information is entered here.

Column A contains the names of the variables.

Columns B and C describe model structure. For each variable, the source node and the destination node are entered in columns B and C. The number 0 describes primary sources (e.g. crude oil), that do not come from any node. The number 1000 is used for variables that have no destination node (e.g. demand variables). The numbering of the nodes are in the same order as they are listed.

Columns D to G describe share limit constraints. Column D contains an integer. If it is 0 it means there is no share constraint associated with the variable. If the share constraint exists, column D is described by a four digit integer, KLMN, where Kis either 1 or 2, L is 1, M is 1,2 or 3, and N is 1. If K is 1 then the share constraint is on the incoming supply at the node; and if K is 2, then the share constraint is on the outgoing supply from the node. If M is 1, there are upper share limits; if M is 2 there are lower share limits; and if M is 3, there are equality shares. The share itself is specified in column E. Columns F and G are exactly similar so one can describe another set of share constraints on the same variable.

Columns H to K describe bounds on the variable. In a similar manner as above, if a bound exists, column H is described by an integer L,M and N. The description is identical to the shares except here they are bounds.

Columns L and M describe per unit costs (natural units). If a cost exists column L is 1; or else if no costs exist it is 0. The cost is entered in column M (or the formula for calculating the cost, based on data given in the same row in the "unused" portion of the spreadsheet, which then gives the cost).

Columns N,O and P are zeros. Columns Q and R describe conversion efficiency. Column Q is a switch; if it is 0 the conversion efficiency is 1; if it is 1, the conversion efficiency is a constant and is specified in column R. Columns S,T and U are zeros.

Column W describes a conversion factor that gives the number of basic units per natural unit of energy for the variable. Column V gives the natural unit used to describe the variable.

A.1.2 Second segment

This segment contains data that calculates costs or share parameters, etc., described in the previous section. This data is linked with formulae that calculate the above mentioned parameters.

Starting with row 5, columns X to AA contain various consumer price indices. These are used for cost calculations. Columns AD to AG describe fractional time of the year for each electrical supply mode of the load duration curve.

In column X, row 10 to 21, consists of supply cost data that is mapped on from the scenario spreadsheet. Rows 26 to 52 contain end-use demands that are again mapped on from the scenario spreadsheet. So is the information described in rows 60 to 73. These cells describe parameters that were used to generate the end-use demands. Rows 78 to 93 again provide costs of export and import of various fuels. These also are mapped from the scenario spreadsheet. These figures are mapped to the appropriate cells described in the first segment.

Rows 206 to 208, and 247 to 266, starting with column X to column AN, contain costing data for the processes. These are, in sequential order, starting with column X, capital cost, operating cost, operating credits, pilot plant size, equal capacity plant size, equal capacity factor, uncertainty factor, lead time during construction, fraction of lead time when half expenditures are made, interest rate during construction, modified capital cost (formulae based on above data), modified operating cost (formulae based on above data), consumer price indices associated with the processes (two columns) interest rate, project lifetime and service factor.

Rows 283 to 310, starting with column X to AF contain costing data for fossil and nuclear generation plants. Starting with column X, these are, capital cost per kW, operating cost per kW, fraction of lead time when half expenditures occur, interest rate during construction, modified capital cost (formulae), modified operating cost (formulae), plant lifetime, sevice factor and discount rate.

Rows 316 to 321, 331 to 334 and 349 to 354 has the same description for hydro options.

In rows 395 to 511, wherever applicable, contain costing data for end-use device options, starting with column X to AB. These are capital costs, operating costs, lifetime, capacity and discount rate.

In rows 512 to 514, starting with column X, are capital costs, operating costs, lifetime and discount rates for industrial boilers.

From rows 529 to 578, wherever applicable, contain costing data for transportation sector. Starting with column X, these are capital cost, lifetime, discount rate and consumer price index.

The following pages show the actual spreadsheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	MODEL NAME:	Ontario Energy Optimisation Model											
2	DO												
3	NOT												
4	DELETE												
5	154	419	0	1	1	0.1	1985						
6	Gas Supply	0	0	0	0	0	1	$/PJ					
7	Propane Supply	0	0	0	0	0	1	$/PJ					
8	Coal Supply	0	0	0	0	0	1	$/PJ					
9	Uranium Supply	0	0	0	0	0	1	$/PJ					
10	Wood Supply	0	0	0	0	0	1	$/PJ					
11	Syncrude	0	0	0	0	0	1	$/PJ					
12	Refineries Dist.	0	0	0	0	0	1	$/PJ					
13	Gas-Gasoline (Mobil)	1	0.0132	0	0	0	1	$/PJ					
14	Gas-Methanol	1	0.0097	0	0	0	1	$/PJ					
15	Gas-ethanol	1	0.0467	0	0	0	1	$/PJ					
16	Gas-Liquid Hydrogen	1	0.23	0	0	0	1	$/PJ					
17	Coal-Gsl+Dsl (FT-SASOL)	0	0	0	0	0	1	$/PJ					
18	Coal-Gasoline (ZnCl2)	1	0.0484	0	0	0	1	$/PJ					
19	Coal-Gasoline (Mobil)	1	0.0011	0	0	0	1	$/PJ					
20	Coal-Methanol	0	0	0	0	0	1	$/PJ					
21	Coal-Ethanol	1	0.1842	0	0	0	1	$/PJ					
22	Coal-Liquid Hydrogen	1	0.223	0	0	0	1	$/PJ					
23	Wood-Methanol	0	0	0	0	0	1	$/PJ					
24	Wood-Ethanol	1	0.1583	0	0	0	1	$/PJ					
25	Corn-Ethanol	1	0.3586	0	0	0	1	$/PJ					
26	Barley-Ethanol	1	0.386	0	0	0	1	$/PJ					
27	Wheat-Ethanol	1	0.3774	0	0	0	1	$/PJ					
28	Methanol	0	0	0	0	0	1	$/PJ					
29	Ethanol	0	0	0	0	0	1	$/PJ					
30	CNG	1	0.026	0	0	0	1	$/PJ					
31	LNG	1	0.0571	0	0	0	1	$/PJ					
32	Gasoline	0	0	0	0	0	1	$/PJ					
33	Diesel	0	0	0	0	0	1	$/PJ					

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1										
2										
3										
4										
5	127.2	122.1	130.1	118			0.022	0.228	0.685	1
6										
7										
8										
9										
10	6210									
11	6210									
12	300000									
13	128000									
14	97000									
15	49000									
16	297000									
17	82000									
18	71000									
19	198000									
20	191000									
21	225000									
22										
23										
24										
25										
26	16.10									
27	43.65									
28	97.04									
29	19.15									
30	11.94									
31	114.24									
32	15.94									
33	21.55									

	A	B	C	D	E	F	G	H	I	J	K	L	M
34	Aviation Gasoline	0	0	0	0	0	1	$/PJ					
35	Turbo Jet Fuel	0	0	0	0	0	1	$/PJ					
36	Light Fuel Oil	0	0	0	0	0	1	$/PJ					
37	Heavy Fuel Oil	0	0	0	0	0	1	$/PJ					
38	PCF+Petroleum Products	0	0	0	0	0	1	$/PJ					
39	Methanol-Gasoline (MOBIL)	1	0.0011	0	0	0	1	$/PJ					
40	Methanol Gasoline	0	0	0	0	0	1	$/PJ					
41	Ethanol Gasoline	0	0	0	0	0	1	$/PJ					
42	Elec / Gas-SBC	0	0	0	0	0	1	$/PJ					
43	Elec / Gas-SPC	0	0	0	0	0	1	$/PJ					
44	Elec / LF Oil-CTU	0	0	0	0	0	1	$/PJ					
45	Elec / HF Oil-SBC	0	0	0	0	0	1	$/PJ					
46	Elec / Coal-PFC1	0	0	0	0	0	1	$/PJ					
47	Elec / Coal-PFC2	0	0	0	0	0	1	$/PJ					
48	Elec / Coal-AFBC	0	0	0	0	0	1	$/PJ					
49	Elec / Lignite-	0	0	0	0	0	1	$/PJ					
50	Elec / Uran-New Darl	0	0	0	0	0	1	$/PJ					
51	Elec / Uran-Existing Darl	0	0	0	0	0	1	$/PJ					
52	Elec / New Hydro (Large)	0	0	0	0	0	1	$/PJ					
53	Elec / Existing Hydro	0	0	0	0	0	1	$/PJ					
54	Elec / Mun. Refuse	0	0	0	0	0	1	$/PJ					
55	Seasonal Peak	0	0	0	0	0	1	$/PJ					
56	Daily Peak	0	0	0	0	0	1	$/PJ					
57	Cycling	0	0	0	0	0	1	$/PJ					
58	Base	0	0	0	0	0	1	$/PJ					
59	Electricity	0	0	0	0	0	1	$/PJ					
60	Electricity-Liquid Hydrogen	0	0	0	0	0	1	$/PJ					
61	Liquid Hydrogen	0	0	0	0	0	1	$/PJ					
62	Heat-Pump / R2000 SH	0	0	0	0	0	1	$/PJ					
63	Heat Pump + Backups / R2000 SH	0	0	0	0	0	1	$/PJ					
64	Wood Furnace + Backups / R2000 SH	0	0	0	0	0	1	$/PJ					
65	Active Solar / R2000 SH	1	0.0909	0	0	0	1	$/PJ					
66	Heating Devices / R2000 SH	0	0	0	0	0	1	$/PJ					

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
34	115.38									
35	194.14									
36	60.78									
37	14.39									
38	47.46									
39	100.72									
40	572.94									
41	544.08									
42	254.40									
43	151.79									
44	436.12									
45	121083.40									
46	21069.18									
47	2.27									
48	6.60									
49	2.75									
50	14.99									
51	18.53									
52	1.61									
53										
54										
55										
56										
57										
58										
59										
60	10.4764									
61	5.5979									
62	0.61									
63	0.39									
64	0.45									
65	0.5									
66	0.05									

	A	B	C	D	E	F	G	H	I	J	K	L	M
67	Heat-Pump / ISH	0	0	0	0	0	1	$/PJ					
68	Heat Pump + Backups / ISH	0	0	0	0	0	1	$/PJ					
69	Wood Furnace + Backups / ISH	0	0	0	0	0	1	$/PJ					
70	Active Solar / ISH	1	0.0909	0	0	0	1	$/PJ					
71	Active Solar + Backups / ISH	0	0	0	0	0	1	$/PJ					
72	Heating Devices / ISH	0	0	0	0	0	1	$/PJ					
73	Heat-Pump / OBC80H	0	0	0	0	0	1	$/PJ					
74	Heat Pump + Backups / OBC80H	0	0	0	0	0	1	$/PJ					
75	Wood Furnace + Backups / OBC80H	0	0	0	0	0	1	$/PJ					
76	Active Solar / OBC80H	1	0.0909	0	0	0	1	$/PJ					
77	Active Solar + Backups / OBC80H	0	0	0	0	0	1	$/PJ					
78	Heating Devices / OBC80H	0	0	0	0	0	1	$/PJ					
79	Heating Devices / Apts	0	0	0	0	0	1	$/PJ					
80	Housing Types	0	0	0	0	0	1	$/PJ					
81	Apartment / Types	0	0	0	0	0	1	$/PJ					
82	Residential Space Heating	0	0	0	0	0	1	$/PJ					
83	Active Solar - WH / Houses	0	0	0	0	0	1	$/PJ					
84	Active Solar + WH Backups / Houses	0	0	0	0	0	1	$/PJ					
85	Water Heating Devices / Houses	0	0	0	0	0	1	$/PJ					
86	Water Heating Devices / Apts	0	0	0	0	0	1	$/PJ					
87	Residential Water Heating	0	0	0	0	0	1	$/PJ					
88	Heat Pump - Cooling / Houses	0	0	0	0	0	1	$/PJ					
89	Active Solar - Cooling / Houses	0	0	0	0	0	1	$/PJ					
90	Central Air-Conditioning	0	0	0	0	0	1	$/PJ					
91	Residential Air-Conditioning	0	0	0	0	0	1	$/PJ					
92	Heating Devices / C&I	0	0	0	0	0	1	$/PJ					
93	C&I Space Heating	0	0	0	0	0	1	$/PJ					
94	C&I Water Heating	0	0	0	0	0	1	$/PJ					
95	C&I Air-Condioning	0	0	0	0	0	1	$/PJ					
96	Ind. Indirect Heat	0	0	0	0	0	1	$/PJ					
97	Ind. Direct Heat	0	0	0	0	0	1	$/PJ					
98	Ind. Utilities	0	0	0	0	0	1	$/PJ					
99	Ind. PCF + PP	0	0	0	0	0	1	$/PJ					

	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
67	0.8									
68	0.3									
69	2.51									
70	1.82									
71	1									
72										
73	1.55									
74										
75										
76										
77										
78	4.533									
79	6.121									
80	380.38									
81	380.38									
82	380.38									
83	380.38									
84	380.38									
85	380.38									
86	380.38									
87	377.28									
88	377.28									
89	377.28									
90	377.28									
91	377.28									
92	377.28									
93	377.28									
94										
95										
96										
97										
98										
99										

	A	B	C	D	E	F	G	H	I	J	K	L	M
100	Automobiles	0	0	0	0	0	1	$/PJ					
101	Aircraft	0	0	0	0	0	1	$/PJ					
102	Buses	0	0	0	0	0	1	$/PJ					
103	Marine	0	0	0	0	0	1	$/PJ					
104	Rail	0	0	0	0	0	1	$/PJ					
105	Trucks	0	0	0	0	0	1	$/PJ					
106	Gasolines - Ref 2	0	0	0	0	0	1	$/PJ					
107	Distillates - Ref 2	0	0	0	0	0	1	$/PJ					
108	H.Oil&PCF&PP - Ref 2	0	0	0	0	0	1	$/PJ					
109	Lt.Trucks & Vans	0	0	0	0	0	1	$/PJ					
110	Small Hydro	0	0	0	0	0	1	$/PJ					
111	Gas Tran&Dist	1	0.084	0	0	0	1	$/PJ					
112	Propane Tran&Dist	1	0.003	0	0	0	1	$/PJ					
113	Methanol Tran&Dist	1	0.003	0	0	0	1	$/PJ					
114	Ethanol Tran&Dist	1	0.003	0	0	0	1	$/PJ					
115	Gasoline Tran&Dist	1	0.003	0	0	0	1	$/PJ					
116	Diesel Tran&Dist	1	0.003	0	0	0	1	$/PJ					
117	Aviation Gasoline Tran&Dist	1	0.003	0	0	0	1	$/PJ					
118	Jet fuel Tran&Dist	1	0.003	0	0	0	1	$/PJ					
119	Light Fuel Oil Tran&Dist	1	0.003	0	0	0	1	$/PJ					
120	Heavy Fuel Oil Tran&Dist	1	0,003	0	0	0	1	$/PJ					
121	PCF & Petrochemicals Tran&Dist	1	0.003	0	0	0	1	$/PJ					
122	Electrical Tran&Dist	1	0.092	0	0	0	1	$/PJ					
123	Wood Tran&Dist	0	0	0	0	0	1	$/PJ					
124	Liq. Hydrogen Tran&Dist	1	0.003	0	0	0	1	$/PJ					
125	LNG Tran&Dist	1	0.003	0	0	0	1	$/PJ					
126	Refinery - 2 (High Complexity)	1	0.045	0	0	0	1	$/PJ					
127	Refinery - 1 (Low Complexity)	1	0.042	0	0	0	1	$/PJ					
128	Gasolines - Ref 1	0	0	0	0	0	1	$/PJ					
129	Distillates - Ref 1	0	0	0	0	0	1	$/PJ					
130	Heavy Oils - Ref 1	0	0	0	0	0	1	$/PJ					
131	Electricity Imp/Exp	0	0	0	0	0	1	$/PJ					
132	Electricity Exports - Transmission	1	0.096	0	0	0	1	$/PJ					

	A	B	C	D	E	F	G	H	I	J	K	L	M
133	Mun.Ref Elec - CY	1	-1	0	0	0	1	$/PJ					
134	Mun.Ref Elec - BS	1	-1	0	0	0	1	$/PJ					
135	Mun.Ref Elec - Power	0	0	0	0	0	1	$/GW					
136	Hydro Elec - >10 MW -SP	1	-1	0	0	0	1	$/PJ					
137	Hydro Elec - >10 MW -DP	1	-1	0	0	0	1	$/PJ					
138	Hydro Elec - >10 MW -CY	1	-1	0	0	0	1	$/PJ					
139	Hydro Elec - >10 MW -BS	1	-1	0	0	0	1	$/PJ					
140	Hydro Elec - >10 MW -POWER	0	0	0	0	0	1	$/GW					
141	Hydro Elec - 2-10 MW -SP	1	-1	0	0	0	1	$/PJ					
142	Hydro Elec - 2-10 MW -DP	1	-1	0	0	0	1	$/PJ					
143	Hydro Elec - 2-10 MW -CY	1	-1	0	0	0	1	$/PJ					
144	Hydro Elec - 2-10 MW -BS	1	-1	0	0	0	1	$/PJ					
145	Hydro Elec - 2-10 MW -POWER	0	0	0	0	0	1	$/GW					
146	Hydro Elec - EXIST. -SP	1	-1	0	0	0	1	$/PJ					
147	Hydro Elec - EXIST. -DP	1	-1	0	0	0	1	$/PJ					
148	Hydro Elec - EXIST. -CY	1	-1	0	0	0	1	$/PJ					
149	Hydro Elec - EXIST. -BS	1	-1	0	0	0	1	$/PJ					
150	Hydro Elec - EXIST. -POWER	0	0	0	0	0	1	$/GW					
151	Hydro Elec - >10 MW - Peak	0	0	0	0	0	1	$/PJ					
152	Hydro Elec - >10 MW - Peak - SP	1	-1	0	0	0	1	$/PJ					
153	Hydro Elec - >10 MW - Peak - DP	1	-1	0	0	0	1	$/PJ					
154	Hydro Elec - >10 MW - Peak - Power	0	0	0	0	0	1	$/GW					
155	Hydro Elec - EXIST. - Peak	0	0	0	0	0	1	$/PJ					
156	Hydro Elec - EXIST. - Peak - SP	1	-1	0	0	0	1	$/PJ					
157	Hydro Elec - EXIST. - Peak - DP	1	-1	0	0	0	1	$/PJ					
158	Hydro Elec - EXIST. - Peak - Power	0	0	0	0	0	1	$/GW					
159	Electricity Imports	0	0	0	0	0	1	$/PJ					
160	GAS ONT	0	1	0	0	0	0	111	5514	0	0	1	6210
161	GAS-MAC-BFT/EAS.OFF/ARCTIC ISL.	0	1	0	0	0	0	0	0	0	0	1	6210
162	PROPANE-WEST	0	2	0	0	0	0	0	0	0	0	1	300000
163	COAL-WEST	0	3	1131	0.3	0	0	0	0	0	0	1	128000
164	COAL-US	0	3	0	0	0	0	0	0	0	0	1	97000
165	CRUDEOIL-FOREIGN/REGIONAL IMP.	0	7	0	0	0	0	0	0	0	0	1	49000

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
133																
134																
135																
136																
137																
138																
139																
140																
141																
142																
143																
144																
145																
146																
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148																
149																
150																
151																
152																
153																
154																
155																
156																
157																
158																
159																
160	0	0	0	0	0	0	0	0	0.00107	1000	Mcf/yr					
161	0	0	0	0	0	0	0	0	0.00107	1000	Mcf/yr					
162	0	0	0	0	0	0	0	0	0.0256	MLts/yr						
163	0	0	0	0	0	0	0	0	0.02933	1000	Tns/yr					
164	0	0	0	0	0	0	0	0	0.02999	1000	Tns/yr					
165	0	0	0	0	0	0	0	0	0.0061	1000	Brls/yr					

	A	B	C	D	E	F	G	H	I	J	K	L	M
166	URANIUM-SASKAT	0	4	0	0	0	0	0	0	0	0	1	297000
167	WOOD-ONT	0	5	0	0	0	0	111	1000	0	0	1	82000
168	LIGNITE-SASKAT.	0	44	0	0	0	0	0	0	0	0	1	215151.515
169	EXISTING HYDRO - PEAKING UNITS	0	150	0	0	0	0	111	1516.3	0	0	0	0
170	NEW HYDRO (>10 MW) - PEAKING UNI	0	146	0	0	0	0	111	1962.2	0	0	0	0
171	EXISTING HYDRO - ALL CATEG.	0	48	0	0	0	0	111	31605.1	0	0	0	0
172	NEW HYDRO (>10MW) - ALL CATEG.	0	47	0	0	0	0	111	4073.44	0	0	0	0
173	SMALL HYDRO (2-10 MW) - ALL CATEG.	0	105	0	0	0	0	111	628.092	0	0	0	0
174	CORN-ONT-ETHL	0	20	0	0	0	0	0	0	0	0	1	309859.154
175	BARLEY-ONT-ETHL	0	21	0	0	0	0	0	0	0	0	1	350265.908
176	WHEAT-ONT-ETHL	0	22	0	0	0	0	0	0	0	0	1	389273.356
177	MUNREFUSE-ELEC	0	49	0	0	0	0	0	0	0	0	0	0
178	COAL-SYNCRUDE	3	6	0	0	0	0	0	0	0	0	0	0
179	GAS-GSL(MOBIL)	1	8	0	0	0	0	0	0	0	0	0	0
180	COAL-GSL(ZNCL2)	3	13	0	0	0	0	0	0	0	0	0	0
181	COAL-GSL(MOBIL)	3	14	0	0	0	0	0	0	0	0	0	0
182	COAL-GSLDSL(SASOL)	3	12	0	0	0	0	0	0	0	0	0	0
183	ELEC-GAS-GSL(MOBIL)	117	8	1131	0.0132	0	0	0	0	0	0	0	0
184	ELEC-COAL-GSL(MOBIL)	117	14	1131	0.0011	0	0	0	0	0	0	0	0
185	GAS-MTHL	1	9	0	0	0	0	0	0	0	0	0	0
186	COAL-MTHL	3	15	0	0	0	0	0	0	0	0	0	0
187	WOOD-MTHL	5	18	0	0	0	0	0	0	0	0	0	0
188	ELEC-GAS-MTHL	117	9	1131	0.0097	0	0	0	0	0	0	0	0
189	MTHL-GSL(MOBIL)	23	34	0	0	0	0	0	0	0	0	0	0
190	ELEC-MTHL-GSL(MOBIL)	117	34	1131	0.0011	0	0	0	0	0	0	0	0
191	GAS-ETHL	1	10	0	0	0	0	0	0	0	0	0	0
192	COAL-ETHL	3	16	0	0	0	0	0	0	0	0	0	0
193	WOOD-ETHL	5	19	0	0	0	0	0	0	0	0	0	0
194	COAL-CORN-ETHL	3	20	1131	0.3586	0	0	0	0	0	0	0	0
195	COAL-BARLEY-ETHL	3	21	1131	0.386	0	0	0	0	0	0	0	0
196	COAL-WHEAT-ETHL	3	22	1131	0.3774	0	0	0	0	0	0	0	0
197	ELEC-GAS-ETHL	117	10	1131	0.0467	0	0	0	0	0	0	0	0
198	GAS-COAL-ETHL	1	16	1131	0.1526	0	0	0	0	0	0	0	0

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
166	0	0	0	0	0	0	0	0	0.18054	Tns/yr						
167	0	0	0	0	0	0	0	0	0.02	1000 TNS						
168	0	0	0	i	0.33	0	0	0	0.01534	1000 Tns/yr						
169	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
170	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
171	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
172	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
173	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
174	0	0	0	1	0.639	0	0	0	0.0142	1000 TNS						
175	0	0	0	1	0.5453	0	0	0	0.0142	1000 TNS						
176	0	0	0	1	0.578	0	0	0	0.0142	1000 TNS						
177	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
178	0	0	0	1	0.5488	0	0	0	1	PJ/yr						
179	0	0	0	1	0.4994	0	0	0	1	PJ/yr						
180	0	0	0	1	0.5659	0	0	0	1	PJ/yr						
181	0	0	0	1	0.3079	0	0	0	1	PJ/yr						
182	0	0	0	1	0.2593	0	0	0	1	PJ/yr						
183	0	0	0	0	0	0	0	0	1	PJ/yr						
184	0	0	0	0	0	0	0	0	1	PJ/yr						
185	0	0	0	1	0.6222	0	0	0	1	PJ/yr						
186	0	0	0	1	0.3835	0	0	0	1	PJ/yr						
187	0	0	0	1	0.4189	0	0	0	1	PJ/yr						
188	0	0	0	0	0	0	0	0	1	PJ/yr						
189	0	0	0	1	0.8027	0	0	0	1	PJ/yr						
190	0	0	0	0	0	0	0	0	1	PJ/yr						
191	0	0	0	1	0.4171	0	0	0	1	PJ/yr						
192	0	0	0	1	0.3352	0	0	0	1	PJ/yr						
193	0	0	0	1	0.3351	0	0	0	1	PJ/yr						
194	0	0	0	0	0	0	0	0	1	PJ/yr						
195	0	0	0	0	0	0	0	0	1	PJ/yr						
196	0	0	0	0	0	0	0	0	1	PJ/yr						
197	0	0	0	0	0	0	0	0	1	PJ/yr						
198	0	0	0	0	0	0	0	0	1	PJ/yr						

	A	B	C	D	E	F	G	H	I	J	K	L	M
199	ELEC-COAL-ETHL	117	16	1131	0.0316	0	0	0	0	0	0	0	0
200	ELEC-WOOD-ETHL	117	19	1131	0.1583	0	0	0	0	0	0	0	0
201	COAL-LHYGN	3	17	0	0	0	0	0	0	0	0	0	0
202	GAS-LHYGN	1	11	0	0	0	0	0	0	0	0	0	0
203	ELEC-LHYGN	117	55	0	0	0	0	0	0	0	0	0	0
204	ELEC-COAL-LHYGN	117	17	1131	0.223	0	0	0	0	0	0	0	0
205	ELEC-GAS-LHYGN	117	11	1131	0.23	0	0	0	0	0	0	0	0
206	SYNCRUDE-REF	6	7	0	0	0	0	0	0	0	0	1	3212.89939
207	CRUDE-REF 1 (LOW COMPLEX.)	7	122	0	0	0	0	0	0	0	0	1	393.809067
208	CRUDE-REF 2 (HIGH COMPLEX.)	7	121	0	0	0	0	0	0	0	0	1	689.110509
209	REF 2-GASOLINES	121	101	2111	0.5232	2121	0.373	0	0	0	0	0	0
210	REF 2-DISTILLATES	121	102	2111	0.4267	2121	0.2654	0	0	0	0	0	0
211	REF 2-H.OIL&PCF&PP	121	103	2111	0.1374	2121	0.1347	0	0	0	0	0	0
212	REF 2-PROPANE	121	2	2111	0.0281	2121	0.0207	0	0	0	0	0	0
213	GSL 2-GASOLINES	101	27	0	0	0	0	0	0	0	0	0	0
214	DSL 2-DISTILLATES	102	28	0	0	0	0	0	0	0	0	0	0
215	AGSL 2-GASOLINES	101	29	0	0	0	0	0	0	0	0	0	0
216	TJF 2-DISTILLATES	102	30	0	0	0	0	0	0	0	0	0	0
217	LFO 2-DISTILLATES	102	31	0	0	0	0	0	0	0	0	0	0
218	HFO 2-H.OIL&PCF&PP	103	32	0	0	0	0	0	0	0	0	0	0
219	PCF&PP 2-H.OIL&PCF&PP	103	33	0	0	0	0	0	0	0	0	0	0
220	REF 1-GASOLINES	122	123	2111	0.212	2121	0.1313	0	0	0	0	0	0
221	REF 1-DISTILLATES	122	124	2111	0.2931	2121	0.2071	0	0	0	0	0	0
222	REF 1-H.OIL&PCF&PP	122	125	2111	0.5318	2121	0.5269	0	0	0	0	0	0
223	REF 1-PROPANE	122	2	2111	0.0065	2121	0.0064	0	0	0	0	0	0
224	GSL 1-GASOLINES	123	27	0	0	0	0	0	0	0	0	0	0
225	DSL 1-DISTILLATES	124	28	0	0	0	0	0	0	0	0	0	0
226	AGSL 1-GASOLINES	123	29	0	0	0	0	0	0	0	0	0	0
227	TJF 1-DISTILLATES	124	30	0	0	0	0	0	0	0	0	0	0
228	LFO 1-DISTILLATES	124	31	0	0	0	0	0	0	0	0	0	0
229	HFO 1-H.OIL&PCF&PP	125	32	0	0	0	0	0	0	0	0	0	0
230	PCF&PP 1-H.OIL&PCF&PP	125	33	0	0	0	0	0	0	0	0	0	0
231	GSL-IMPORTS	0	27	0	0	0	0	111	0.01	0	0	1	10064408.7

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
199	0	0	0	0	0	0	0	0	1	PJ/yr						
200	0	0	0	0	0	0	0	0	1	PJ/yr						
201	0	0	0	1	0.4646	0	0	0	1	PJ/yr						
202	0	0	0	1	0.6326	0	0	0	1	PJ/yr						
203	0	0	0	1	0.6008	0	0	0	1	PJ/yr						
204	0	0	0	0	0	0	0	0	1	PJ/yr						
205	0	0	0	0	0	0	0	0	1	PJ/yr						
206	0	0	0	0	0	0	0	0	0.001	TJ/yr	1418.7	98.32	48.21	326760	250000	0.83
207	0	0	0	0	0	0	0	0	0.001	TJ/yr	135.49	13.89	0	1	1	1
208	0	0	0	0	0	0	0	0	0.001	TJ/yr	236.79	24.34	0	1	1	1
209	0	0	0	0	0	0	0	0	0.001	TJ/yr						
210	0	0	0	0	0	0	0	0	0.001	TJ/yr						
211	0	0	0	0	0	0	0	0	0.001	TJ/yr						
212	0	0	0	0	0	0	0	0	0.001	TJ/yr						
213	0	0	0	0	0	0	0	0	0.001	TJ/yr						
214	0	0	0	0	0	0	0	0	0.001	TJ/yr						
215	0	0	0	0	0	0	0	0	0.001	TJ/yr						
216	0	0	0	0	0	0	0	0	0.001	TJ/yr						
217	0	0	0	0	0	0	0	0	0.001	TJ/yr						
218	0	0	0	0	0	0	0	0	0.001	TJ/yr						
219	0	0	0	0	0	0	0	0	0.001	TJ/yr						
220	0	0	0	0	0	0	0	0	0.001	TJ/yr						
221	0	0	0	0	0	0	0	0	0.001	TJ/yr						
222	0	0	0	0	0	0	0	0	0.001	TJ/yr						
223	0	0	0	0	0	0	0	0	0.001	TJ/yr						
224	0	0	0	0	0	0	0	0	0.001	TJ/yr						
225	0	0	0	0	0	0	0	0	0.001	TJ/yr						
226	0	0	0	0	0	0	0	0	0.001	TJ/yr						
227	0	0	0	0	0	0	0	0	0.001	TJ/yr						
228	0	0	0	0	0	0	0	0	0.001	TJ/yr						
229	0	0	0	0	0	0	0	0	0.001	TJ/yr						
230	0	0	0	0	0	0	0	0	0.001	TJ/yr						
231	0	0	0	0	0	0	0	0	1	PJ/yr						

	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
199											
200											
201											
202											
203											
204											
205											
206	1.47	5	0.6	0.08	1994.794	38.33853	112.8	114.1	0.08	30	0.8
207	1	5	0.6	0.08	161.8516	13.89	42	47.6	0.08	30	0.9
208	1	5	0.6	0.08	282.8611	24.34	42	47.6	0.08	30	0.9
209											
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	A	B	C	D	E	F	G	H	I	J	K	L	M
232	DSL-IMPORTS	0	28	0	0	0	0	111	0.01	0	0	1	10064408.7
233	AGSL-IMPORTS	0	29	0	0	0	0	111	0.01	0	0	1	10064408.7
234	TJF-IMPORTS	0	30	0	0	0	0	111	0.01	0	0	1	10064408.7
235	LFO-IMPORTS	0	31	0	0	0	0	111	0.01	0	0	1	10064408.7
236	HFO-IMPORTS	0	32	0	0	0	0	111	0.01	0	0	1	10064408.7
237	PCF&PP IMPORTS	0	33	0	0	0	0	111	0.01	0	0	1	10064408.7
238	GSL-EXPORTS	27	1000	0	0	0	0	111	0	0	0	1	-9982386.3
239	DSL-EXPORTS	28	1000	0	0	0	0	111	0	0	0	1	-9982386.3
240	AGSL-EXPORTS	29	1000	0	0	0	0	111	0	0	0	1	-9982386.3
241	TJF-EXPORTS	30	1000	0	0	0	0	111	0	0	0	1	-9982386.3
242	LFO-EXPORTS	31	1000	0	0	0	0	111	0	0	0	1	-9982386.3
243	HFO-EXPORTS	32	1000	0	0	0	0	111	0	0	0	1	-9982386.3
244	PCF&PP-EXPORTS	33	1000	0	0	0	0	111	0	0	0	1	-9982386.3
245	ELEC-CNG	117	25	0	0	0	0	0	0	0	0	0	0
246	ELEC-LNG	117	26	0	0	0	0	0	0	0	0	0	0
247	CNG	106	25	0	0	0	0	0	0	0	0	1	3226.58469
248	LNG	1	26	0	0	0	0	0	0	0	0	1	6700.27525
249	GSL(MOBIL)-GAS	8	27	0	0	0	0	0	0	0	0	1	6184.54862
250	GSL(ZNCL2)-COAL	13	27	0	0	0	0	0	0	0	0	1	9420.13372
251	GSL(MOBIL)-COAL	14	27	0	0	0	0	0	0	0	0	1	8638.64531
252	GSL(MOBIL)-MTHL	34	27	0	0	0	0	0	0	0	0	1	906.323053
253	GSL-COAL(SASOL)	12	27	2131	0.9139	0	0	0	0	0	0	1	9545.71633
254	DSL-COAL(SASOL)	12	28	0	0	0	0	0	0	0	0	1	9545.71633
255	MTHL-GAS	9	23	0	0	0	0	0	0	0	0	1	4125.34983
256	MTHL-COAL	15	23	0	0	0	0	0	0	0	0	1	6236.19917
257	MTHL-WOOD	18	23	0	0	0	0	0	0	0	0	1	7101.99218
258	ETHL-GAS	10	24	0	0	0	0	0	0	0	0	1	8784.63591
259	ETHL-COAL	16	24	0	0	0	0	0	0	0	0	1	14867.8121
260	ETHL-WOOD	19	24	0	0	0	0	0	0	0	0	1	10151.7970
261	ETHL-CORN	20	24	0	0	0	0	0	0	0	0	1	4004.75714
262	ETHL-BARLEY	21	24	0	0	0	0	0	0	0	0	1	2060.74439
263	ETHL-WHEAT	22	24	0	0	0	0	0	0	0	0	1	3668.77677
264	LHYGN-GAS	11	56	0	0	0	0	0	0	0	0	1	2634.26412

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
232	0	0	0	0	0	0	0	0	1	PJ/yr						
233	0	0	0	0	0	0	0	0	1	PJ/yr						
234	0	0	0	0	0	0	0	0	1	PJ/yr						
235	0	0	0	0	0	0	0	0	1	PJ/yr						
236	0	0	0	0	0	0	0	0	1	PJ/yr						
237	0	0	0	0	0	0	0	0	1	PJ/yr						
238	0	0	0	0	0	0	0	0	1	PJ/yr						
239	0	0	0	0	0	0	0	0	1	PJ/yr						
240	0	0	0	0	0	0	0	0	1	PJ/yr						
241	0	0	0	0	0	0	0	0	1	PJ/yr						
242	0	0	0	0	0	0	0	0	1	PJ/yr						
243	0	0	0	0	0	0	0	0	1	PJ/yr						
244	0	0	0	0	0	0	0	0	1	PJ/yr						
245	0	0	0	0	0	0	0	0	1	PJ/yr						
246	0	0	0	0	0	0	0	0	1	PJ/yr						
247	0	0	0	0	0	0	0	0	0.001	TJ/yr	0.562	0.10724	0	156	40000	1
248	0	0	0	0	0	0	0	0	0.001	TJ/yr	5.81	1.56	0	1000	40000	1
249	0	0	0	0	0	0	0	0	0.001	TJ/yr	1988.87	214.01	37.53	270199	250000	0.85
250	0	0	0	0	0	0	0	0	0.001	TJ/yr	2635.46	197.45	28.35	307227	250000	0.82
251	0	0	0	0	0	0	0	0	0.001	TJ/yr	3280.78	194.89	39.76	270199	250000	0.81
252	0	0	0	0	0	0	0	0	0.001	TJ/yr	625.44	20.18	37.53	270199	250000	0.85
253	0	0	0	0	0	0	0	0	0.001	TJ/yr	3911.64	296.88	149.57	226503	250000	0.8
254	0	0	0	0	0	0	0	0	0.001	TJ/yr	3911.64	296.88	149.57	226503	250000	0.8
255	0	0	0	0	0	0	0	0	0.001	TJ/yr	171.2	17.5	0	22717	250000	0.79
256	0	0	0	0	0	0	0	0	0.001	TJ/yr	2816.45	187.88	2.18	308933	250000	0.85
257	0	0	0	0	0	0	0	0	0.001	TJ/yr	270.82	19.46	0	22696	250000	0.79
258	0	0	0	0	0	0	0	0	0.001	TJ/yr	410.45	64.79	15.34	32105	250000	0.76
259	0	0	0	0	0	0	0	0	0.001	TJ/yr	692.12	76.71	13.77	32105	250000	0.78
260	0	0	0	0	0	0	0	0	0.001	TJ/yr	37.59	6.09	2.54	1591	250000	0.74
261	0	0	0	0	0	0	0	0	0.001	TJ/yr	116.23	16.41	7.47	13558	250000	0.83
262	0	0	0	0	0	0	0	0	0.001	TJ/yr	135.55	13.71	13.71	13558	250000	0.83
263	0	0	0	0	0	0	0	0	0.001	TJ/yr	124.26	17.01	9.9	13558	250000	0.83
264	0	0	0	0	0	0	0	0	0.001	TJ/yr	267.04	11.82	12.56	31848	40000	0.68

	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
232											
233											
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246											
247	1	0.5	0.6	0.08	146.6263	27.49743	112.8	114.1	0.08	30	0.95
248	1.01	1	0.6	0.08	243.0404	62.4	112.8	114.1	0.08	30	0.95
249	1.26	5	0.6	0.08	2802.236	163.2870	112.8	114.1	0.08	30	0.8
250	2.09	5	0.6	0.08	5556.570	137.6018	112.8	114.1	0.08	30	0.8
251	1.33	5	0.6	0.08	4894.477	143.5330	112.8	114.1	0.08	30	0.8
252	1.25	5	0.6	0.08	874.2255	-16.0529	112.8	114.1	0.08	30	0.8
253	1.15	5	0.6	0.08	5815.131	162.5916	112.8	114.1	0.08	30	0.85
254	1.15	5	0.6	0.08	5815.131	162.5916	112.8	114.1	0.08	30	0.85
255	1.02	3	0.6	0.08	1290.637	192.5870	112.8	114.1	0.08	30	0.9
256	1.17	5	0.6	0.08	3288.230	150.2753	112.8	114.1	0.08	30	0.85
257	1.35	5	0.6	0.08	2906.679	214.3549	112.8	114.1	0.08	30	0.8
258	1.4	3	0.6	0.08	3038.593	385.0646	112.8	114.1	0.08	30	0.9
259	1.47	3	0.6	0.08	5605.448	490.1105	112.8	114.1	0.08	30	0.8
260	1.25	3	0.6	0.08	2203.267	557.8252	112.8	114.1	0.08	30	0.9
261	1.04	3	0.6	0.08	1509.261	164.8473	112.8	114.1	0.08	30	0.9
262	1.04	3	0.6	0.08	1760.134	0	112.8	114.1	0.08	30	0.9
263	1.04	3	0.6	0.08	1613.532	131.1034	112.8	114.1	0.08	30	0.9
264	1.07	3	0.6	0.08	370.7747	-0.92941	112.8	114.1	0.08	30	0.9

	A	B	C	D	E	F	G	H	I	J	K	L	M
265	LHYGN-COAL	17	56	0	0	0	0	0	0	0	0	1	7755.29733
266	LHYGN-ELEC	55	56	0	0	0	0	0	0	0	0	1	7916.02374
267	GSL-MTHLGSLBLD	110	35	1131	0.945	0	0	0	0	0	0	0	0
268	GSL-ETHLGSLBLD	110	36	1131	0.931	0	0	0	0	0	0	0	0
269	MTHL-MTHLGSLBLD	108	35	0	0	0	0	0	0	0	0	0	0
270	ETHL-ETHLGSLBLD	109	36	0	0	0	0	0	0	0	0	0	0
271	PROPANE-MOBIL(GAS)	8	2	2131	0.0543	0	0	0	0	0	0	0	0
272	PROPANE-MOBIL(COAL)	14	2	2131	0.0543	0	0	0	0	0	0	0	0
273	PROPANE-MOBIL(MTHL)	34	2	2131	0.0543	0	0	0	0	0	0	0	0
274	GAS-SBC-ELEC	1	37	0	0	0	0	0	0	0	0	0	0
275	GAS-SPC-ELEC	1	38	0	0	0	0	0	0	0	0	0	0
276	COAL-PFC1-ELEC	3	41	0	0	0	0	0	0	0	0	0	0
277	COAL-PFC2-ELEC	3	42	0	0	0	0	0	0	0	0	0	0
278	COAL-AFBC-ELEC	3	43	0	0	0	0	0	0	0	0	0	0
279	HOIL-SBC-ELEC	32	40	0	0	0	0	0	0	0	0	0	0
280	LOIL-CTU-ELEC	31	39	0	0	0	0	0	0	0	0	0	0
281	URAN-NWDL-ELEC	4	45	0	0	0	0	0	0	0	0	0	0
282	URAN-EXDL-ELEC	4	46	0	0	0	0	111	230.85	0	0	0	0
283	ELEC-GAS-SBC-SP	37	50	0	0	0	0	0	0	0	0	1	207370.012
284	ELEC-GAS-SBC-DP	37	51	0	0	0	0	0	0	0	0	1	20009.3871
285	ELEC-GAS-SPC-SP	38	50	0	0	0	0	0	0	0	0	1	232757.729
286	ELEC-GAS-SPC-DP	38	51	0	0	0	0	0	0	0	0	1	22459.0791
287	ELEC-LOIL-CTU-SP	39	50	0	0	0	0	0	0	0	0	1	291856.271
288	ELEC-LOIL-CTU-DP	39	51	0	0	0	0	0	0	0	0	1	28161.5700
289	ELEC-HOIL-SBC-SP	40	50	0	0	0	0	0	0	0	0	1	391959.429
290	ELEC-HOIL-SBC-DP	40	51	0	0	0	0	0	0	0	0	1	37820.6466
291	ELEC-HOIL-SBC-CYC	40	52	0	0	0	0	0	0	0	0	1	12588.4780
292	ELEC-HOIL-SBC-BASE	40	53	0	0	0	0	0	0	0	0	1	8623.10743
293	ELEC-COAL-PFC1-SP	41	50	0	0	0	0	0	0	0	0	1	378724.765
294	ELEC-COAL-PFC1-DP	41	51	0	0	0	0	0	0	0	0	1	36543.6177
295	ELEC-COAL-PFC1-CYC	41	52	0	0	0	0	0	0	0	0	1	12163.4231
296	ELEC-COAL-PFC1-BASE	41	53	0	0	0	0	0	0	0	0	1	8331.94484
297	ELEC-COAL-PFC2-SP	42	50	0	0	0	0	0	0	0	0	1	364322.189

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
265	0	0	0	0	0	0	0	0	0.001	TJ/yr	448.02	26.29	1.05	31848	40000	0.72
266	0	0	0	0	0	0	0	0	0.001	TJ/yr	648.53	26.36	13.09	32562	40000	0.85
267	0	0	0	0	0	0	0	0	1	PJ/yr						
268	0	0	0	0	0	0	0	0	1	PJ/yr						
269	0	0	0	0	0	0	0	0	1	PJ/yr						
270	0	0	0	0	0	0	0	0	1	PJ/yr						
271	0	0	0	0	0	0	0	0	0.001	TJ/yr						
272	0	0	0	0	0	0	0	0	0.001	TJ/yr						
273	0	0	0	0	0	0	0	0	0.001	TJ/yr						
274	0	0	0	1	0.34	0	0	0	1	PJ/yr						
275	0	0	0	1	0.3504	0	0	0	1	PJ/yr						
276	0	0	0	1	0.3545	0	0	0	1	PJ/yr						
277	0	0	0	1	0.3641	0	0	0	1	PJ/yr						
278	0	0	0	1	0.35	0	0	0	1	PJ/yr						
279	0	0	0	1	0.3494	0	0	0	1	PJ/yr						
280	0	0	0	1	0.2435	0	0	0	1	PJ/yr						
281	0	0	0	0	0	0	0	0	1	PJ/yr						
282	0	0	0	0	0	0	0	0	1	PJ/yr						
283	0	0	0	0	0	0	0	0	0.0036	GWh/yr	497	11	0.6	0.03	577.2100	7
284	0	0	0	0	0	0	0	0	0.0036	GWh/yr	497	11	0.6	0.03	577.2100	7
285	0	0	0	0	0	0	0	0	0.0036	GWh/yr	555	11	0.6	0.03	644.5705	8
286	0	0	0	0	0	0	0	0	0.0036	GWh/yr	555	11	0.6	0.03	644.5705	8
287	0	0	0	0	0	0	0	0	0.0036	GWh/yr	788	5	0.6	0.03	842.7647	2
288	0	0	0	0	0	0	0	0	0.0036	GWh/yr	788	5	0.6	0.03	842.7647	2
289	0	0	0	0	0	0	0	0	0.0036	GWh/yr	944	11	0.6	0.03	1096.350	13
290	0	0	0	0	0	0	0	0	0.0036	GWh/yr	944	11	0.6	0.03	1096.350	13
291	0	0	0	0	0	0	0	0	0.0036	GWh/yr	944	11	0.6	0.03	1096.350	13
292	0	0	0	0	0	0	0	0	0.0036	GWh/yr	944	11	0.6	0.03	1096.350	13
293	0	0	0	0	0	0	0	0	0.0036	GWh/yr	983	11	0.6	0.03	1141.644	9
294	0	0	0	0	0	0	0	0	0.0036	GWh/yr	983	11	0.6	0.03	1141.644	9
295	0	0	0	0	0	0	0	0	0.0036	GWh/yr	983	11	0.6	0.03	1141.644	9
296	0	0	0	0	0	0	0	0	0.0036	GWh/yr	983	11	0.6	0.03	1141.644	9
297	0	0	0	0	0	0	0	0	0.0036	GWh/yr	899	11	0.6	0.03	1044.088	11

	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
265	1.18	3	0.6	0.08	692.2908	31.70057	112.8	114.1	0.08	30	0.9
266	1.04	3	0.6	0.08	892.8019	16.30120	112.8	114.1	0.08	30	0.9
267											
268											
269											
270											
271											
272											
273											
274											
275											
276											
277											
278											
279											
280											
281											
282											
283	40	0.8	0.03								
284	40	0.8	0.03								
285	40	0.8	0.03								
286	40	0.8	0.03								
287	30	0.8	0.03								
288	30	0.8	0.03								
289	40	0.8	0.03								
290	40	0.8	0.03								
291	40	0.8	0.03								
292	40	0.8	0.03								
293	40	0.8	0.03								
294	40	0.8	0.03								
295	40	0.8	0.03								
296	40	0.8	0.03								
297	40	0.8	0.03								

	A	B	C	D	E	F	G	H	I	J	K	L	M
298	ELEC-COAL-PFC2-DP	42	51	0	0	0	0	0	0	0	0	1	35153.8954
299	ELEC-COAL-PFC2-CYC	42	52	0	0	0	0	0	0	0	0	1	11700.8586
300	ELEC-COAL-PFC2-BASE	42	53	0	0	0	0	0	0	0	0	1	8015.08815
301	ELEC-COAL-AFBC-SP	43	50	0	0	0	0	0	0	0	0	1	561105.183
302	ELEC-COAL-AFBC-DP	43	51	0	0	0	0	0	0	0	0	1	54141.7282
303	ELEC-COAL-AFBC-CYC	43	52	0	0	0	0	0	0	0	0	1	18020.8964
304	ELEC-COAL-AFBC-BASE	43	53	0	0	0	0	0	0	0	0	1	12344.3140
305	ELEC-LGTE-ELEC-SP	44	50	0	0	0	0	0	0	0	0	1	720107.822
306	ELEC-LGTE-ELEC-DP	44	51	0	0	0	0	0	0	0	0	1	69484.0881
307	ELEC-LGTE-ELEC-CYC	44	52	0	0	0	0	0	0	0	0	1	23127.5504
308	ELEC-LGTE-ELEC-BASE	44	53	0	0	0	0	0	0	0	0	1	15842.3720
309	ELEC-URAN-NWDL-BASE	45	53	0	0	0	0	0	0	0	0	1	14171.4381
310	ELEC-URAN-EXDL-BASE	46	53	0	0	0	0	0	0	0	0	1	2954.60650
311	ELEC-NWHY(>10MW)-SP	146	147	0	0	0	0	0	0	0	0	0	0
312	ELEC-NWHY(>10MW)-DP	146	148	0	0	0	0	0	0	0	0	0	0
313	ELEC-NWHY(>10 MW)-PEAK U.-SP-E.T.P	147	149	2131	0.5	0	0	0	0	0	0	0	0
314	ELEC-NWHY(>10 MW)-PEAK U.-DP-E.T.P	148	149	2131	0.5	0	0	0	0	0	0	0	0
315	ELEC-NWHY(>10MW)-PEAK U!-POWER	149	1000	0	0	0	0	111	1.723	0	0	0	0
316	ELEC-NWHY(>10MW)-SP	147	50	0	0	0	0	0	0	0	0	1	1523288.44
317	ELEC-NWHY(>10MW)-DP	148	51	0	0	0	0	0	0	0	0	1	146983.972
318	ELEC-NWHY(>10 MW)-SP	47	131	0	0	0	0	0	0	0	0	1	1200706.16
319	ELEC-NWHY(>10 MW)-DP	47	132	0	0	0	0	0	0	0	0	1	115857.612
320	ELEC-NWHY(>10 MW)-CYC	47	133	0	0	0	0	0	0	0	0	1	38562.8258
321	ELEC-NWHY(>10 MW)-BASE	47	134	0	0	0	0	0	0	0	0	1	26415.5357
322	ELEC-NWHY(>10 MW)-SP-ENGY TO PWR	131	135	2131	0.5	0	0	0	0	0	0	0	0
323	ELEC-NWHY(>10 MW)-DP-ENGY TO PWR	132	135	2131	0.5	0	0	0	0	0	0	0	0
324	ELEC-NWHY(>10 MW)-CY-ENGY TO PWR	133	135	2131	0.5	0	0	0	0	0	0	0	0
325	ELEC-NWHY(>10 MW)-BS-ENGY TO PWR	134	135	2131	0.5	0	0	0	0	0	0	0	0
326	ELEC-NWHY(>10 MW)-POWER	135	1000	0	0	0	0	111	1.904	0	0	0	0
327	ELEC-NWHY(>10 MW)-SP	131	50	0	0	0	0	0	0	0	0	0	0
328	ELEC-NWHY(>10 MW)-DP	132	51	0	0	0	0	0	0	0	0	0	0
329	ELEC-NWHY(>10 MW)-CYC	133	52	0	0	0	0	0	0	0	0	0	0
330	ELEC-NWHY(>10 MW)-BASE	134	53	0	0	0	0	0	0	0	0	0	0

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
298	0	0	0	0	0	0	0	0	0.0036	GWh/yr	899	11	0.6	0.03	1044.088	11
299	0	0	0	0	0	0	0	0	0.0036	GWh/yr	899	11	0.6	0.03	1044.088	11
300	0	0	0	0	0	0	0	0	0.0036	GWh/yr	899	11	0.6	0.03	1044.088	11
301	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1264	11	0.6	0.03	1467.994	23
302	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1264	11	0.6	0.03	1467.994	23
303	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1264	11	0.6	0.03	1467.994	23
304	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1264	11	0.6	0.03	1467.994	23
305	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1732	11	0.6	0.03	2011.524	24
306	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1732	11	0.6	0.03	2011.524	24
307	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1732	11	0.6	0.03	2011.524	24
308	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1732	11	0.6	0.03	2011.524	24
309	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1594	14	0.6	0.03	1930.557	22
310	0	0	0	0	0	0	0	0	0.0036	GWh/yr	0	14	0.6	0.03	0	22
311	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
312	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
313	0	0	0	1	1.80175	0	0	0	1	PJ/yr						
314	0	0	0	1	0.17385	0	0	0	1	PJ/yr						
315	0	0	0	0	0	0	0	0	1	GW						
316	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1640	8	0.6	0.03	1827.327	70
317	0	0	0	0	0	0	0	0	0.0036	GWh/yr	1640	8	0.6	0.03	1827.327	70
318	0	0	0	0	0	0	0	0	0.0036	GWh/yr	2638	8	0.6	0.03	2939.322	70
319	0	0	0	0	0	0	0	0	0.0036	GWh/yr	2638	8	0.6	0.03	2939.322	70
320	0	0	0	0	0	0	0	0	0.0036	GWh/yr	2638	8	0.6	0.03	2939.322	70
321	0	0	0	0	0	0	0	0	0.0036	GWh/yr	2638	8	0.6	0.03	2939.322	70
322	0	0	0	1	1.80175	0	0	0	1	PJ/yr						
323	0	0	0	1	0.17385	0	0	0	1	PJ/yr						
324	0	0	0	1	0.05786	0	0	0	1	PJ/yr						
325	0	0	0	1	0.03964	0	0	0	1	PJ/yr						
326	0	0	0	0	0	0	0	0	1	GW						
327	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
328	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
329	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
330	0	0	0	0	0	0	0	0	0.0036	GWh/yr						

	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
298	40	0.8	0.03								
299	40	0.8	0.03								
300	40	0.8	0.03								
301	40	0.8	0.03								
302	40	0.8	0.03								
303	40	0.8	0.03								
304	40	0.8	0.03								
305	40	0.8	0.03								
306	40	0.8	0.03								
307	40	0.8	0.03								
308	40	0.8	0.03								
309	40	0.85	0.03								
310	40	0.85	0.03								
311											
312											
313											
314											
315											
316	0.03	62.74424	1.261	1.751	1962.15						
317	0.03	62.74424	1.261	1.751	1962.15						
318	0.03	100.9264	3.186	3.491	4073.49						
319	0.03	100.9264	3.186	3.491	4073.49						
320	0.03	100.9264	3.186	3.491	4073.49						
321	0.03	100.9264	3.186	3.491	4073.49						
322											
323											
324											
325											
326											
327											
328											
329											
330											

	A	B	C	D	E	F	G	H	I	J	K	L	M
331	ELEC-NWHY(2-10 MW)-SP	105	136	0	0	0	0	0	0	0	0	1	1323518.63
332	ELEC-NWHY(2-10 MW)-DP	105	137	0	0	0	0	0	0	0	0	1	127707.938
333	ELEC-NWHY(2-10 MW)-CYC	105	138	0	0	0	0	0	0	0	0	1	42507.1678
334	ELEC-NWHY(2-10 MW)-BASE	105	139	0	0	0	0	0	0	0	0	1	29117.4099
335	ELEC-NWHY(2-10 MW)-SP-ENGY TO PWR	136	140	2131	0.5	0	0	0	0	0	0	0	0
336	ELEC-NWHY(2-10 MW)-DP-ENGY TO PWR	137	140	2131	0.5	0	0	0	0	0	0	0	0
337	ELEC-NWHY(2-10 MW)-CY-ENGY TO PWR	138	140	2131	0.5	0	0	0	0	0	0	0	0
338	ELEC-NWHY(2-10 MW)-BS-ENGY TO PWR	139	140	2131	0.5	0	0	0	0	0	0	0	0
339	ELEC-NWHY(2-10 MW)-POWER	140	1000	0	0	0	0	111	1.234	0	0	0	0
340	ELEC-NWHY(2-10 MW)-SP	136	50	0	0	0	0	0	0	0	0	0	0
341	ELEC-NWHY(2-10 MW)-DP	137	51	0	0	0	0	0	0	0	0	0	0
342	ELEC-NWHY(2-10 MW)-CYC	138	52	0	0	0	0	0	0	0	0	0	0
343	ELEC-NWHY(2-10 MW)-BASE	139	53	0	0	0	0	0	0	0	0	0	0
344	ELEC-EX.HYDRO-PEAK U.-SP	150	151	0	0	0	0	0	0	0	0	0	0
345	ELEC-EX.HYDRO-PEAK U.-DP	150	152	0	0	0	0	0	0	0	0	0	0
346	ELEC-EX.HYDRO-PEAK U.-SP-E.T.PWR	151	153	2131	0.5	0	0	0	0	0	0	0	0
347	ELEC-EX.HYDRO-PEAK U.-DP-E.T.PWR	152	153	2131	0.5	0	0	0	0	0	0	0	0
348	ELEC-EX.HYDRO-PEAK U.-POWER	153	1000	0	0	0	0	111	0.967	0	0	0	0
349	ELEC-EX.HYDRO-PEAK U.-SP	151	50	0	0	0	0	0	0	0	0	1	90293.1668
350	ELEC-EX.HYDRO-PEAK U.-DP	152	51	0	0	0	0	0	0	0	0	1	8712.49855
351	ELEC-EXHY-SP	48	141	0	0	0	0	0	0	0	0	1	4331.86457
352	ELEC-EXHY-DP	48	142	0	0	0	0	0	0	0	0	1	417.986932
353	ELEC-EXHY-CYC	48	143	0	0	0	0	0	0	0	0	1	308.413506
354	ELEC-EXHY-BASE	48	144	0	0	0	0	0	0	0	0	1	211.263251
355	ELEC-EXHY-SP-ENGY TO POWER	141	145	2131	0.5	0	0	0	0	0	0	0	0
356	ELEC-EXHY-DP-ENGY TO POWER	142	145	2131	0.5	0	0	0	0	0	0	0	0
357	ELEC-EXHY-CYC-ENGY TO POWER	143	145	2131	0.5	0	0	0	0	0	0	0	0
358	ELEC-EXHY-BASE-ENGY TO POWER	144	145	2131	0.5	0	0	0	0	0	0	0	0
359	ELEC-EXHY-POWER	145	1000	0	0	0	0	111	4.687	0	0	0	0
360	ELEC-EXHY-SP	141	50	0	0	0	0	0	0	0	0	0	0
361	ELEC-EXHY-DP	142	51	0	0	0	0	0	0	0	0	0	0
362	ELEC-EXHY-CYC	143	52	0	0	0	0	0	0	0	0	0	0
363	ELEC-EXHY-BASE	144	53	0	0	0	0	0	0	0	0	0	0

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
331	0	0	0	0	0	0	0	0	0.0036	GWh/yr	427.7	5	0.6	0.03	457.4244	70
332	0	0	0	0	0	0	0	0	0.0036	GWh/yr	427.7	5	0.6	0.03	457.4244	70
333	0	0	0	0	0	0	0	0	0.0036	GWh/yr	427.7	5	0.6	0.03	457.4244	70
334	0	0	0	0	0	0	0	0	0.0036	GWh/yr	427.7	5	0.6	0.03	457.4244	70
335	0	0	0	1	1.80175	0	0	0	1	PJ/yr						
336	0	0	0	1	0.17385	0	0	0	1	PJ/yr						
337	0	0	0	1	0.05786	0	0	0	1	PJ/yr						
338	0	0	0	1	0.03964	0	0	0	1	PJ/yr						
339	0	0	0	0	0	0	0	0	1	GW						
340	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
341	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
342	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
343	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
344	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
345	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
346	0	0	0	1	1.80175	0	0	0	1	PJ/yr						
347	0	0	0	1	0.17385	0	0	0	1	PJ/yr						
348	0	0	0	0	0	0	0	0	1	GW						
349	0	0	0	0	0	0	0	0	0.0036	GWh/yr	0	8	0.6	0.03	0	70
350	0	0	0	0	0	0	0	0	0.0036	GWh/yr	0	8	0.6	0.03	0	70
351	0	0	0	0	0	0	0	0	0.0036	GWh/yr	0	8	0.6	0.03	0	70
352	0	0	0	0	0	0	0	0	0.0036	GWh/yr	0	8	0.6	0.03	0	70
353	0	0	0	0	0	0	0	0	0.0036	GWh/yr	0	8	0.6	0.03	0	70
354	0	0	0	0	0	0	0	0	0.0036	GWh/yr	0	8	0.6	0.03	0	70
355	0	0	0	1	1.80175	0	0	0	1	PJ/yr						
356	0	0	0	1	0.17385	0	0	0	1	PJ/yr						
357	0	0	0	1	0.05786	0	0	0	1	PJ/yr						
358	0	0	0	1	0.03964	0	0	0	1	PJ/yr						
359	0	0	0	0	0	0	0	0	1	GW						
360	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
361	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
362	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
363	0	0	0	0	0	0	0	0	0.0036	GWh/yr						

	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
331	0.03	15.70641	2.032	0.55	628.092						
332	0.03	15.70641	2.032	0.55	628.092						
333	0.03	15.70641	2.032	0.55	628.092						
334	0.03	15.70641	2.032	0.55	628.092						
335											
336											
337											
338											
339											
340											
341											
342											
343											
344											
345											
346											
347											
348											
349	0.03	0	1.261	1.751	1516.273						
350	0.03	0	1.261	1.751	1516.273						
351	0.03	0	1.261	1.751	31605.11						
352	0.03	0	1.261	1.751	31605.11						
353	0.03	0	3.186	3.491	31605.11						
354	0.03	0	3.186	3.491	31605.11						
355											
356											
357											
358											
359											
360											
361											
362											
363											

	A	B	C	D	E	F	G	H	I	J	K	L	M
364	ELEC-MUNREFUSE-CYC	49	128	0	0	0	0	0	0	0	0	1	17000
365	ELEC-MUNREFUSE-BASE	49	129	0	0	0	0	0	0	0	0	1	8000
366	ELEC-MUNREFUSE-CYC-ENGY TO POWER	128	130	2131	0.5	0	0	0	0	0	0	0	0
367	ELEC-MUNREFUSE-BASE-ENGY TO POWER	129	130	2131	0.5	0	0	0	0	0	0	0	0
368	ELEC-MUNREFUSE-POWER	130	1000	0	0	0	0	111	0.2	0	0	0	0
369	ELEC-MUNREFUSE-CYC	128	52	0	0	0	0	0	0	0	0	0	0
370	ELEC-MUNREFUSE-BASE	129	53	0	0	0	0	0	0	0	0	0	0
371	ELEC-TOTALSP	50	54	1131	0.007	0	0	0	0	0	0	0	0
372	ELEC-TOTALDP	51	54	1131	0.0383	0	0	0	0	0	0	0	0
373	ELEC-TOTALCYC	52	54	1131	0.1832	0	0	0	0	0	0	0	0
374	ELEC-TOTALBASE	53	54	0	0	0	0	0	0	0	0	0	0
375	ELEC-TOTAL	54	126	0	0	0	0	0	0	0	0	0	0
376	ELEC-EXPORTS-TRAN.	126	127	0	0	0	0	0	0	0	0	1	2835600
377	ELEC-EXPORT	127	1000	0	0	0	0	111	50	0	0	1	-12591666.
378	ELEC-IMPORT	0	154	0	0	0	0	111	0.01	0	0	1	17002777.7
379	ELEC-IMPORTS-TRAN.	154	126	0	0	0	0	0	0	0	0	1	2835600
380	GAS-TRAN&DIST	1	106	0	0	0	0	0	0	0	0	1	1890000
381	PROPANE-TRAN&DIST	2	107	0	0	0	0	0	0	0	0	1	3785000
382	METHANOL-TRAN&DIST	23	108	0	0	0	0	0	0	0	0	1	5354000
383	ETHANOL-TRAN&DIST	24	109	0	0	0	0	0	0	0	0	1	4176000
384	GASOLINE-TRAN&DIST	27	110	0	0	0	0	0	0	0	0	1	2520000
385	DIESEL-TRAN&DIST	28	111	0	0	0	0	0	0	0	0	1	2495000
386	AV.GAS-TRAN&DIST	29	112	0	0	0	0	0	0	0	0	1	2890000
387	JET FUEL-TRAN&DIST	30	113	0	0	0	0	0	0	0	0	1	2697000
388	LFO-TRAN&DIST	31	114	0	0	0	0	0	0	0	0	1	2495000
389	HFO-TRAN&DIST	32	115	0	0	0	0	0	0	0	0	1	2324000
390	PCF&PP-TRAN&DIST	33	116	0	0	0	0	0	0	0	0	1	2287000
391	ELEC-TRAN&DIST	126	117	0	0	0	0	0	0	0	0	1	5671200
392	WOOD-TRAN&DIST	5	118	0	0	0	0	0	0	0	0	1	2350000
393	LHYGN-TRAN&DIST	56	119	0	0	0	0	0	0	0	0	1	57632000
394	LNG-TRAN&DIST	26	120	0	0	0	0	0	0	0	0	1	4746000
395	ELEC-HTP-R2SH-SH&AC	117	57	0	0	0	0	0	0	0	0	1	68706.9921
396	GAS-FCE+HTP-R2SH-SH	106	58	0	0	0	0	0	0	0	0	1	39343.2642

	N	D	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
364	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
365	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
366	0	0	0	1	0.07122	0	0	0	1	PJ/yr						
367	0	0	0	1	0.04878	0	0	0	1	PJ/yr						
368	0	0	0	0	0	0	0	0	1	GW						
369	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
370	0	0	0	0	0	0	0	0	0.0036	GWh/yr						
371	0	0	0	0	0	0	0	0	1	PJ/yr						
372	0	0	0	0	0	0	0	0	1	PJ/yr						
373	0	0	0	0	0	0	0	0	1	PJ/yr						
374	0	0	0	0	0	0	0	0	1	PJ/yr						
375	0	0	0	0	0	0	0	0	1	PJ/yr						
376	0	0	0	0	0	0	0	0	1	PJ/yr						
377	0	0	0	0	0	0	0	0	1	PJ/yr						
378	0	0	0	0	0	0	0	0	1	PJ/yr						
379	0	0	0	0	0	0	0	0	1	PJ/yr						
380	0	0	0	0	0	0	0	0	1	PJ/yr						
381	0	0	0	0	0	0	0	0	1	PJ/yr						
382	0	0	0	0	0	0	0	0	1	PJ/yr						
383	0	0	0	0	0	0	0	0	1	PJ/yr						
384	0	0	0	0	0	0	0	0	1	PJ/yr						
385	0	0	0	0	0	0	0	0	1	PJ/yr						
386	0	0	0	0	0	0	0	0	1	PJ/yr						
387	0	0	0	0	0	0	0	0	1	PJ/yr						
388	0	0	0	0	0	0	0	0	1	PJ/yr						
389	0	0	0	0	0	0	0	0	1	PJ/yr						
390	0	0	0	0	0	0	0	0	1	PJ/yr						
391	0	0	0	0	0	0	0	0	1	PJ/yr						
392	0	0	0	0	0	0	0	0	1	PJ/yr						
393	0	0	0	0	0	0	0	0	1	PJ/yr						
394	0	0	0	0	0	0	0	0	1	PJ/yr						
395	0	0	0	0	0	0	0	0	0.001	TJ/yr	3100	70	20	4	0.08	
396	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	1107	35	20	4	0.08	

	A	B	C	D	E	F	G	H	I	J	K	L	M
397	LOIL-FCE+HTP-R2SH-SH	114	58	0	0	0	0	0	0	0	0	1	41142.2988
398	ELEC-RES+HTP-R2SH-SH	117	58	0	0	0	0	0	0	0	0	1	25438.5951
399	HT-ENERGY-HTP-R2SH-SH	57	58	1131	0.7	2131	0.8448	0	0	0	0	0	0
400	ENERGY-OPTS+HTP-R2SH-SH	58	61	0	0	0	0	0	0	0	0	0	0
401	GAS-WCBFCE-R2SH-SH	106	59	0	0	0	0	0	0	0	0	0	0
402	LOIL-WCBFCE-R2SH-SH	114	59	0	0	0	0	0	0	0	0	0	0
403	ELEC-WDFCE+RES-R2SH-SH	117	59	0	0	0	0	0	0	0	0	0	0
404	WOOD-OPTS+WDFCE-R2SH-SH	118	59	1131	0.9	0	0	0	0	0	0	1	19352.4735
405	ENERGY-OPTS+WDFCE-R2SH-SH	59	61	0	0	0	0	0	0	0	0	0	0
406	ELEC-ASR-R2SH-SH&WH&AC	117	60	1131	0.0909	0	0	0	0	0	0	0	0
407	ASR-R2SH-SH&WH&AC	0	60	0	0	0	0	0	0	0	0	0	0
408	HT ENERGY-ASR-R2SH-SH	60	61	0	0	0	0	0	0	0	0	1	37654.4399
409	GAS-CGF-R2SH-SH	106	61	0	0	0	0	0	0	0	0	1	16817.0817
410	GAS-FCE-R2SH-SH	106	61	0	0	0	0	0	0	0	0	1	11802.9792
411	LOIL-FCE-R2SH-SH	114	61	0	0	0	0	0	0	0	0	1	12342.6896
412	ELEC-RES-R2SH-SH	117	61	0	0	0	0	0	0	0	0	1	7631.57853
413	ELEC-HTP-ISH-SH&AC	117	62	0	0	0	0	0	0	0	0	1	30734.0736
414	GAS-FCE+HTP-ISH-SH	106	63	0	0	0	0	0	0	0	0	1	18550.7212
415	LOIL-FCE+HTP-ISH-SH	114	63	0	0	0	0	0	0	0	0	1	18934.6477
416	ELEC-RES+HTP-ISH-SH	117	63	0	0	0	0	0	0	0	0	1	12427.5881
417	HT-ENERGY-ISH-SH	62	63	1131	0.7	2131	0.8448	0	0	0	0	0	0
418	ENERGY-OPTS+HTP-ISH-SH	63	67	0	0	0	0	0	0	0	0	0	0
419	GAS-WCBFCE-ISH-SH	106	64	0	0	0	0	0	0	0	0	0	0
420	LOIL-WCBFCE-ISH-SH	114	64	0	0	0	0	0	0	0	0	0	0
421	ELEC-WDFCE+RES-ISH-SH	117	64	0	0	0	0	0	0	0	0	0	0
422	WOOD-WCBFCE+OPTS-ISH-SH	118	64	1131	0.9	0	0	0	0	0	0	1	8527.38209
423	ENERGY-WCBFCE+OPTS-ISH-SH	64	67	0	0	0	0	0	0	0	0	0	0
424	GAS-FCE+ASR-ISH-SH	106	66	0	0	0	0	0	0	0	0	1	5565.21636
425	LOIL-FCE+ASR-ISH-SH	114	66	0	0	0	0	0	0	0	0	1	5680.39431
426	ELEC-RES+ASR-ISH-SH	117	66	0	0	0	0	0	0	0	0	1	3728.27644
427	ELEC-ASR-ISH-SH&WH&AC	117	65	1131	0.0909	0	0	0	0	0	0	0	0
428	ASR-ISH-SH&WH&AC	0	65	0	0	0	0	0	0	0	0	0	0
429	HT ENERGY-ASR-ISH-SH	65	66	1131	0.92	0	0	0	0	0	0	1	18642.0348

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
397	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	933	60	20	4	0.08	
398	0	0	0	0	0	0	0	0	0.001	TJ/yr	933	0	20	4	0.08	
399	0	0	0	1	1.9	0	0	0	1	PJ/yr						
400	0	0	0	0	0	0	0	0	1	PJ/yr						
401	0	0	0	1	0.65	0	0	0	1	PJ/yr	0	0	20	4	0.08	
402	0	0	0	1	0.65	0	0	0	1	PJ/yr	0	0	20	4	0.08	
403	0	0	0	0	0	0	0	0	1	PJ/yr	0	0	20	4	0.08	
404	0	0	0	1	0.6	0	0	0	0.001	TJ/yr	1550	85	20	4	0.08	
405	0	0	0	0	0	0	0	0	1	PJ/yr						
406	0	0	0	0	0	0	0	0	1	PJ/yr						
407	0	0	0	0	0	0	0	0	1	PJ/yr						
408	0	0	0	0	0	0	0	0	0.001	TJ/yr	5400	60	20	27	0.08	
409	0	0	0	1	0.92	0	0	0	0.001	TJ/yr	1720	35	20	4	0.08	
410	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	1107	35	20	4	0.08	
411	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	933	60	20	4	0.08	
412	0	0	0	0	0	0	0	0	0.001	TJ/yr	933	0	20	4	0.08	
413	0	0	0	0	0	0	0	0	0.001	TJ/yr	3400	70	20	4	0.08	
414	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	1306	35	20	6	0.08	
415	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	1100	60	20	6	0.08	
416	0	0	0	0	0	0	0	0	0.001	TJ/yr	1100	0	20	6	0.08	
417	0	0	0	1	1.9	0	0	0	1	PJ/yr						
418	0	0	0	0	0	0	0	0	1	PJ/yr						
419	0	0	0	1	0.65	0	0	0	1	PJ/yr	0	0	20	6	0.08	
420	0	0	0	1	0.65	0	0	0	1	PJ/yr	0	0	20	6	0.08	
421	0	0	0	0	0	0	0	0	1	PJ/yr	0	0	20	6	0.08	
422	0	0	0	1	0.6	0	0	0	0.001	TJ/yr	1700	85	20	6	0.08	
423	0	0	0	0	0	0	0	0	1	PJ/yr						
424	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	1306	35	20	6	0.08	
425	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	1100	60	20	6	0.08	
426	0	0	0	0	0	0	0	0	0.001	TJ/yr	1100	0	20	6	0.08	
427	0	0	0	0	0	0	0	0	1	PJ/yr						
428	0	0	0	0	0	0	0	0	1	PJ/yr						
429	0	0	0	0	0	0	0	0	0.001	TJ/yr	6000	60	20	27	0.08	

	A	B	C	D	E	F	G	H	I	J	K	L	M
430	ENERGY-ASR+OPTS-ISH-SH	66	67	0	0	0	0	0	0	0	0	0	0
431	GAS-CGF-ISH-SH	106	67	0	0	0	0	0	0	0	0	1	7849.63302
432	GAS-FCE-ISH-SH	106	67	0	0	0	0	0	0	0	0	1	5565.21636
433	LOIL-FCE-ISH-SH	114	67	0	0	0	0	0	0	0	0	1	5680.39431
434	ELEC-RES-ISH-SH	117	67	0	0	0	0	0	0	0	0	1	3728.27644
435	ELEC-HTP-OBC80-SH&AC	117	68	0	0	0	0	0	0	0	0	1	17337.3302
436	GAS-FCE+HTP-OBC80-SH	106	69	0	0	0	0	0	0	0	0	1	3189.29269
437	LOIL-FCE+HTP-OBC80-SH	114	69	0	0	0	0	0	0	0	0	1	3207.06890
438	ELEC-RES+HTP-OBC80-SH	117	69	0	0	0	0	0	0	0	0	1	2181.42788
439	HT ENERGY-HTP-OBC80-SH	68	69	1131	0.7	2131	0.8448	0	0	0	0	0	0
440	ENERGY-OPTS+HTP-OBC80-SH	69	73	0	0	0	0	0	0	0	0	0	0
441	GAS-WCBFCE-OBC80-SH	106	70	0	0	0	0	0	0	0	0	0	0
442	LOIL-WCBFCE-OBC80-SH	114	70	0	0	0	0	0	0	0	0	0	0
443	ELEC-WDFCE+RES-OBC80-SH	117	70	0	0	0	0	0	0	0	0	0	0
444	WOOD-WCBFCE-OBC80-SH	118	70	1131	0.9	0	0	0	0	0	0	1	4884.51106
445	ENERGY-WCBFCE+OPTS-OBC80-SH	70	73	0	0	0	0	0	0	0	0	0	0
446	GAS-FCE+ASR-OBC80-SH	106	72	0	0	0	0	0	0	0	0	1	3189.29269
447	LOIL-FCE+ASR-OBC80-SH	114	72	0	0	0	0	0	0	0	0	1	3207.06890
448	ELEC-RES+ASR-OBC80-SH	117	72	0	0	0	0	0	0	0	0	1	2181.42788
449	ELEC-ASR-OBC80-SH&WH&AC	117	71	1131	0.0909	0	0	0	0	0	0	0	0
450	ASR-OBC80-SH&WH&AC	0	71	0	0	0	0	0	0	0	0	0	0
451	HT ENERGY-ASR-OBC80-SH	71	72	1131	0.48	0	0	0	0	0	0	1	18642.0348
452	ENERGY-ASR+OPTS-OBC80-SH	72	73	0	0	0	0	0	0	0	0	0	0
453	GAS-CGF-OBC80-SH	106	73	0	0	0	0	0	0	0	0	1	4471.43806
454	GAS-FCE-OBC80-SH	106	73	0	0	0	0	0	0	0	0	1	3189.29269
455	LOIL-FCE-OBC80-SH	114	73	0	0	0	0	0	0	0	0	1	3207.06890
456	ELEC-RES-OBC80-SH	117	73	0	0	0	0	0	0	0	0	1	2181.42788
457	GAS-CGB-APT-SH	106	74	0	0	0	0	0	0	0	0	1	8450.50782
458	GAS-IGB-APT-SH	106	74	0	0	0	0	0	0	0	0	1	6428.99666
459	LOIL-BLR-APT-SH	114	74	0	0	0	0	0	0	0	0	1	5609.79326
460	ELEC-BLR-APT-SH	117	74	0	0	0	0	0	0	0	0	1	5083.25731
461	ELEC-BSD-APT-SH	117	74	0	0	0	0	0	0	0	0	1	6523.86697
462	ENERGY-R2SH-SH	61	75	0	0	0	0	121	16.10394	0	0	1	28997451.9

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
430	0	0	0	0	0	0	0	0	1	PJ/yr						
431	0	0	0	1	0.92	0	0	0	0.001	TJ/yr	1980	35	20	6	0.08	
432	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	1306	35	20	6	0.08	
433	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	1100	60	20	6	0.08	
434	0	0	0	0	0	0	0	0	0.001	TJ/yr	1100	0	20	6	0.08	
435	0	0	0	0	0	0	0	0	0.001	TJ/yr	3700	70	20	6	0.08	
436	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	1455	35	20	7.5	0.08	
437	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	1225	60	20	7.5	0.08	
438	0	0	0	0	0	0	0	0	0.001	TJ/yr	1225	0	20	7.5	0.08	
439	0	0	0	1	1.9	0	0	0	1	PJ/yr						
440	0	0	0	0	0	0	0	0	1	PJ/yr						
441	0	0	0	1	0.65	0	0	0	1	PJ/yr	0	0	20	7.5	0.08	
442	0	0	0	1	0.65	0	0	0	1	PJ/yr	0	0	20	7.5	0.08	
443	0	0	0	0	0	0	0	0	1	PJ/yr	0	0	20	7.5	0.08	
444	0	0	0	1	0.6	0	0	0	0.001	TJ/yr	1927	85	20	7.5	0.08	
445	0	0	0	0	0	0	0	0	1	PJ/yr						
446	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	1455	35	20	7.5	0.08	
447	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	1225	60	20	7.5	0.08	
448	0	0	0	0	0	0	0	0	0.001	TJ/yr	1225	0	20	7.5	0.08	
449	0	0	0	0	0	0	0	0	1	PJ/yr						
450	0	0	0	0	0	0	0	0	1	PJ/yr						
451	0	0	0	0	0	0	0	0	0.001	TJ/yr	6000	60	20	27	0.08	
452	0	0	0	0	0	0	0	0	1	PJ/yr						
453	0	0	0	1	0.92	0	0	0	0.001	TJ/yr	2175	35	20	7.5	0.08	
454	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	1455	35	20	7.5	0.08	
455	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	1225	60	20	7.5	0.08	
456	0	0	0	0	0	0	0	0	0.001	TJ/yr	1225	0	20	7.5	0.08	
457	0	0	0	1	0.87	0	0	0	0.001	TJ/yr	6505	89	20	6	0.08	
458	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	4683	89	20	6	0.08	
459	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	4107	76	20	6	0.08	
460	0	0	0	0	0	0	0	0	0.001	TJ/yr	4107	38	20	6	0.08	
461	0	0	0	0	0	0	0	0	0.001	TJ/yr	980	0	20	1	0.08	
462	0	0	0	0	0	0	0	0	1	PJ/yr	5250	0	70		0.08	

	A	B	C	D	E	F	G	H	I	J	K	L	M
463	ENERGY-ISH-SH	67	75	0	0	0	0	121	43.65379	0	0	1	14498725.9
464	ENERGY-OBC80-SH	73	75	0	0	0	0	121	97.03837	0	0	0	0
465	ENERGY-NWA-SH	74	76	0	0	0	0	121	19.14687	0	0	0	0
466	ENERGY-ODA-SH	74	76	0	0	0	0	121	11.94457	0	0	0	0
467	ENERGY-H-SH	75	77	0	0	0	0	0	0	0	0	0	0
468	ENERGY-A-SH	76	77	0	0	0	0	0	0	0	0	0	0
469	ENERGY-RES-SH	77	1000	0	0	0	0	0	0	0	0	0	0
470	ENERGY-SR(WH)-R2SH	60	78	0	0	0	0	0	0	0	0	1	94459076.6
471	ENERGY-SR(WH)-ISH	65	78	0	0	0	0	0	0	0	0	1	94459076.6
472	ENERGY-SR(WH)-OBC80H	71	78	0	0	0	0	0	0	0	0	1	94459076.6
473	ENERGY-SR(WH)-HOUSES	78	79	1131	0.32	0	0	0	0	0	0	0	0
474	ENERGY-ASR+BKP-H-WH	79	80	0	0	0	0	0	0	0	0	0	0
475	GAS-WHR+ASR-H-WH	106	79	0	0	0	0	0	0	0	0	1	4554891.64
476	ELEC-WHR+ASR-H-WH	117	79	0	0	0	0	0	0	0	0	1	2053043.40
477	GAS-WHR-H-WH	106	80	0	0	0	0	0	0	0	0	1	3097326.31
478	ELEC-WHR-H-WH	117	80	0	0	0	0	0	0	0	0	1	1396069.51
479	GAS-BLR-A-WH	106	81	0	0	0	0	0	0	0	0	1	1720736.84
480	ELEC-BLR-A-WH	117	81	0	0	0	0	0	0	0	0	1	1396069.51
481	ENERGY-H-WH	80	82	1131	0.61	0	0	0	0	0	0	0	0
482	ENERGY-A-WH	81	82	0	0	0	0	0	0	0	0	0	0
483	ENERGY-RES-WH	82	1000	0	0	0	0	121	114.2383	0	0	0	0
484	ELEC-IWAC-AC	117	86	0	0	0	0	121	5.312729	0	0	1	841081.634
485	ENERGY-HTR(CAC)-R2SH	57	83	1131	0.13	0	0	0	0	0	0	0	0
486	ENERGY-HTP(CAC)-ISH	62	83	1131	0.3	0	0	0	0	0	0	0	0
487	ENERGY-HTP(CAC)-OBC80	68	83	0	0	0	0	0	0	0	0	0	0
488	ENERGY-HTP(CAC)-HOUSES	83	85	0	0	0	0	0	0	0	0	0	0
489	ENERGY-ASR(CAC)-R2SH	60	84	1131	0.13	0	0	0	0	0	0	1	18924336.7
490	ENERGY-ASR(CAC)-ISH	65	84	1131	0.3	0	0	0	0	0	0	1	18924336.7
491	ENERGY-ASR(CAC)-OBC80	71	84	0	0	0	0	0	0	0	0	1	18924336.7
492	ENERGY-ASR(CAC)-HOUSES	84	85	0	0	0	0	0	0	0	0	0	0
493	ELEC-CAC-AC-HOUSES	117	85	0	0	0	0	0	0	0	0	1	10250682.4
494	ELEC-CAC-AC (APT)	117	85	1131	0.3137	0	0	0	0	0	0	0	0
495	ENERGY-CAC-RES	85	86	0	0	0	0	121	21.54525	0	0	0	0

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
463	0	0	0	0	0	0	0	0	1	PJ/yr	2625	0	70		0.08	
464	0	0	0	0	0	0	0	0	1	PJ/yr						
465	0	0	0	0	0	0	0	0	1	PJ/yr						
466	0	0	0	0	0	0	0	0	1	PJ/yr						
467	0	0	0	0	0	0	0	0	1	PJ/yr						
468	0	0	0	0	0	0	0	0	1	PJ/yr						
469	0	0	0	0	0	0	0	0	1	PJ/yr						
470	0	0	0	0	0	0	0	0	1	PJ/yr	3000	60	20	27	0.08	
471	0	0	0	0	0	0	0	0	1	PJ/yr	3000	60	20	27	0.08	
472	0	0	0	0	0	0	0	0	1	PJ/yr	3000	60	20	27	0.08	
473	0	0	0	0	0	0	0	0	1	PJ/yr						
474	0	0	0	0	0	0	0	0	1	PJ/yr						
475	0	0	0	1	0.8	0	0	0	1	PJ/yr	477	0	20		0.08	
476	0	0	0	0	0	0	0	0	1	PJ/yr	215	0	20		0.08	
477	0	0	0	1	0.8	0	0	0	1	PJ/yr	477	0	20		0.08	
478	0	0	0	0	0	0	0	0	1	PJ/yr	215	0	20		0.08	
479	0	0	0	1	0.8	0	0	0	1	PJ/yr	265	0	20		0.08	
480	0	0	0	0	0	0	0	0	1	PJ/yr	215	0	20		0.08	
481	0	0	0	0	0	0	0	0	1	PJ/yr						
482	0	0	0	0	0	0	0	0	1	PJ/yr						
483	0	0	0	0	0	0	0	0	1	PJ/yr						
484	0	0	0	1	3	0	0	0	1	PJ/yr	400	20	0.08	114.1		
485	0	0	0	1	3	0	0	0	1	PJ/yr						
486	0	0	0	1	3	0	0	0	1	PJ/yr						
487	0	0	0	1	3	0	0	0	1	PJ/yr						
488	0	0	0	0	0	0	0	0	1	PJ/yr						
489	0	0	0	1	0.8	0	0	0	1	PJ/yr	3000	20	0.08	114.1		
490	0	0	0	1	0.8	0	0	0	1	PJ/yr	3000	20	0.08	114.1		
491	0	0	0	1	0.8	0	0	0	1	PJ/yr	3000	20	0.08	114.1		
492	0	0	0	0	0	0	0	0	1	PJ/yr						
493	0	0	0	1	3	0	0	0	1	PJ/yr	1625	20	0.08	114.1		
494	0	0	0	1	3	0	0	0	1	PJ/yr						
495	0	0	0	0	0	0	0	0	1	PJ/yr						

	A	B	C	D	E	F	G	H	I	J	K	L	M
496	ENERGY-RES-AC	86	1000	0	0	0	0	0	0	0	0	0	0
497	ELEC-RES-APP&LTG	117	1000	0	0	0	0	121	115.3790	0	0	0	0
498	GAS-CGB-C&I-SH	106	87	0	0	0	0	0	0	0	0	1	8450.50782
499	GAS-IGB-C&I-SH	106	87	0	0	0	0	0	0	0	0	1	6428.99666
500	LOIL-BLR-C&I-SH	114	87	0	0	0	0	0	0	0	0	1	5609.79326
501	ELEC-BLR-C&I-SH	117	87	0	0	0	0	0	0	0	0	1	5083.25731
502	ELEC-BSD-C&I-SH	117	87	0	0	0	0	0	0	0	0	1	6523.86697
503	ENERGY-NWBDGS-C&I-SH	87	88	0	0	0	0	121	194.1356	0	0	0	0
504	ENERGY-ODBDGS-C&I-SH	87	88	0	0	0	0	121	60.7804	0	0	0	0
505	ENERGY-C&I-SH	88	1000	0	0	0	0	0	0	0	0	0	0
506	GAS-BLR-C&I-WH	106	89	0	0	0	0	0	0	0	0	1	1720736.84
507	ELEC-BLR-C&I-WH	117	89	0	0	0	0	0	0	0	0	1	1396069.51
508	ENERGY-C&I-WH	89	1000	0	0	0	0	121	14.38795	0	0	0	0
509	ELEC-C&I-AC	117	90	0	0	0	0	0	0	0	0	0	0
510	ENERGY-C&I-AC	90	1000	0	0	0	0	121	47.45777	0	0	0	0
511	ELEC-C&I-EQPT&LTG	117	1000	0	0	0	0	121	100.7157	0	0	0	0
512	GAS-BLR-I-IH	106	91	0	0	0	0	0	0	0	0	1	749763.628
513	HOIL-BLR-I-IH	115	91	0	0	0	0	0	0	0	0	1	1025364.52
514	COAL-BLR-I-IH	3	91	0	0	0	0	0	0	0	0	1	2265237.36
515	ENERGY-I-IH	91	1000	0	0	0	0	121	572.9435	0	0	0	0
516	GAS-BR-I-DH	106	92	1131	0.08	0	0	0	0	0	0	0	0
517	HOIL-BR-I-DH	115	92	1131	0.08	0	0	0	0	0	0	0	0
518	ELEC-HD-I-DH	117	92	0	0	0	0	0	0	0	0	0	0
519	COAL-BF-I-DH	3	92	1131	0.83	0	0	0	0	0	0	0	0
520	ENERGY-I-DH	92	1000	0	0	0	0	121	544.0825	0	0	0	0
521	ELEC-EM&EL.CHMLS-I	117	1000	0	0	0	0	121	254.4040	0	0	0	0
522	GAS-I-UTL	106	93	0	0	0	0	0	0	0	0	0	0
523	ELEC-I-UTL	117	93	1131	0.35	0	0	0	0	0	0	0	0
524	LOIL-I-UTL	114	93	0	0	0	0	0	0	0	0	0	0
525	ENERGY-I-UTL	93	1000	0	0	0	0	121	151.7872	0	0	0	0
526	PROPANE-I-PPCF	107	94	0	0	0	0	0	0	0	0	0	0
527	OBPPCF-I-REF	116	94	0	0	0	0	0	0	0	0	0	0
528	ENERGY-I-PPCF	94	1000	0	0	0	0	121	436.1212	0	0	0	0

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
496	0	0	0	0	0	0	0	0	1	PJ/yr						
497	0	0	0	0	0	0	0	0	1	PJ/yr						
498	0	0	0	1	0.87	0	0	0	0.001	TJ/yr	6505	89	20	6	0.08	
499	0	0	0	1	0.8	0	0	0	0.001	TJ/yr	4683	89	20	6	0.08	
500	0	0	0	1	0.75	0	0	0	0.001	TJ/yr	4107	76	20	6	0.08	
501	0	0	0	0	0	0	0	0	0.001	TJ/yr	4107	38	20	6	0.08	
502	0	0	0	0	0	0	0	0	0.001	TJ/yr	980	0	20	1	0.08	
503	0	0	0	0	0	0	0	0	1	PJ/yr						
504	0	0	0	0	0	0	0	0	1	PJ/yr						
505	0	0	0	0	0	0	0	0	1	PJ/yr						
506	0	0	0	1	0.8	0	0	0	1	PJ/yr	265	0	20		0.08	
507	0	0	0	0	0	0	0	0	1	PJ/yr	215	0	20		0.08	
508	0	0	0	0	0	0	0	0	1	PJ/yr						
509	0	0	0	1	3	0	0	0	1	PJ/yr						
510	0	0	0	0	0	0	0	0	1	PJ/yr						
511	0	0	0	0	0	0	0	0	1	PJ/yr						
512	0	0	0	1	0.8	0	0	0	1	PJ/yr	2260	235	20	0.08		
513	0	0	0	1	0.75	0	0	0	1	PJ/yr	3200	310	20	0.08		
514	0	0	0	1	0.8	0	0	0	1	PJ/yr	7500	640	20	0.08		
515	0	0	0	0	0	0	0	0	1	PJ/yr						
516	0	0	0	0	0	0	0	0	1	PJ/yr						
517	0	0	0	0	0	0	0	0	1	PJ/yr						
518	0	0	0	0	0	0	0	0	1	PJ/yr						
519	0	0	0	1	0.87	0	0	0	1	PJ/yr						
520	0	0	0	0	0	0	0	0	1	PJ/yr						
521	0	0	0	0	0	0	0	0	1	PJ/yr						
522	0	0	0	0	0	0	0	0	1	PJ/yr						
523	0	0	0	0	0	0	0	0	1	PJ/yr						
524	0	0	0	0	0	0	0	0	1	PJ/yr						
525	0	0	0	0	0	0	0	0	1	PJ/yr						
526	0	0	0	0	0	0	0	0	1	PJ/yr						
527	0	0	0	0	0	0	0	0	1	PJ/yr						
528	0	0	0	0	0	0	0	0	1	PJ/yr						

!	A	B	C	D	E	F	G	H	I	J	K	L	M
529	PROPANE-TRN-AUTO	107	95	0	0	0	0	0	0	0	0	1	0.00348778
530	MTHL-TRN-AUTO	108	95	0	0	0	0	0	0	0	0	1	0.00348778
531	ETHL-TRN-AUTO	109	95	0	0	0	0	0	0	0	0	1	0.00348778
532	CNG-TRN-AUTO	25	95	0	0	0	0	0	0	0	0	1	0.00348778
533	LNG-TRN-AUTO	120	95	0	0	0	0	0	0	0	0	1	0.00348778
534	GASOLINE-TRN-AUTO	110	95	0	0	0	0	0	0	0	0	0	0
535	DIESEL-TRN-AUTO	111	95	0	0	0	0	0	0	0	0	0	0
536	METHGSL-TRN-AUTO	35	95	0	0	0	0	0	0	0	0	1	0.00092077
537	ETHGSL-TRN-AUTO	36	95	0	0	0	0	0	0	0	0	1	0.00092077
538	LHYGN-TRN-AUTO	119	95	0	0	0	0	0	0	0	0	1	0.03836580
539	ELEC-TRN-AUTO	117	95	1111	0.2	0	0	0	0	0	0	1	0.01028011
540	ENERGY-TRN-AUTO	95	1000	0	0	0	0	121	121083.4	0	0	0	0
541	PROPANE-TRN-LT.TKS&VANS	107	104	0	0	0	0	0	0	0	0	1	0.00487407
542	MTHL-TRN-LT.TKS&VANS	108	104	0	0	0	0	0	0	0	0	1	0.00487407
543	ETHL-TRN-LT.TKS&VANS	109	104	0	0	0	0	0	0	0	0	1	0.00487407
544	CNG-TRN-LT.TKS&VANS	25	104	0	0	0	0	0	0	0	0	1	0.00487407
545	LNG-TRN-LT.TKS&VANS	120	104	0	0	0	0	0	0	0	0	1	0.00487407
546	GASOLINE-TRN-LT.TKS&VANS	110	104	0	0	0	0	0	0	0	0	1	0
547	DIESEL-TRN-LT.TKS&VANS	111	104	0	0	0	0	0	0	0	0	1	0
548	METHGSL-TRN-LT.TKS&VANS	35	104	0	0	0	0	0	0	0	0	1	0.00128675
549	ETHGSL-TRN-LT.TKS&VANS	36	104	0	0	0	0	0	0	0	0	1	0.00128675
550	LHYGN-TRN-LT.TKS&VANS	119	104	0	0	0	0	0	0	0	0	1	0.05361498
551	ELEC-TRN-LT.TRKS&VANS	117	104	1111	0.2	0	0	0	0	0	0	1	0.01436107
552	ENERGY-TRN-LT.TKS&VANS	104	1000	0	0	0	0	121	21069.18	0	0	0	0
553	AVGAS-TRN-ACRAFT	112	96	1131	0.004	0	0	0	0	0	0	0	0
554	TJFUEL-TRN-ACRAFT	113	96	0	0	0	0	0	0	0	0	0	0
555	ENERGY-TRN-ACRAFT	96	1000	0	0	0	0	121	14.99348	0	0	0	0
556	DSL-TRN-BUS	111	97	0	0	0	0	0	0	0	0	0	0
557	PROPANE-TRN-BUS	107	97	0	0	0	0	0	0	0	0	1	1.27749106
558	CNG-TRN-BUS	25	97	0	0	0	0	0	0	0	0	1	1.27749106
559	LNG-TRN-BUS	120	97	0	0	0	0	0	0	0	0	1	1.27749106
560	MTHL-TRN-BUS	108	97	0	0	0	0	0	0	0	0	1	1.27749106
561	ETHL-TRN-BUS	109	97	0	0	0	0	0	0	0	0	1	1.27749106

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
529	0	0	0	1	386.08	0	0	0	1	PJ/yr	500	10	0.08	114.1		
530	0	0	0	1	386.08	0	0	0	1	PJ/yr	500	10	0.08	114.1		
531	0	0	0	1	386.08	0	0	0	1	PJ/yr	500	10	0.08	114.1		
532	0	0	0	1	386.08	0	0	0	1	PJ/yr	500	10	0.08	114.1		
533	0	0	0	1	386.08	0	0	0	1	PJ/yr	500	10	0.08	114.1		
534	0	0	0	1	350.98	0	0	0	1	PJ/yr	0	10	0.08	114.1		
535	0	0	0	1	386.08	0	0	0	1	PJ/yr	0	10	0.08	114.1		
536	0	0	0	1	350.98	0	0	0	1	PJ/yr	120	10	0.08	114.1		
537	0	0	0	1	350.98	0	0	0	1	PJ/yr	120	10	0.08	114.1		
538	0	0	0	1	350.98	0	0	0	1	PJ/yr	5000	10	0.08	114.1		
539	0	0	0	1	555.6	0	0	0	1	PJ/yr	1500	10	0.08	80.7		
540	0	0	0	0	0	0	0	0	1	Mkms/yr						
541	0	0	0	1	287.86	0	0	0	1	PJ/yr	500	10	0.08	114.1		
542	0	0	0	1	287.86	0	0	0	1	PJ/yr	500	10	0.08	114.1		
543	0	0	0	1	287.86	0	0	0	1	PJ/yr	500	10	0.08	114.1		
544	0	0	0	1	287.86	0	0	0	1	PJ/yr	500	10	0.08	114.1		
545	0	0	0	1	287.86	0	0	0	1	PJ/yr	500	10	0.08	114.1		
546	0	0	0	1	261.69	0	0	0	1	PJ/yr	0	10	0.08	114.1		
547	0	0	0	1	287.86	0	0	0	1	PJ/yr	0	10	0.08	114.1		
548	0	0	0	1	261.69	0	0	0	1	PJ/yr	120	10	0.08	114.1		
549	0	0	0	1	261.69	0	0	0	1	PJ/yr	120	10	0.08	114.1		
550	0	0	0	1	261.69	0	0	0	1	PJ/yr	5000	10	0.08	114.1		
551	0	0	0	1	414.4	0	0	0	1	PJ/yr	1500	10	0.08	80.7		
552	0	0	0	0	0	0	0	0	1	Mkms/yr						
553	0	0	0	1	0.22	0	0	0	1	PJ/yr						
554	0	0	0	1	0.33	0	0	0	1	PJ/yr						
555	0	0	0	0	0	0	0	0	1	PJ/yr						
556	0	0	0	1	0.26	0	0	0	1	PJ/yr	0	7	0.08	114.1		
557	0	0	0	1	0.24	0	0	0	1	PJ/yr	1500	7	0.08	114.1		
558	0	0	0	1	0.24	0	0	0	1	PJ/yr	1500	7	0.08	114.1		
559	0	0	0	1	0.24	0	0	0	1	PJ/yr	1500	7	0.08	114.1		
560	0	0	0	1	0.24	0	0	0	1	PJ/yr	1500	7	0.08	114.1		
561	0	0	0	1	0.24	0	0	0	1	PJ/yr	1500	7	0.08	114.1		

	A	B	C	D	E	F	G	H	I	J	K	L	M
562	LHYGN-TRN-BUS	119	97	0	0	0	0	0	0	0	0	1	12.7749106
563	ENERGY-TRN-BUS	97	1000	0	0	0	0	121	2.267036	0	0	0	0
564	DIESEL-TRN-MRN	111	98	1131	0.47	0	0	0	0	0	0	0	0
565	HOIL-TRN-MRN	115	98	0	0	0	0	0	0	0	0	0	0
566	ENERGY-TRN-MRN	98	1000	0	0	0	0	121	2.753185	0	0	0	0
567	DSL-TRN-RAIL	111	99	1131	1	0	0	0	0	0	0	0	0
568	ELEC-TRN-RAIL	117	99	0	0	0	0	0	0	0	0	1	0
569	ENERGY-TRN-RAIL	99	1000	0	0	0	0	121	6.596791	0	0	0	0
570	DIESEL-TRN-TRUCK	111	100	0	0	0	0	0	0	0	0	0	0
571	PROPANE-TRN-TRUCK	107	100	0	0	0	0	0	0	0	0	1	2.66143971
572	CNG-TRN-TRUCK	25	100	0	0	0	0	0	0	0	0	1	2.66143971
573	LNG-TRN-TRUCK	120	100	0	0	0	0	0	0	0	0	1	2.66143971
574	MTHL-TRN-TRUCK	108	100	0	0	0	0	0	0	0	0	1	2.66143971
575	ETHL-TRN-TRUCK	109	100	0	0	0	0	0	0	0	0	1	2.66143971
576	LHYGN-TRN-TRUCK	119	100	0	0	0	0	0	0	0	0	1	26.6143971
577	ENERGY-TRN-TRUCK	100	1000	0	0	0	0	121	18.52843	0	0	0	0
578	ELEC-TRN-STC&SBY	117	1000	0	0	0	0	121	1.609729	0	0	0	0

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
562	0	0	0	1	0.22	0	0	0	1	PJ/yr	15000	7	0.08	114.1		
563	0	0	0	0	0	0	0	0	1	PJ/yr						
564	0	0	0	1	0.17	0	0	0	1	PJ/yr						
565	0	0	0	1	0.11	0	0	0	1	PJ/yr						
566	0	0	0	0	0	0	0	0	1	PJ/yr						
567	0	0	0	1	0.26	0	0	0	1	PJ/yr						
568	0	0	0	1	0.8	0	0	0	1	PJ/yr						
569	0	0	0	0	0	0	0	0	1	PJ/yr						
570	0	0	0	1	0.26	0	0	0	1	PJ/yr	0	7	0.08	114.1		
571	0	0	0	1	0.24	0	0	0	1	PJ/yr	3750	7	0.08	114.1		
572	0	0	0	1	0.24	0	0	0	1	PJ/yr	3750	7	0.08	114.1		
573	0	0	0	1	0.24	0	0	0	1	PJ/yr	3750	7	0.08	114.1		
574	0	0	0	1	0.24	0	0	0	1	PJ/yr	3750	7	0.08	114.1		
575	0	0	0	1	0.24	0	0	0	1	PJ/yr	3750	7	0.08	114.1		
576	0	0	0	1	0.22	0	0	0	1	PJ/yr	37500	7	0.08	114.1		
577	0	0	0	0	0	0	0	0	1	PJ/yr						
578	0	0	0	0	0	0	0	0	1	PJ/yr						

A.2 Scenario spreadsheet

The scenario spreadsheet contains supply price data and parameters that generate end-use demands. The latter are used by formulae entered in this spreadsheet. The spreadsheet entries are self explanatory. Data entry is in column D from row 3 to row 45. The end-use demand formulae are entered in column C from row 49 to 75. The following pages display this spreadsheet.

	A	B	C	D
1	SCENARIO SPECIFICATIONS (All data entry in column D)			
2	Supply Resources Cost Data for the year 2021 (1985 Dollars)			
3	Natural Gas	Southern Ontario	$/1000's of Mcf	6210
4		Mck.-Bft/East/Arc	$/1000's of Mcf	6210
5	Propane	Western Canada	$/Millions of Lts	300000
6	Coal	Western Canadian	$/1000's of Tns	128000
7		North-Eastern US	$/1000's of Tns	97000
8	Crude Oil	Frgn/Reg. Imp.	$/1000's of Brls	49000
9	Uranium	Saskat/Ont.	$/Tonne	297000
10	Wood	Ontario	$/1000's of Tns	82000
11	Lignite	Saskatchewan	$/1000's of Tns	71000
12	Corn	Ontario	$/1000's of Tns	198000
13	Barley	Ontario	$/1000's of Tns	191000
14	Wheat	Ontario	$/1000's of Tns	225000
15	Electricity Exports		c/kWh	4.533
16	Electricity Imports		c/kWh	6.121
17	Gasoline - Imports		$/Cubic Metres	380.38
18	Diesel - Imports		$/Cubic Metres	380.38
19	Aviation Gasoline - Imports		$/Cubic Metres	380.38
20	Turbo Jet Fuel - Imports		$/Cubic Metres	380.38
21	Light Fuel Oil - Imports		$/Cubic Metres	380.38
22	Heavy Fuel Oil - Imports		$/Cubic Metres	380.38
23	Petroleum Pr. & PCF - Imports		$/Cubic Metres	380.38
24	Gasoline - Exports		$/Cubic Metres	377.28
25	Diesel - Exports		$/Cubic Metres	377.28
26	Aviation Gasoline - Exports		$/Cubic Metres	377.28
27	Turbo Jet Fuel - Exports		$/Cubic Metres	377.28
28	Light Fuel Oil - Exports		$/Cubic Metres	377.28
29	Heavy Fuel Oil - Exports		$/Cubic Metres	377.28
30	Petroleum Pr. & PCF - Exports		$/Cubic Metres	377.28
31	End-use Demand Estimation (Data entry in column D)			
32	Population in 2021 (Millions)			10.4764
33	# of households in 2021 (Millions)			5.5979
34	Fraction of Houses			0.61
35	Fraction of Apartments			0.39
36	Fraction of new R2000SH			0.45
37	Fraction of new ISH			0.5
38	Fraction of new CBCH			0.05
39	Fraction of housing units with a/c			0.8
40	C&I(new buildings) fr. improvement in heating load			0.3
41	C&I Floor-space trend			2.51
42	Industrial production trend			1.82
43	Transportation trend (all categories			1
44		except passenger cars)		
45	Passenger cars and Light trucks&Vans trend			1.55
46				
47				
48				

	A	B	C	D
49	ENERGY-R2000SH-SH		16.10	
50	ENERGY-ISH-SH		43.65	
51	ENERGY-CBCH-SH		97.04	
52	ENERGY-NWAPTS-SH		19.15	
53	ENERGY-ODAPTS-SH		11.94	
54	ENERGY-WH		114.24	
55	ENERGY-WU-AC		15.94	
56	ENERGY-CAC-AC		21.55	
57	ENERGY-APP&LTG		115.38	
58	ENERGY-NWC&I-SH		194.14	
59	ENERGY-ODC&I-SH		60.78	
60	ENERGY-C&I-WH		14.39	
61	ENERGY-C&I-AC		47.46	
62	ENERGY-C&I-EQ&LG		100.72	
63	ENERGY-I-IH		572.94	
64	ENERGY-I-DH		544.08	
65	ENERGY-I-EL.DR&P		254.40	
66	ENERGY-I-UTLS		151.79	
67	ENERGY-PCF&PP		436.12	
68	DIST-TRN-AUTO		121083.40	
69	DIST-TRN-L.TS&VS		21069.18	
70	ENERGY-TRN-BUSES		2.27	
71	ENERGY-TRN-RAIL		6.60	
72	ENERGY-TRN-MRN		2.75	
73	ENERGY-TRN-AIRCRAFT		14.99	
74	ENERGY-TRN-TRKS		18.53	
75	ENERGY-TRN-SWAY		1.61	

APPENDIX B

MODEL RESULTS FOR THE LOW, BASE AND HIGH ENERGY DEMAND SCENARIOS

The following pages show detailed results for the low, base and high energy demand scenarios.

MODEL NAME:	Ontario Energy Optimisation Model	
SOLUTION	Low Energy Demand Scenario	
OBJECTIVE FUNCTION VALUE	Dollars	2.862756000E+10

MARGINAL COST

Node Name	Units	Value
Gas Supply	$/PJ	6808000
Propane Supply	$/PJ	9568283
Coal Supply	$/PJ	4253200
Uranium Supply	$/PJ	1959000
Wood Supply	$/PJ	3654249
Syncrude	$/PJ	6628000
Refineries Dist.	$/PJ	9691000
Gas-Gasoline (Mobil)	$/PJ	13836400
Gas-Methanol	$/PJ	11091220
Gas-ethanol	$/PJ	412160.8
Gas-Liquid Hydrogen	$/PJ	0
Coal-Gsl+Dsl (FT-SASOL)	$/PJ	16402620
Coal-Gasoline (ZnCl2)	$/PJ	7898089
Coal-Gasoline (Mobil)	$/PJ	1436107
Coal-Methanol	$/PJ	11090480
Coal-Ethanol	$/PJ	0
Coal-Liquid Hydrogen	$/PJ	0
Wood-Methanol	$/PJ	894160.8
Wood-Ethanol	$/PJ	0
Corn-Ethanol	$/PJ	4970161
Barley-Ethanol	$/PJ	6823161
Wheat-Ethanol	$/PJ	5290161
Methanol	$/PJ	7665161
Ethanol	$/PJ	8788161
CNG	$/PJ	12808590
LNG	$/PJ	13995120
Gasoline	$/PJ	9206175
Diesel	$/PJ	10391160
Aviation Gasoline	$/PJ	9206175
Turbo Jet Fuel	$/PJ	10391160
Light Fuel Oil	$/PJ	10391160
Heavy Fuel Oil	$/PJ	10996280
PCF+Petroleum Products	$/PJ	10996280
Methanol-Gasoline (MOBIL)	$/PJ	8408658
Methanol Gasoline	$/PJ	11644110
Ethanol Gasoline	$/PJ	11724460
Elec / Gas-SBC	$/PJ	20023530
Elec / Gas-SPC	$/PJ	19429230
Elec / LF Oil-CTU	$/PJ	13533410
Elec / HF Oil-SBC	$/PJ	11446410
Elec / Coal-PFC1	$/PJ	11559410
Elec / Coal-PFC2	$/PJ	11681410

LOW SCENARIO

Node Name	Units	Value
Elec / Coal-AFBC	$/PJ	12152000
Elec / Lignite-	$/PJ	8655407
Elec / Uran-New Darl	$/PJ	1959000
Elec / Uran-Existing Darl	$/PJ	4929500
Elec / New Hydro (Large)	$/PJ	4570407
Elec / Existing Hydro	$/PJ	0
Elec / Mun. Refuse	$/PJ	0
Seasonal Peak	$/PJ	74943530
Daily Peak	$/PJ	20992410
Cycling	$/PJ	14780410
Base	$/PJ	5712000
Electricity	$/PJ	8443193
Electricity-Liquid Hydrogen	$/PJ	25388680
Liquid Hydrogen	$/PJ	0
Heat-Pump / R2000 SH	$/PJ	80763520
Heat Pump + Backups / R2000 SH	$/PJ	22529520
Wood Furnace + Backups / R2000 SH	$/PJ	22529520
Active Solar / R2000 SH	$/PJ	1525185
Heating Devices / R2000 SH	$/PJ	22529520
Heat-Pump / ISH	$/PJ	44553520
Heat Pump + Backups / ISH	$/PJ	17055690
Wood Furnace + Backups / ISH	$/PJ	17605960
Active Solar / ISH	$/PJ	1525185
Active Solar + Backups / ISH	$/PJ	19116030
Heating Devices / ISH	$/PJ	17055690
Heat-Pump / OBC80H	$/PJ	31783520
Heat Pump + Backups / OBC80H	$/PJ	24131980
Wood Furnace + Backups / OBC80H	$/PJ	14479960
Active ~~Solar~~ / OBC80H	$/PJ	1525185
Active Solar + Backups / OBC80H	$/PJ	16952860
Heating Devices / OBC80H	$/PJ	14479960
Heating Devices / Apts	$/PJ	17879450
Housing Types	$/PJ	0
Apartment / Types	$/PJ	0
Residential Space Heating	$/PJ	0
Active Solar - WH / Houses	$/PJ	91585180
Active Solar + WH Backups / Houses	$/PJ	40249790
Water Heating Devices / Houses	$/PJ	14703200
Water Heating Devices / Apts	$/PJ	13390700
Residential Water Heating	$/PJ	14191330
Heat Pump - Cooling / Houses	$/PJ	14857840
Active Solar - Cooling / Houses	$/PJ	14857840
Central Air-Conditioning	$/PJ	11791940
Residential Air-Conditioning	$/PJ	0
Heating Devices / C&I	$/PJ	17879450
C&I Space Heating	$/PJ	0
C&I Water Heating	$/PJ	13390700
C&I Air-Condioning	$/PJ	5084506

LOW SCENARIO

Node Name	Units	Value
Ind. Indirect Heat	$/PJ	7476500
Ind. Direct Heat	$/PJ	6022308
Ind. Utilities	$/PJ	11448450
Ind. PCF + PP	$/PJ	13216930
Automobiles	$/PJ	32031.62
Aircraft	$/PJ	39458030
Buses	$/PJ	49263800
Marine	$/PJ	99262700
Rail	$/PJ	49263800
Trucks	$/PJ	49263800
Gasolines - Ref 2	$/PJ	9206175
Distillates - Ref 2	$/PJ	10391160
H.Oil&PCF&PP - Ref 2	$/PJ	10996280
Lt.Trucks & Vans	$/PJ	42958.39
Small Hydro	$/PJ	3520407
Gas Tran&Dist	$/PJ	9399563
Propane Tran&Dist	$/PJ	13216930
Methanol Tran&Dist	$/PJ	12808590
Ethanol Tran&Dist	$/PJ	12808590
Gasoline Tran&Dist	$/PJ	11644110
Diesel Tran&Dist	$/PJ	12808590
Aviation Gasoline Tran&Dist	$/PJ	11998170
Jet fuel Tran&Dist	$/PJ	13001170
Light Fuel Oil Tran&Dist	$/PJ	9399563
Heavy Fuel Oil Tran&Dist	$/PJ	13252040
PCF & Petrochemicals Tran&Dist	$/PJ	13216930
Electrical Tran&Dist	$/PJ	15253520
Wood Tran&Dist	$/PJ	5895249
Liq. Hydrogen Tran&Dist	$/PJ	11644090
LNG Tran&Dist	$/PJ	12808590
Refinery - 2 (High Complexity)	$/PJ	10015270
Refinery - 1 (Low Complexity)	$/PJ	10507830
Gasolines - Ref 1	$/PJ	9206175
Distillates - Ref 1	$/PJ	10391160
Heavy Oils - Ref 1	$/PJ	10996280
Electricity Imp/Exp	$/PJ	8443193
Electricity Exports - Transmission	$/PJ	12330970
Mun.Ref Elec - CY	$/PJ	2251000
Mun.Ref Elec - BS	$/PJ	-663944.1
Mun.Ref Elec - Power	$/GW	-144319100
Hydro Elec - >10 MW -SP	$/PJ	161285200
Hydro Elec - >10 MW -DP	$/PJ	17625200
Hydro Elec - >10 MW -CY	$/PJ	7390203
Hydro Elec - >10 MW -BS	$/PJ	5783203
Hydro Elec - >10 MW -POWER	$/GW	0
Hydro Elec - 2-10 MW -SP	$/PJ	37471770
Hydro Elec - 2-10 MW -DP	$/PJ	10496200
Hydro Elec - 2-10 MW -CY	$/PJ	7390203

LOW SCENARIO

Node Name	Units	Value
Hydro Elec - 2-10 MW -BS	$/PJ	2856000
Hydro Elec - 2-10 MW -POWER	$/GW	0
Hydro Elec - EXIST. -SP	$/PJ	-191386000
Hydro Elec - EXIST. -DP	$/PJ	-11586180
Hydro Elec - EXIST. -CY	$/PJ	40840
Hydro Elec - EXIST. -BS	$/PJ	-2179063
Hydro Elec - EXIST. -POWER	$/GW	-254039500
Hydro Elec - >10 MW - Peak	$/PJ	0
Hydro Elec - >10 MW - Peak - SP	$/PJ	0
Hydro Elec - >10 MW - Peak - DP	$/PJ	0
Hydro Elec - >10 MW - Peak - Power	$/GW	0
Hydro Elec - EXIST. - Peak	$/PJ	15229710
Hydro Elec - EXIST. - Peak - SP	$/PJ	7614857
Hydro Elec - EXIST. - Peak - DP	$/PJ	7614857
Hydro Elec - EXIST. - Peak - Power	$/GW	-19871690
Electricity Imports	$/PJ	5739193

VARIABLES

Variable Name	Units	Value	Reduced Cost
GAS ONT	1000 Mcf/yr	5514.015	0
GAS-MAC-BFT/EAS.OFF/ARCTIC ISL.	1000 Mcf/yr	713608.8	0
PROPANE-WEST	MLts/yr	0	4581717
COAL-WEST	1000 Tns/yr	9994.066	0
COAL-US	1000 Tns/yr	22806.27	0
CRUDEOIL-FOREIGN/REGIONAL IMP.	1000 Brls/yr	115291.6	0
URANIUM-SASKAT	Tns/yr	2546.469	0
WOOD-ONT	1000 TNS	0	1255751
LIGNITE-SASKAT.	1000 Tns/yr	0	2675716
EXISTING HYDRO - PEAKING UNITS	GWh/yr	1516.388	-15229710
NEW HYDRO (>10 MW) - PEAKING UNI	GWh/yr	0	0
EXISTING HYDRO - ALL CATEG.	GWh/yr	22501.62	0
NEW HYDRO (>10MW) - ALL CATEG.	GWh/yr	4073.333	-4570407
SMALL HYDRO (2-10 MW) - ALL CATEG.	GWh/yr	628.0554	-3520407
CORN-ONT-ETHL	1000 TNS	0	14993560
BARLEY-ONT-ETHL	1000 TNS	0	13787370
WHEAT-ONT-ETHL	1000 TNS	0	17302460
MUNREFUSE-ELEC	GWh/yr	780.0556	0
COAL-SYNCRUDE	PJ/yr	0	615753.6
GAS-GSL(MOBIL)	PJ/yr	0	0
COAL-GSL(ZNCL2)	PJ/yr	0	0
COAL-GSL(MOBIL)	PJ/yr	0	3816195
COAL-GSLDSL(SASOL)	PJ/yr	0	0
ELEC-GAS-GSL(MOBIL)	PJ/yr	0	0
ELEC-COAL-GSL(MOBIL)	PJ/yr	0	0
GAS-MTHL	PJ/yr	0	0
COAL-MTHL	PJ/yr	0	0
WOOD-MTHL	PJ/yr	0	3279685
ELEC-GAS-MTHL	PJ/yr	0	0
MTHL-GSL(MOBIL)	PJ/yr	0	929014.1

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-MTHL-GSL(MOBIL)	PJ/yr	0	0
GAS-ETHL	PJ/yr	0	6947760
COAL-ETHL	PJ/yr	0	0
WOOD-ETHL	PJ/yr	0	0
COAL-CORN-ETHL	PJ/yr	0	0
COAL-BARLEY-ETHL	PJ/yr	0	0
COAL-WHEAT-ETHL	PJ/yr	0	0
ELEC-GAS-ETHL	PJ/yr	0	0
GAS-COAL-ETHL	PJ/yr	0	77799640
ELEC-COAL-ETHL	PJ/yr	0	0
ELEC-WOOD-ETHL	PJ/yr	0	73236440
COAL-LHYGN	PJ/yr	0	0
GAS-LHYGN	PJ/yr	0	0
ELEC-LHYGN	PJ/yr	0	0
ELEC-COAL-LHYGN	PJ/yr	0	47150720
ELEC-GAS-LHYGN	PJ/yr	0	51282590
SYNCRUDE-REF	TJ/yr	0	0
CRUDE-REF 1 (LOW COMPLEX.)	TJ/yr	703278.8	0
CRUDE-REF 2 (HIGH COMPLEX.)	TJ/yr	0	783415.5
REF 2-GASOLINES	TJ/yr	0	0
REF 2-DISTILLATES	TJ/yr	0	0
REF 2-H.OIL&PCF&PP	TJ/yr	0	0
REF 2-PROPANE	TJ/yr	0	0
GSL 2-GASOLINES	TJ/yr	0	0
DSL 2-DISTILLATES	TJ/yr	0	0
AGSL 2-GASOLINES	TJ/yr	0	0
TJF 2-DISTILLATES	TJ/yr	0	0
LFO 2-DISTILLATES	TJ/yr	0	0
HFO 2-H.OIL&PCF&PP	TJ/yr	0	0
PCF&PP 2-H.OIL&PCF&PP	TJ/yr	0	0
REF 1-GASOLINES	TJ/yr	113592.5	0
REF 1-DISTILLATES	TJ/yr	197473.5	0
REF 1-H.OIL&PCF&PP	TJ/yr	358295.8	0
REF 1-PROPANE	TJ/yr	4379.316	0
GSL 1-GASOLINES	TJ/yr	113392.5	0
DSL 1-DISTILLATES	TJ/yr	164267.5	0
AGSL 1-GASOLINES	TJ/yr	200.0365	0
TJF 1-DISTILLATES	TJ/yr	33206.05	0
LFO 1-DISTILLATES	TJ/yr	0	0
HFO 1-H.OIL&PCF&PP	TJ/yr	41761.41	0
PCF&PP 1-H.OIL&PCF&PP	TJ/yr	316534.4	0
GSL-IMPORTS	PJ/yr	0	2783825
DSL-IMPORTS	PJ/yr	0	1598838
AGSL-IMPORTS	PJ/yr	0	2783825
TJF-IMPORTS	PJ/yr	0	1598838
LFO-IMPORTS	PJ/yr	0	1598838
HFO-IMPORTS	PJ/yr	0	993716.5
PCF&PP IMPORTS	PJ/yr	0	993716.5

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
GSL-EXPORTS	PJ/yr	0	-2693825
DSL-EXPORTS	PJ/yr	0	-1508838
AGSL-EXPORTS	PJ/yr	0	-2693825
TJF-EXPORTS	PJ/yr	0	-1508838
LFO-EXPORTS	PJ/yr	0	-1508838
HFO-EXPORTS	PJ/yr	0	-903716.5
PCF&PP-EXPORTS	PJ/yr	0	-903716.5
ELEC-CNG	PJ/yr	0	2777954
ELEC-LNG	PJ/yr	0	2057517
CNG	TJ/yr	43634.85	0
LNG	TJ/yr	0	0
GSL(MOBIL)-GAS	TJ/yr	0	10772290
GSL(ZNCL2)-COAL	TJ/yr	0	7673914
GSL(MOBIL)-COAL	TJ/yr	0	0
GSL(MOBIL)-MTHL	TJ/yr	0	0
GSL-COAL(SASOL)	TJ/yr	0	16297450
DSL-COAL(SASOL)	TJ/yr	0	15112460
MTHL-GAS	TJ/yr	0	7359061
MTHL-COAL	TJ/yr	0	9371322
MTHL-WOOD	TJ/yr	0	0
ETHL-GAS	TJ/yr	0	0
ETHL-COAL	TJ/yr	0	5391839
ETHL-WOOD	TJ/yr	0	890839.1
ETHL-CORN	TJ/yr	0	0
ETHL-BARLEY	TJ/yr	0	0
ETHL-WHEAT	TJ/yr	0	0
LHYGN-GAS	TJ/yr	0	2512000
LHYGN-COAL	TJ/yr	0	7394000
LHYGN-ELEC	TJ/yr	0	32936680
GSL-MTHLGSLBLD	PJ/yr	0	0
GSL-ETHLGSLBLD	PJ/yr	0	0
MTHL-MTHLGSLBLD	PJ/yr	0	1164479
ETHL-ETHLGSLBLD	PJ/yr	0	0
PROPANE-MOBIL(GAS)	TJ/yr	0	0
PROPANE-MOBIL(COAL)	TJ/yr	0	0
PROPANE-MOBIL(MTHL)	TJ/yr	0	0
GAS-SBC-ELEC	PJ/yr	12.23618	0
GAS-SPC-ELEC	PJ/yr	0	0
COAL-PFC1-ELEC	PJ/yr	0	155390.3
COAL-PFC2-ELEC	PJ/yr	70.87518	0
COAL-AFBC-ELEC	PJ/yr	0	0
HOIL-SBC-ELEC	PJ/yr	0	6996909
LOIL-CTU-ELEC	PJ/yr	0	7095778
URAN-NWDL-ELEC	PJ/yr	228.8896	0
URAN-EXDL-ELEC	PJ/yr	230.85	-2970500
ELEC-GAS-SBC-SP	GWh/yr	1155.638	0
ELEC-GAS-SBC-DP	GWh/yr	0	4331124
ELEC-GAS-SPC-SP	GWh/yr	0	6135694

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-GAS-SPC-DP	GWh/yr	0	4384818
ELEC-LOIL-CTU-SP	GWh/yr	0	15889880
ELEC-LOIL-CTU-DP	GWh/yr	0	0
ELEC-HOIL-SBC-SP	GWh/yr	0	40302880
ELEC-HOIL-SBC-DP	GWh/yr	0	474000
ELEC-HOIL-SBC-CYC	GWh/yr	0	0
ELEC-HOIL-SBC-BASE	GWh/yr	0	8018407
ELEC-COAL-PFC1-SP	GWh/yr	0	36915880
ELEC-COAL-PFC1-DP	GWh/yr	0	246000
ELEC-COAL-PFC1-CYC	GWh/yr	0	0
ELEC-COAL-PFC1-BASE	GWh/yr	0	8054407
ELEC-COAL-PFC2-SP	GWh/yr	0	33227880
ELEC-COAL-PFC2-DP	GWh/yr	4826.433	0
ELEC-COAL-PFC2-CYC	GWh/yr	2341.802	0
ELEC-COAL-PFC2-BASE	GWh/yr	0	8092407
ELEC-COAL-AFBC-SP	GWh/yr	0	85808460
ELEC-COAL-AFBC-DP	GWh/yr	0	5499592
ELEC-COAL-AFBC-CYC	GWh/yr	0	2144592
ELEC-COAL-AFBC-BASE	GWh/yr	0	9708999
ELEC-LGTE-ELEC-SP	GWh/yr	0	124411900
ELEC-LGTE-ELEC-DP	GWh/yr	0	6063000
ELEC-LGTE-ELEC-CYC	GWh/yr	0	0
ELEC-LGTE-ELEC-BASE	GWh/yr	0	7139407
ELEC-URAN-NWDL-BASE	GWh/yr	63580.46	0
ELEC-URAN-EXDL-BASE	GWh/yr	64125	0
ELEC-NWHY(>10MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-PEAK U.-SP-E.T.P	PJ/yr	0	0
ELEC-NWHY(>10 MW)-PEAK U.-DP-E.T.P	PJ/yr	0	0
ELEC-NWHY(>10MW)-PEAK U.-POWER	GW	0	0
ELEC-NWHY(>10MW)-SP	GWh/yr	0	328456400
ELEC-NWHY(>10MW)-DP	GWh/yr	0	17937580
ELEC-NWHY(>10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-CYC	GWh/yr	4073.333	0
ELEC-NWHY(>10 MW)-BASE	GWh/yr	0	0
ELEC-NWHY(>10 MW)-SP-ENGY TO PWR	PJ/yr	0	247627000
ELEC-NWHY(>10 MW)-DP-ENGY TO PWR	PJ/yr	0	14258000
ELEC-NWHY(>10 MW)-CY-ENGY TO PWR	PJ/yr	14.66399	0
ELEC-NWHY(>10 MW)-BS-ENGY TO PWR	PJ/yr	0	5783203
ELEC-NWHY(>10 MW)-POWER	GW	0.848459	0
ELEC-NWHY(>10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-CYC	GWh/yr	4073.333	0
ELEC-NWHY(>10 MW)-BASE	GWh/yr	0	71203.5
ELEC-NWHY(2-10 MW)-SP	GWh/yr	0	279077100
ELEC-NWHY(2-10 MW)-DP	GWh/yr	0	16348000
ELEC-NWHY(2-10 MW)-CYC	GWh/yr	628.0554	0

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-NWHY(2-10 MW)-BASE	GWh/yr	0	5520407
ELEC-NWHY(2-10 MW)-SP-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-DP-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-CY-ENGY TO PWR	PJ/yr	2.261	0
ELEC-NWHY(2-10 MW)-BS-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-POWER	GW	0.130821	0
ELEC-NWHY(2-10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-CYC	GWh/yr	628.0554	0
ELEC-NWHY(2-10 MW)-BASE	GWh/yr	0	0
ELEC-EX.HYDRO-PEAK U.-SP	GWh/yr	3.063408	0
ELEC-EX.HYDRO-PEAK U.-DP	GWh/yr	1513.325	0
ELEC-EX.HYDRO-PEAK U.-SP-E.T.PWR	PJ/yr	0.011028	0
ELEC-EX.HYDRO-PEAK U.-DP-E.T.PWR	PJ/yr	5.447971	0
ELEC-EX.HYDRO-PEAK U.-POWER	GW	0.967	-19871690
ELEC-EX.HYDRO-PEAK U.-SP	GWh/yr	3.063408	0
ELEC-EX.HYDRO-PEAK U.-DP	GWh/yr	1513.325	0
ELEC-EXHY-SP	GWh/yr	0	383919100
ELEC-EXHY-DP	GWh/yr	0	23283070
ELEC-EXHY-CYC	GWh/yr	22501.62	0
ELEC-EXHY-BASE	GWh/yr	0	4414077
ELEC-EXHY-SP-ENGY TO POWER	PJ/yr	0	0
ELEC-EXHY-DP-ENGY TO POWER	PJ/yr	0	0
ELEC-EXHY-CYC-ENGY TO POWER	PJ/yr	81.00587	0
ELEC-EXHY-BASE-ENGY TO POWER	PJ/yr	0	0
ELEC-EXHY-POWER	GW	4.687	-254039500
ELEC-EXHY-SP	GWh/yr	0	0
ELEC-EXHY-DP	GWh/yr	0	0
ELEC-EXHY-CYC	GWh/yr	22501.62	0
ELEC-EXHY-BASE	GWh/yr	0	0
ELEC-MUNREFUSE-CYC	GWh/yr	780.0556	0
ELEC-MUNREFUSE-BASE	GWh/yr	0	3446888
ELEC-MUNREFUSE-CYC-ENGY TO POWER	PJ/yr	2.808201	0
ELEC-MUNREFUSE-BASE-ENGY TO POWER	PJ/yr	0	0
ELEC-MUNREFUSE-POWER	GW	0.2	-144319100
ELEC-MUNREFUSE-CYC	GWh/yr	780.0556	0
ELEC-MUNREFUSE-BASE	GWh/yr	0	0
ELEC-TOTALSP	PJ/yr	4.171328	0
ELEC-TOTALDP	PJ/yr	22.82313	0
ELEC-TOTALCYC	PJ/yr	109.1696	0
ELEC-TOTALBASE	PJ/yr	459.7397	0
ELEC-TOTAL	PJ/yr	595.9038	0
ELEC-EXPORTS-TRAN.	PJ/yr	55.30973	0
ELEC-EXPORT	PJ/yr	50	-2679034
ELEC-IMPORT	PJ/yr	0	14520810
ELEC-IMPORTS-TRAN.	PJ/yr	0	0
GAS-TRAN&DIST	PJ/yr	757.2253	0
PROPANE-TRAN&DIST	PJ/yr	4.379319	0

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
METHANOL-TRAN&DIST	PJ/yr	0	0
ETHANOL-TRAN&DIST	PJ/yr	0	0
GASOLINE-TRAN&DIST	PJ/yr	113.3925	0
DIESEL-TRAN&DIST	PJ/yr	164.2675	0
AV.GAS-TRAN&DIST	PJ/yr	0.200037	0
JET FUEL-TRAN&DIST	PJ/yr	33.20605	0
LFO-TRAN&DIST	PJ/yr	0	3398798
HFO-TRAN&DIST	PJ/yr	41.76141	0
PCF&PP-TRAN&DIST	PJ/yr	316.5344	0
ELEC-TRAN&DIST	PJ/yr	540.5939	0
WOOD-TRAN&DIST	PJ/yr	0	0
LHYGN-TRAN&DIST	PJ/yr	0	43340840
LNG-TRAN&DIST	PJ/yr	0	5749961
ELEC-HTP-R2SH-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-R2SH-SH	TJ/yr	0	7806749
LOIL-FCE+HTP-R2SH-SH	TJ/yr	0	9191926
ELEC-RES+HTP-R2SH-SH	TJ/yr	0	0
HT-ENERGY-HTP-R2SH-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-R2SH-SH	PJ/yr	0	0
GAS-WCBFCE-R2SH-SH	PJ/yr	0	0
LOIL-WCBFCE-R2SH-SH	PJ/yr	0	0
ELEC-WDFCE+RES-R2SH-SH	PJ/yr	0	792649.8
WOOD-OPTS+WDFCE-R2SH-SH	TJ/yr	0	2909634
ENERGY-OPTS+WDFCE-R2SH-SH	PJ/yr	0	0
ELEC-ASR-R2SH-SH&WH&AC	PJ/yr	0	0
ASR-R2SH-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-R2SH-SH	TJ/yr	0	14895670
GAS-CGF-R2SH-SH	TJ/yr	0	3422407
GAS-FCE-R2SH-SH	TJ/yr	0	378949.3
LOIL-FCE-R2SH-SH	TJ/yr	0	1328426
ELEC-RES-R2SH-SH	TJ/yr	18953.99	0
ELEC-HTP-ISH-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-ISH-SH	TJ/yr	0	1866749
LOIL-FCE+HTP-ISH-SH	TJ/yr	0	2611926
ELEC-RES+HTP-ISH-SH	TJ/yr	0	0
HT-ENERGY-ISH-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-ISH-SH	PJ/yr	0	0
GAS-WCBFCE-ISH-SH	PJ/yr	0	0
LOIL-WCBFCE-ISH-SH	PJ/yr	0	0
ELEC-WDFCE+RES-ISH-SH	PJ/yr	0	792649.8
WOOD-WCBFCE+OPTS-ISH-SH	TJ/yr	0	0
ENERGY-WCBFCE+OPTS-ISH-SH	PJ/yr	0	550259
GAS-FCE+ASR-ISH-SH	TJ/yr	0	0
LOIL-FCE+ASR-ISH-SH	TJ/yr	0	669785.3
ELEC-RES+ASR-ISH-SH	TJ/yr	0	1752813
ELEC-ASR-ISH-SH&WH&AC	PJ/yr	0	0
ASR-ISH-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-ISH-SH	TJ/yr	0	0

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
ENERGY-ASR+OPTS-ISH-SH	PJ/yr	0	2060324
GAS-CGF-ISH-SH	TJ/yr	0	594315.5
GAS-FCE-ISH-SH	TJ/yr	36801.23	0
LOIL-FCE-ISH-SH	TJ/yr	0	669785.3
ELEC-RES-ISH-SH	TJ/yr	0	1752813
ELEC-HTP-OBC80-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-OBC80-SH	TJ/yr	0	0
LOIL-FCE+HTP-OBC80-SH	TJ/yr	0	599535.3
ELEC-RES+HTP-OBC80-SH	TJ/yr	0	2542813
HT ENERGY-HTP-OBC80-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-OBC80-SH	PJ/yr	0	9652034
GAS-WCBFCE-OBC80-SH	PJ/yr	0	0
LOIL-WCBFCE-OBC80-SH	PJ/yr	0	0
ELEC-WDFCE+RES-OBC80-SH	PJ/yr	0	792649.8
WOOD-WCBFCE-OBC80-SH	TJ/yr	0	0
ENERGY-WCBFCE+OPTS-OBC80-SH	PJ/yr	0	0
GAS-FCE+ASR-OBC80-SH	TJ/yr	0	0
LOIL-FCE+ASR-OBC80-SH	TJ/yr	0	599535.3
ELEC-RES+ASR-OBC80-SH	TJ/yr	0	2542813
ELEC-ASR-OBC80-SH&WH&AC	PJ/yr	0	0
ASR-OBC80-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-OBC80-SH	TJ/yr	0	0
ENERGY-ASR+OPTS-OBC80-SH	PJ/yr	0	2472895
GAS-CGF-OBC80-SH	TJ/yr	99696.68	0
GAS-FCE-OBC80-SH	TJ/yr	0	248595.1
LOIL-FCE-OBC80-SH	TJ/yr	0	832593.3
ELEC-RES-OBC80-SH	TJ/yr	0	2853557
GAS-CGB-APT-SH	TJ/yr	0	854438.3
GAS-IEB-APT-SH	TJ/yr	36256.25	0
LOIL-BLR-APT-SH	TJ/yr	0	1972.902
ELEC-BLR-APT-SH	TJ/yr	0	2221063
ELEC-BSD-APT-SH	TJ/yr	0	3594063
ENERGY-R2SH-SH	PJ/yr	18.95399	50179520
ENERGY-ISH-SH	PJ/yr	29.44099	30875690
ENERGY-OBC80-SH	PJ/yr	91.72099	14479960
ENERGY-NWA-SH	PJ/yr	17.05999	17879450
ENERGY-ODA-SH	PJ/yr	11.94499	17879450
ENERGY-H-SH	PJ/yr	140.1159	0
ENERGY-A-SH	PJ/yr	29.005	0
ENERGY-RES-SH	PJ/yr	169.121	0
ENERGY-SR(WH)-R2SH	PJ/yr	0	0
ENERGY-SR(WH)-ISH	PJ/yr	0	0
ENERGY-SR(WH)-OBC80H	PJ/yr	0	0
ENERGY-SR(WH)-HOUSES	PJ/yr	0	0
ENERGY-ASR+BKP-H-WH	PJ/yr	0	25546570
GAS-WHR+ASR-H-WH	PJ/yr	0	0
ELEC-WHR+ASR-H-WH	PJ/yr	0	1119563
GAS-WHR-H-WH	PJ/yr	80.49789	0

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-WHR-H-WH	PJ/yr	0	1881313
GAS-BLR-A-WH	PJ/yr	51.46585	0
ELEC-BLR-A-WH	PJ/yr	0	3193813
ENERGY-H-WH	PJ/yr	64.39831	0
ENERGY-A-WH	PJ/yr	41.17268	0
ENERGY-RES-WH	PJ/yr	105.5709	14191330
ELEC-IWAC-AC	PJ/yr	4.296	17659520
ENERGY-HTP(CAC)-R2SH	PJ/yr	0	0
ENERGY-HTP(CAC)-ISH	PJ/yr	0	0
ENERGY-HTP(CAC)-OBC80	PJ/yr	0	0
ENERGY-HTP(CAC)-HOUSES	PJ/yr	0	0
ENERGY-ASR(CAC)-R2SH	PJ/yr	0	4068914
ENERGY-ASR(CAC)-ISH	PJ/yr	0	4068914
ENERGY-ASR(CAC)-OBC80	PJ/yr	0	4068914
ENERGY-ASR(CAC)-HOUSES	PJ/yr	0	0
ELEC-CAC-AC-HOUSES	PJ/yr	3.985572	0
ELEC-CAC-AC (APT)	PJ/yr	1.82176	0
ENERGY-CAC-RES	PJ/yr	17.42199	11791940
ENERGY-RES-AC	PJ/yr	30.30999	0
ELEC-RES-APP&LTG	PJ/yr	106.625	15253520
GAS-CGB-C&I-SH	TJ/yr	0	854438.3
GAS-IGB-C&I-SH	TJ/yr	227781.2	0
LOIL-BLR-C&I-SH	TJ/yr	0	1972.902
ELEC-BLR-C&I-SH	TJ/yr	0	2221063
ELEC-BSD-C&I-SH	TJ/yr	0	3594063
ENERGY-NWBDGS-C&I-SH	PJ/yr	121.445	17879450
ENERGY-ODBDGS-C&I-SH	PJ/yr	60.77999	17879450
ENERGY-C&I-SH	PJ/yr	182.225	0
GAS-BLR-C&I-WH	PJ/yr	13.17125	0
ELEC-BLR-C&I-WH	PJ/yr	0	3193813
ENERGY-C&I-WH	PJ/yr	10.53699	13390700
ELEC-C&I-AC	PJ/yr	11.30832	0
ENERGY-C&I-AC	PJ/yr	33.925	5084506
ELEC-C&I-EQPT&LTG	PJ/yr	73.759	15253520
GAS-BLR-I-IH	PJ/yr	0	3990263
HOIL-BLR-I-IH	PJ/yr	0	8377865
COAL-BLR-I-IH	PJ/yr	525.4086	0
ENERGY-I-IH	PJ/yr	420.3269	7476500
GAS-BR-I-DH	PJ/yr	31.93232	0
HOIL-BR-I-DH	PJ/yr	31.93232	0
ELEC-HD-I-DH	PJ/yr	3.991303	0
COAL-BF-I-DH	PJ/yr	380.8024	0
ENERGY-I-DH	PJ/yr	399.154	6022308
ELEC-EN&EL.CHMLS-I	PJ/yr	186.638	15253520
GAS-I-UTL	PJ/yr	72.38073	0
ELEC-I-UTL	PJ/yr	38.97424	0
LOIL-I-UTL	PJ/yr	0	0
ENERGY-I-UTL	PJ/yr	111.3549	11448450

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
PROPANE-I-PPCF	PJ/yr	4.366181	0
OBPPCF-I-REF	PJ/yr	315.5847	0
ENERGY-I-PPCF	PJ/yr	319.9509	13216930
PROPANE-TRN-AUTO	PJ/yr	0	408347.8
MTHL-TRN-AUTO	PJ/yr	0	0
ETHL-TRN-AUTO	PJ/yr	0	0
CNG-TRN-AUTO	PJ/yr	42.50033	0
LNG-TRN-AUTO	PJ/yr	0	0
GASOLINE-TRN-AUTO	PJ/yr	65.9291	0
DIESEL-TRN-AUTO	PJ/yr	81.12582	0
METHGSL-TRN-AUTO	PJ/yr	0	0.3081
ETHGSL-TRN-AUTO	PJ/yr	0	80349.56
LHYGN-TRN-AUTO	PJ/yr	0	0
ELEC-TRN-AUTO	PJ/yr	31.88868	0
ENERGY-TRN-AUTO	Mkms/yr	88586.75	32031.62
PROPANE-TRN-LT.TKS&VANS	PJ/yr	0	408365.3
MTHL-TRN-LT.TKS&VANS	PJ/yr	0	17.56707
ETHL-TRN-LT.TKS&VANS	PJ/yr	0	17.56707
CNG-TRN-LT.TKS&VANS	PJ/yr	0	17.56707
LNG-TRN-LT.TKS&VANS	PJ/yr	0	17.56707
GASOLINE-TRN-LT.TKS&VANS	PJ/yr	47.12318	0
DIESEL-TRN-LT.TKS&VANS	PJ/yr	0	17.51307
METHGSL-TRN-LT.TKS&VANS	PJ/yr	0	0.3211
ETHGSL-TRN-LT.TKS&VANS	PJ/yr	0	80349.56
LHYGN-TRN-LT.TKS&VANS	PJ/yr	0	0.54
ELEC-TRN-LT.TRKS&VANS	PJ/yr	7.439472	0
ENERGY-TRN-LT.TKS&VANS	Mkms/yr	15414.57	42958.39
AVGAS-TRN-ACRAFT	PJ/yr	0.199436	0
TJFUEL-TRN-ACRAFT	PJ/yr	33.10644	0
ENERGY-TRN-ACRAFT	PJ/yr	10.96899	39458030
DSL-TRN-BUS	PJ/yr	6.380771	0
PROPANE-TRN-BUS	PJ/yr	0	1393622
CNG-TRN-BUS	PJ/yr	0	985274.1
LNG-TRN-BUS	PJ/yr	0	985274.1
MTHL-TRN-BUS	PJ/yr	0	985274.1
ETHL-TRN-BUS	PJ/yr	0	985274.1
LHYGN-TRN-BUS	PJ/yr	0	806059.6
ENERGY-TRN-BUS	PJ/yr	1.659	49263800
DIESEL-TRN-MRN	PJ/yr	5.568119	0
HOIL-TRN-MRN	PJ/yr	9.703813	0
ENERGY-TRN-MRN	PJ/yr	2.014	99262700
DSL-TRN-RAIL	PJ/yr	18.56153	0
ELEC-TRN-RAIL	PJ/yr	0	0
ENERGY-TRN-RAIL	PJ/yr	4.826	49263800
DIESEL-TRN-TRUCK	PJ/yr	52.13845	0
PROPANE-TRN-TRUCK	PJ/yr	0	1393622
CNG-TRN-TRUCK	PJ/yr	0	985274.3
LNG-TRN-TRUCK	PJ/yr	0	985274.3

LOW SCENARIO

Variable Name	Units	Value	Reduced Cost
MTHL-TRN-TRUCK	PJ/yr	0	985274.3
ETHL-TRN-TRUCK	PJ/yr	0	985274.3
LHYGN-TRN-TRUCK	PJ/yr	0	806062.5
ENERGY-TRN-TRUCK	PJ/yr	13.55599	49263800
ELEC-TRN-STC&SBY	PJ/yr	1.178	15253520

MODEL NAME: Ontario Energy Optimisation Model
SOLUTION Base Energy Demand Scenario
OBJECTIVE FUNCTION VALUE Dollars 3.365974000E+10

MARGINAL COST

Node Name	Units	Value
Gas Supply	$/PJ	5534000
Propane Supply	$/PJ	7737488
Coal Supply	$/PJ	3407100
Uranium Supply	$/PJ	1569000
Wood Supply	$/PJ	2789050
Syncrude	$/PJ	4596000
Refineries Dist.	$/PJ	7659000
Gas-Gasoline (Mobil)	$/PJ	11272930
Gas-Methanol	$/PJ	9034569
Gas-ethanol	$/PJ	0
Gas-Liquid Hydrogen	$/PJ	0
Coal-Gsl+Dsl (FT-SASOL)	$/PJ	13139610
Coal-Gasoline (ZnCl2)	$/PJ	6326902
Coal-Gasoline (Mobil)	$/PJ	112731.3
Coal-Methanol	$/PJ	8884225
Coal-Ethanol	$/PJ	0
Coal-Liquid Hydrogen	$/PJ	0
Wood-Methanol	$/PJ	0
Wood-Ethanol	$/PJ	0
Corn-Ethanol	$/PJ	3546488
Barley-Ethanol	$/PJ	5399488
Wheat-Ethanol	$/PJ	3866488
Methanol	$/PJ	6241488
Ethanol	$/PJ	7364488
CNG	$/PJ	11380630
LNG	$/PJ	12643970
Gasoline	$/PJ	7911934
Diesel	$/PJ	8967489
Aviation Gasoline	$/PJ	7911934
Turbo Jet Fuel	$/PJ	8967489
Light Fuel Oil	$/PJ	5690406

BASE SCENARIO

Node Name	Units	Value
Heavy Fuel Oil	$/PJ	8225101
PCF+Petroleum Products	$/PJ	8225101
Methanol-Gasoline (MOBIL)	$/PJ	7791394
Methanol Gasoline	$/PJ	10345970
Ethanol Gasoline	$/PJ	10417360
Elec / Gas-SBC	$/PJ	16276470
Elec / Gas-SPC	$/PJ	15793380
Elec / LF Oil-CTU	$/PJ	11209590
Elec / HF Oil-SBC	$/PJ	9122595
Elec / Coal-PFC1	$/PJ	9235595
Elec / Coal-PFC2	$/PJ	9357595
Elec / Coal-AFBC	$/PJ	9734571
Elec / Lignite-	$/PJ	6331595
Elec / Uran-New Darl	$/PJ	1569000
Elec / Uran-Existing Darl	$/PJ	4539500
Elec / New Hydro (Large)	$/PJ	2246595
Elec / Existing Hydro	$/PJ	0
Elec / Mun. Refuse	$/PJ	0
Seasonal Peak	$/PJ	71196460
Daily Peak	$/PJ	18668590
Cycling	$/PJ	12456590
Base	$/PJ	5322000
Electricity	$/PJ	7601354
Electricity-Liquid Hydrogen	$/PJ	23845500
Liquid Hydrogen	$/PJ	0
Heat-Pump / R2000 SH	$/PJ	79836380
Heat Pump + Backups / R2000 SH	$/PJ	21264670
Wood Furnace + Backups / R2000 SH	$/PJ	21264670
Active Solar / R2000 SH	$/PJ	1432482
Heating Devices / R2000 SH	$/PJ	21264670
Heat-Pump / ISH	$/PJ	43626380
Heat Pump + Backups / ISH	$/PJ	15317170
Wood Furnace + Backups / ISH	$/?J	15317170
Active Solar / ISH	$/PJ	1432482
Active Solar + Backups / ISH	$/PJ	18891660
Heating Devices / ISH	$/PJ	15317170
Heat-Pump / OBC80H	$/PJ	30856380
Heat Pump + Backups / OBC80H	$/PJ	24004840
Wood Furnace + Backups / OBC80H	$/PJ	12968190
Active Solar / OBC80H	$/PJ	1432482
Active Solar + Backups / OBC80H	$/PJ	12968190
Heating Devices / OBC80H	$/PJ	12968190
Heating Devices / Apts	$/PJ	16140920
Housing Types	$/PJ	0
Apartment / Types	$/PJ	0
Residential Space Heating	$/PJ	0
Active Solar - WH / Houses	$/PJ	91492480
Active Solar + WH Backups / Houses	$/PJ	39037920

BASE SCENARIO

Node Name	Units	Value
Water Heating Devices / Houses	$/PJ	12964670
Water Heating Devices / Apts	$/PJ	11652170
Residential Water Heating	$/PJ	12452790
Heat Pump - Cooling / Houses	$/PJ	14548790
Active Solar - Cooling / Houses	$/PJ	14548790
Central Air-Conditioning	$/PJ	11482900
Residential Air-Conditioning	$/PJ	0
Heating Devices / C&I	$/PJ	16140920
C&I Space Heating	$/PJ	0
C&I Water Heating	$/PJ	11652170
C&I Air-Condioning	$/PJ	4775461
Ind. Indirect Heat	$/PJ	6418875
Ind. Direct Heat	$/PJ	4872210
Ind. Utilities	$/PJ	10219910
Ind. PCF + PP	$/PJ	10437410
Automobiles	$/PJ	28738.98
Aircraft	$/PJ	35124600
Buses	$/PJ	43771660
Marine	$/PJ	81922570
Rail	$/PJ	43771660
Trucks	$/PJ	43771660
Gasolines - Ref 2	$/PJ	7911934
Distillates - Ref 2	$/PJ	8967489
H.Oil&PCF&PP - Ref 2	$/PJ	8225101
Lt.Trucks & Vans	$/PJ	38542.46
Small Hydro	$/PJ	1196595
Gas Tran&Dist	$/PJ	8008734
Propane Tran&Dist	$/PJ	11380630
Methanol Tran&Dist	$/PJ	11380630
Ethanol Tran&Dist	$/PJ	11380630
Gasoline Tran&Dist	$/PJ	10345970
Diesel Tran&Dist	$/PJ	11380630
Aviation Gasoline Tran&Dist	$/PJ	10700030
Jet fuel Tran&Dist	$/PJ	11573210
Light Fuel Oil Tran&Dist	$/PJ	8093688
Heavy Fuel Oil Tran&Dist	$/PJ	10472520
PCF & Petrochemicals Tran&Dist	$/PJ	10437410
Electrical Tran&Dist	$/PJ	14326380
Wood Tran&Dist	$/PJ	5030050
Liq. Hydrogen Tran&Dist	$/PJ	10345960
LNG Tran&Dist	$/PJ	11380630
Refinery - 2 (High Complexity)	$/PJ	8448306
Refinery - 1 (Low Complexity)	$/PJ	8386743
Gasolines - Ref 1	$/PJ	7911934
Distillates - Ref 1	$/PJ	8967489
Heavy Oils - Ref 1	$/PJ	8225101
Electricity Imp/Exp	$/PJ	7601354
Electricity Exports - Transmission	$/PJ	11399730

BASE SCENARIO

Node Name	Units	Value
Mun.Ref Elec - CY	$/PJ	2251000
Mun.Ref Elec - BS	$/PJ	-63131.19
Mun.Ref Elec - Power	$/GW	-111690400
Hydro Elec - >10 MW -SP	$/PJ	160123400
Hydro Elec - >10 MW -DP	$/PJ	16463300
Hydro Elec - >10 MW -CY	$/PJ	6228297
Hydro Elec - >10 MW -BS	$/PJ	4621297
Hydro Elec - >10 MW -POWER	$/GW	0
Hydro Elec - 2-10 MW -SP	$/PJ	35598240
Hydro Elec - 2-10 MW -DP	$/PJ	9334297
Hydro Elec - 2-10 MW -CY	$/PJ	6228297
Hydro Elec - 2-10 MW -BS	$/PJ	2661000
Hydro Elec - 2-10 MW -POWER	$/GW	0
Hydro Elec - EXIST. -SP	$/PJ	-157078000
Hydro Elec - EXIST. -DP	$/PJ	-9256949
Hydro Elec - EXIST. -CY	$/PJ	40840
Hydro Elec - EXIST. -BS	$/PJ	-1578039
Hydro Elec - EXIST. -POWER	$/GW	-213876800
Hydro Elec - >10 MW - Peak	$/PJ	0
Hydro Elec - >10 MW - Peak - SP	$/PJ	0
Hydro Elec - >10 MW - Peak - DP	$/PJ	0
Hydro Elec - >10 MW - Peak - Power	$/GW	0
Hydro Elec - EXIST. - Peak	$/PJ	13057900
Hydro Elec - EXIST. - Peak - SP	$/PJ	6528948
Hydro Elec - EXIST. - Peak - DP	$/PJ	6528948
Hydro Elec - EXIST. - Peak - Power	$/GW	-18997400
Electricity Imports	$/PJ	4897354

VARIABLES

Variable name	Units	Value	Reduced Cost
GAS ONT	1000 Mcf/yr	5514.015	0
GAS-MAC-BFT/EAS.OFF/ARCTIC ISL.	1000 Mcf/yr	916668.3	0
PROPANE-WEST	MLts/yr	0	3432512
COAL-WEST	1000 Tns/yr	14194.86	0
COAL-US	1000 Tns/yr	32392.43	0
CRUDEOIL-FOREIGN/REGIONAL IMP.	1000 Brls/yr	159085.4	0
URANIUM-SASKAT	Tns/yr	3120.092	0
WOOD-ONT	1000 TNS	0	1119950
LIGNITE-SASKAT.	1000 Tns/yr	0	2323574
EXISTING HYDRO - PEAKING UNITS	GWh/yr	1516.388	-13057900
NEW HYDRO (>10 MW) - PEAKING UNI	GWh/yr	0	0
EXISTING HYDRO - ALL CATEG.	GWh/yr	22501.62	0
NEW HYDRO (>10MW) - ALL CATEG.	GWh/yr	4073.333	-2246595
SMALL HYDRO (2-10 MW) - ALL CATEG.	GWh/yr	628.0554	-1196595
CORN-ONT-ETHL	1000 TNS	0	12241010
BARLEY-ONT-ETHL	1000 TNS	0	11043650
WHEAT-ONT-ETHL	1000 TNS	0	14068900
MUNREFUSE-ELEC	GWh/yr	780.0556	0
COAL-SYNCRUDE	PJ/yr	0	884815.3

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
GAS-GSL(MOBIL)	PJ/yr	0	0
COAL-GSL(ZNCL2)	PJ/yr	0	0
COAL-GSL(MOBIL)	PJ/yr	0	3377248
COAL-GSLDSL(SASOL)	PJ/yr	0	0
ELEC-GAS-GSL(MOBIL)	PJ/yr	0	0
ELEC-COAL-GSL(MOBIL)	PJ/yr	0	0
GAS-MTHL	PJ/yr	0	0
COAL-MTHL	PJ/yr	0	0
WOOD-MTHL	PJ/yr	0	2789050
ELEC-GAS-MTHL	PJ/yr	0	0
MTHL-GSL(MOBIL)	PJ/yr	0	0
ELEC-MTHL-GSL(MOBIL)	PJ/yr	0	0.000001
GAS-ETHL	PJ/yr	0	5826728
COAL-ETHL	PJ/yr	0	0
WOOD-ETHL	PJ/yr	0	0
COAL-CORN-ETHL	PJ/yr	0	0
COAL-BARLEY-ETHL	PJ/yr	0	0
COAL-WHEAT-ETHL	PJ/yr	0	0
ELEC-GAS-ETHL	PJ/yr	0	0
GAS-COAL-ETHL	PJ/yr	0	62839450
ELEC-COAL-ETHL	PJ/yr	0	0
ELEC-WOOD-ETHL	PJ/yr	0	58580970
COAL-LHYGN	PJ/yr	0	0
GAS-LHYGN	PJ/yr	0	0
ELEC-LHYGN	PJ/yr	0	0
ELEC-COAL-LHYGN	PJ/yr	0	39878200
ELEC-GAS-LHYGN	PJ/yr	0	43613240
SYNCRUDE-REF	TJ/yr	0	0
CRUDE-REF 1 (LOW COMPLEX.)	TJ/yr	970421.1	0
CRUDE-REF 2 (HIGH COMPLEX.)	TJ/yr	0	247867.5
REF 2-GASOLINES	TJ/yr	0	0
REF 2-DISTILLATES	TJ/yr	0	0
REF 2-H.OIL&PCF&PP	TJ/yr	0	0
REF 2-PROPANE	TJ/yr	0	0
GSL 2-GASOLINES	TJ/yr	0	0
DSL 2-DISTILLATES	TJ/yr	0	0
AGSL 2-GASOLINES	TJ/yr	0	0
TJF 2-DISTILLATES	TJ/yr	0	0
LFO 2-DISTILLATES	TJ/yr	0	3277083
HFO 2-H.OIL&PCF&PP	TJ/yr	0	0
PCF&PP 2-H.OIL&PCF&PP	TJ/yr	0	0
REF 1-GASOLINES	TJ/yr	156833.8	0
REF 1-DISTILLATES	TJ/yr	272484.3	0
REF 1-H.OIL&PCF&PP	TJ/yr	494395.5	0
REF 1-PROPANE	TJ/yr	5949.847	0
GSL 1-GASOLINES	TJ/yr	156560.5	0
DSL 1-DISTILLATES	TJ/yr	227096.6	0
AGSL 1-GASOLINES	TJ/yr	273.4201	0

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
TJF 1-DISTILLATES	TJ/yr	45387.77	0
LFO 1-DISTILLATES	TJ/yr	0	3277083
HFO 1-H.OIL&PCF&PP	TJ/yr	56961.97	0
PCF&PP 1-H.OIL&PCF&PP	TJ/yr	437433.3	0
GSL-IMPORTS	PJ/yr	0	1684066
DSL-IMPORTS	PJ/yr	0	628510.6
AGSL-IMPORTS	PJ/yr	0	1684066
TJF-IMPORTS	PJ/yr	0	628510.6
LFO-IMPORTS	PJ/yr	0	3905594
HFO-IMPORTS	PJ/yr	0	1370899
PCF&PP IMPORTS	PJ/yr	0	1370899
GSL-EXPORTS	PJ/yr	0	-1606066
DSL-EXPORTS	PJ/yr	0	-550510.6
AGSL-EXPORTS	PJ/yr	0	-1606066
TJF-EXPORTS	PJ/yr	0	-550510.6
LFO-EXPORTS	PJ/yr	0	-3827594
HFO-EXPORTS	PJ/yr	0	-1292899
PCF&PP-EXPORTS	PJ/yr	0	-1292899
ELEC-CNG	PJ/yr	0	3241648
ELEC-LNG	PJ/yr	0	2404382
CNG	TJ/yr	49455.27	0
LNG	TJ/yr	0	0
GSL(MOBIL)-GAS	TJ/yr	0	9460997
GSL(ZNCL2)-COAL	TJ/yr	0	7396968
GSL(MOBIL)-COAL	TJ/yr	0	0
GSL(MOBIL)-MTHL	TJ/yr	0	746655
GSL-COAL(SASOL)	TJ/yr	0	14328670
DSL-COAL(SASOL)	TJ/yr	0	13273120
MTHL-GAS	TJ/yr	0	6726081
MTHL-COAL	TJ/yr	0	8588737
MTHL-WOOD	TJ/yr	0	529511.8
ETHL-GAS	TJ/yr	0	1011512
ETHL-COAL	TJ/yr	0	6815512
ETHL-WOOD	TJ/yr	0	2314512
ETHL-CORN	TJ/yr	0	0
ETHL-BARLEY	TJ/yr	0	0
ETHL-WHEAT	TJ/yr	0	0
LHYGN-GAS	TJ/yr	0	2512000
LHYGN-COAL	TJ/yr	0	7394000
LHYGN-ELEC	TJ/yr	0	31393500
GSL-MTHLGSLBLD	PJ/yr	0	0
GSL-ETHLGSLBLD	PJ/yr	0	0
MTHL-MTHLGSLBLD	PJ/yr	0	1034658
ETHL-ETHLGSLBLD	PJ/yr	0	0
PROPANE-MOBIL(GAS)	TJ/yr	0	0
PROPANE-MOBIL(COAL)	TJ/yr	0	0
PROPANE-MOBIL(MTHL)	TJ/yr	0	0
GAS-SBC-ELEC	PJ/yr	14.99981	0

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
GAS-SPC-ELEC	PJ/yr	0	0
COAL-PFC1-ELEC	PJ/yr	0	133081.8
COAL-PFC2-ELEC	PJ/yr	152.5364	0
COAL-AFBC-ELEC	PJ/yr	0	0
HOIL-SBC-ELEC	PJ/yr	0	5037666
LOIL-CTU-ELEC	PJ/yr	0	2960870
URAN-NWDL-ELEC	PJ/yr	332.4514	0
URAN-EXDL-ELEC	PJ/yr	230.85	-2970500
ELEC-GAS-SBC-SP	GWh/yr	1416.649	0
ELEC-GAS-SBC-DP	GWh/yr	0	2907877
ELEC-GAS-SPC-SP	GWh/yr	0	6246908
ELEC-GAS-SPC-DP	GWh/yr	0	3072786
ELEC-LOIL-CTU-SP	GWh/yr	0	17313120
ELEC-LOIL-CTU-DP	GWh/yr	0	0
ELEC-HOIL-SBC-SP	GWh/yr	0	41726120
ELEC-HOIL-SBC-DP	GWh/yr	0	474000
ELEC-HOIL-SBC-CYC	GWh/yr	0	0
ELEC-HOIL-SBC-BASE	GWh/yr	0	6084595
ELEC-COAL-PFC1-SP	GWh/yr	0	38339120
ELEC-COAL-PFC1-DP	GWh/yr	0	246000
ELEC-COAL-PFC1-CYC	GWh/yr	0	0
ELEC-COAL-PFC1-BASE	GWh/yr	0	6120595
ELEC-COAL-PFC2-SP	GWh/yr	0	34651120
ELEC-COAL-PFC2-DP	GWh/yr	6254.539	0
ELEC-COAL-PFC2-CYC	GWh/yr	9172.828	0
ELEC-COAL-PFC2-BASE	GWh/yr	0	6158595
ELEC-COAL-AFBC-SP	GWh/yr	0	87138090
ELEC-COAL-AFBC-DP	GWh/yr	0	5405976
ELEC-COAL-AFBC-CYC	GWh/yr	0	2050976
ELEC-COAL-AFBC-BASE	GWh/yr	0	7681571
ELEC-LGTE-ELEC-SP	GWh/yr	0	125835100
ELEC-LGTE-ELEC-DP	GWh/yr	0	6063000
ELEC-LGTE-ELEC-CYC	GWh/yr	0	0
ELEC-LGTE-ELEC-BASE	GWh/yr	0	5205595
ELEC-URAN-NWDL-BASE	GWh/yr	92347.56	0
ELEC-URAN-EXDL-BASE	GWh/yr	64125	0
ELEC-NWHY(>10MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-PEAK U.-SP-E.T.P	PJ/yr	0	0
ELEC-NWHY(>10 MW)-PEAK U.-DP-E.T.P	PJ/yr	0	0
ELEC-NWHY(>10MW)-PEAK U.-POWER	GW	0	0
ELEC-NWHY(>10MW)-SP	GWh/yr	0	332203500
ELEC-NWHY(>10MW)-DP	GWh/yr	0	20261400
ELEC-NWHY(>10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-CYC	GWh/yr	4073.333	0
ELEC-NWHY(>10 MW)-BASE	GWh/yr	0	0
ELEC-NWHY(>10 MW)-SP-ENGY TO PWR	PJ/yr	0	249050300

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-NWHY(>10 MW)-DP-ENGY TO PWR	PJ/yr	0	14258000
ELEC-NWHY(>10 MW)-CY-ENGY TO PWR	PJ/yr	14.66399	0
ELEC-NWHY(>10 MW)-BS-ENGY TO PWR	PJ/yr	0	3920595
ELEC-NWHY(>10 MW)-POWER	GW	0.848459	0
ELEC-NWHY(>10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-CYC	GWh/yr	4073.333	0
ELEC-NWHY(>10 MW)-BASE	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-SP	GWh/yr	0	280500200
ELEC-NWHY(2-10 MW)-DP	GWh/yr	0	16348000
ELEC-NWHY(2-10 MW)-CYC	GWh/yr	628.0554	0
ELEC-NWHY(2-10 MW)-BASE	GWh/yr	0	3586595
ELEC-NWHY(2-10 MW)-SP-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-DP-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-CY-ENGY TO PWR	PJ/yr	2.261	0
ELEC-NWHY(2-10 MW)-BS-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-POWER	GW	0.130821	0
ELEC-NWHY(2-10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-CYC	GWh/yr	628.0554	0
ELEC-NWHY(2-10 MW)-BASE	GWh/yr	0	0
ELEC-EX.HYDRO-PEAK U.-SP	GWh/yr	3.063408	0
ELEC-EX.HYDRO-PEAK U.-DP	GWh/yr	1513.325	0
ELEC-EX.HYDRO-PEAK U.-SP-E.T.PWR	PJ/yr	0.011028	0
ELEC-EX.HYDRO-PEAK U.-DP-E.T.PWR	PJ/yr	5.447971	0
ELEC-EX.HYDRO-PEAK U.-POWER	GW	0.967	-18997400
ELEC-EX.HYDRO-PEAK U.-SP	GWh/yr	3.063408	0
ELEC-EX.HYDRO-PEAK U.-DP	GWh/yr	1513.325	0
ELEC-EXHY-SP	GWh/yr	0	315303100
ELEC-EXHY-DP	GWh/yr	0	18624600
ELEC-EXHY-CYC	GWh/yr	22501.62	0
ELEC-EXHY-BASE	GWh/yr	0	3212028
ELEC-EXHY-SP-ENGY TO POWER	PJ/yr	0	0
ELEC-EXHY-DP-ENGY TO POWER	PJ/yr	0	0
ELEC-EXHY-CYC-ENGY TO POWER	PJ/yr	81.00587	0
ELEC-EXHY-BASE-ENGY TO POWER	PJ/yr	0	0
ELEC-EXHY-POWER	GW	4.687	-213876800
ELEC-EXHY-SP	GWh/yr	0	0
ELEC-EXHY-DP	GWh/yr	0	0
ELEC-EXHY-CYC	GWh/yr	22501.62	0
ELEC-EXHY-BASE	GWh/yr	0	0
ELEC-MUNREFUSE-CYC	GWh/yr	780.0556	0
ELEC-MUNREFUSE-BASE	GWh/yr	0	2245262
ELEC-MUNREFUSE-CYC-ENGY TO POWER	PJ/yr	2.808201	0
ELEC-MUNREFUSE-BASE-ENGY TO POWER	PJ/yr	0	0
ELEC-MUNREFUSE-POWER	GW	0.2	-111690400
ELEC-MUNREFUSE-CYC	GWh/yr	780.0556	0
ELEC-MUNREFUSE-BASE	GWh/yr	0	0

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-TOTALSP	PJ/yr	5.110967	0
ELEC-TOTALDP	PJ/yr	27.9643	0
ELEC-TOTALCYC	PJ/yr	133.7613	0
ELEC-TOTALBASE	PJ/yr	563.3015	0
ELEC-TOTAL	PJ/yr	730.1379	0
ELEC-EXPORTS-TRAN.	PJ/yr	55.30973	0
ELEC-EXPORT	PJ/yr	50	-610271.6
ELEC-IMPORT	PJ/yr	0	11312650
ELEC-IMPORTS-TRAN.	PJ/yr	0	0
GAS-TRAN&DIST	PJ/yr	971.7353	0
PROPANE-TRAN&DIST	PJ/yr	5.949851	0
METHANOL-TRAN&DIST	PJ/yr	0	0
ETHANOL-TRAN&DIST	PJ/yr	0	0
GASOLINE-TRAN&DIST	PJ/yr	156.5605	0
DIESEL-TRAN&DIST	PJ/yr	227.0966	0
AV.GAS-TRAN&DIST	PJ/yr	0.27342	0
JET FUEL-TRAN&DIST	PJ/yr	45.38777	0
LFO-TRAN&DIST	PJ/yr	0	0
HFO-TRAN&DIST	PJ/yr	56.96197	0
PCF&PP-TRAN&DIST	PJ/yr	437.4333	0
ELEC-TRAN&DIST	PJ/yr	674.8281	0
WOOD-TRAN&DIST	PJ/yr	0	0
LHYGN-TRAN&DIST	PJ/yr	0	44635080
LNG-TRAN&DIST	PJ/yr	0	5822483
ELEC-HTP-R2SH-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-R2SH-SH	TJ/yr	0	7157628
LOIL-FCE+HTP-R2SH-SH	TJ/yr	0	8581401
ELEC-RES+HTP-R2SH-SH	TJ/yr	0	0
HT-ENERGY-HTP-R2SH-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-R2SH-SH	PJ/yr	0	0
GAS-WCBFCE-R2SH-SH	PJ/yr	0	0
LOIL-WCBFCE-R2SH-SH	PJ/yr	0	84954
ELEC-WDFCE+RES-R2SH-SH	PJ/yr	0	2005253
WOOD-OPTS+WDFCE-R2SH-SH	TJ/yr	0	2745020
ENERGY-OPTS+WDFCE-R2SH-SH	PJ/yr	0	0
ELEC-ASR-R2SH-SH&WH&AC	PJ/yr	0	0
ASR-R2SH-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-R2SH-SH	TJ/yr	0	16067820
GAS-CGF-R2SH-SH	TJ/yr	0	3195240
GAS-FCE-R2SH-SH	TJ/yr	20130	0
LOIL-FCE-R2SH-SH	TJ/yr	0	971187.6
ELEC-RES-R2SH-SH	TJ/yr	0	337714.8
ELEC-HTP-ISH-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-ISH-SH	TJ/yr	0	1217628
LOIL-FCE+HTP-ISH-SH	TJ/yr	0	2001401
ELEC-RES+HTP-ISH-SH	TJ/yr	0	0
HT-ENERGY-ISH-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-ISH-SH	PJ/yr	0	0

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
GAS-WCBFCE-ISH-SH	PJ/yr	0	0
LOIL-WCBFCE-ISH-SH	PJ/yr	0	84954
ELEC-WDFCE+RES-ISH-SH	PJ/yr	0	2005253
WOOD-WCBFCE+OPTS-ISH-SH	TJ/yr	0	518016
ENERGY-WCBFCE+OPTS-ISH-SH	PJ/yr	0	0
GAS-FCE+ASR-ISH-SH	TJ/yr	0	0
LOIL-FCE+ASR-ISH-SH	TJ/yr	0	667812.5
ELEC-RES+ASR-ISH-SH	TJ/yr	0	2564215
ELEC-ASR-ISH-SH&WH&AC	PJ/yr	0	0
ASR-ISH-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-ISH-SH	TJ/yr	0	0
ENERGY-ASR+OPTS-ISH-SH	PJ/yr	0	3574492
GAS-CGF-ISH-SH	TJ/yr	0	802939.8
GAS-FCE-ISH-SH	TJ/yr	54567.5	0
LOIL-FCE-ISH-SH	TJ/yr	0	667812.5
ELEC-RES-ISH-SH	TJ/yr	0	2564215
ELEC-HTP-OBC80-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-OBC80-SH	TJ/yr	0	0
LOIL-FCE+HTP-OBC80-SH	TJ/yr	0	597562.5
ELEC-RES+HTP-OBC80-SH	TJ/yr	0	3354215
HT ENERGY-HTP-OBC80-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-OBC80-SH	PJ/yr	0	11036660
GAS-WCBFCE-OBC80-SH	PJ/yr	0	0
LOIL-WCBFCE-OBC80-SH	PJ/yr	0	84954
ELEC-WDFCE+RES-OBC80-SH	PJ/yr	0	2005253
WOOD-WCBFCE-OBC80-SH	TJ/yr	0	0
ENERGY-WCBFCE+OPTS-OBC80-SH	PJ/yr	0	0
GAS-FCE+ASR-OBC80-SH	TJ/yr	0	67182.68
LOIL-FCE+ASR-OBC80-SH	TJ/yr	0	660546.1
ELEC-RES+ASR-OBC80-SH	TJ/yr	0	3438193
ELEC-ASR-OBC80-SH&WH&AC	PJ/yr	0	0
ASR-OBC80-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-OBC80-SH	TJ/yr	0	6234293
ENERGY-ASR+OPTS-OBC80-SH	PJ/yr	0	0
GAS-CGF-OBC80-SH	TJ/yr	105476	0
GAS-FCE-OBC80-SH	TJ/yr	0	67182.68
LOIL-FCE-OBC80-SH	TJ/yr	0	660546.1
ELEC-RES-OBC80-SH	TJ/yr	0	3438193
GAS-CGB-APT-SH	TJ/yr	0	976135.8
GAS-IGB-APT-SH	TJ/yr	38865	0
LOIL-BLR-APT-SH	TJ/yr	0	0
ELEC-BLR-APT-SH	TJ/yr	0	3032465
ELEC-BSD-APT-SH	TJ/yr	0	4405465
ENERGY-R2SH-SH	PJ/yr	16.104	48914670
ENERGY-ISH-SH	PJ/yr	43.654	29137160
ENERGY-OBC80-SH	PJ/yr	97.03799	12968190
ENERGY-NWA-SH	PJ/yr	19.147	16140920
ENERGY-ODA-SH	PJ/yr	11.94499	16140920

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
ENERGY-H-SH	PJ/yr	156.796	0
ENERGY-A-SH	PJ/yr	31.09199	0
ENERGY-RES-SH	PJ/yr	187.888	0
ENERGY-SR(WH)-R2SH	PJ/yr	0	0
ENERGY-SR(WH)-ISH	PJ/yr	0	0
ENERGY-SR(WH)-OBC80H	PJ/yr	0	0
ENERGY-SR(WH)-HOUSES	PJ/yr	0	0
ENERGY-ASR+BKP-H-WH	PJ/yr	0	26073240
GAS-WHR+ASR-H-WH	PJ/yr	0	0
ELEC-WHR+ASR-H-WH	PJ/yr	0	1930965
GAS-WHR-H-WH	PJ/yr	87.10649	0
ELEC-WHR-H-WH	PJ/yr	0	2692715
GAS-BLR-A-WH	PJ/yr	55.691	0
ELEC-BLR-A-WH	PJ/yr	0	4005215
ENERGY-H-WH	PJ/yr	69.68519	0
ENERGY-A-WH	PJ/yr	44.55281	0
ENERGY-RES-WH	PJ/yr	114.238	12452790
ELEC-IWAC-AC	PJ/yr	5.313	16732380
ENERGY-HTP(CAC)-R2SH	PJ/yr	0	0
ENERGY-HTP(CAC)-ISH	PJ/yr	0	0
ENERGY-HTP(CAC)-OBC80	PJ/yr	0	0
ENERGY-HTP(CAC)-HOUSES	PJ/yr	0	0
ENERGY-ASR(CAC)-R2SH	PJ/yr	0	4223447
ENERGY-ASR(CAC)-ISH	PJ/yr	0	4223447
ENERGY-ASR(CAC)-OBC80	PJ/yr	0	4223447
ENERGY-ASR(CAC)-HOUSES	PJ/yr	0	0
ELEC-CAC-AC-HOUSES	PJ/yr	4.928777	0
ELEC-CAC-AC (APT)	PJ/yr	2.252889	0
ENERGY-CAC-RES	PJ/yr	21.54499	11482900
ENERGY-RES-AC	PJ/yr	37.48399	0
ELEC-RES-APP&LTG	PJ/yr	115.3789	14326380
GAS-CGB-C&I-SH	TJ/yr	0	976135.8
GAS-IGB-C&I-SH	TJ/yr	318645	0
LOIL-BLR-C&I-SH	TJ/yr	0	0
ELEC-BLR-C&I-SH	TJ/yr	0	3032465
ELEC-BSD-C&I-SH	TJ/yr	0	4405465
ENERGY-NWBDGS-C&I-SH	PJ/yr	194.136	16140920
ENERGY-ODBDGS-C&I-SH	PJ/yr	60.77999	16140920
ENERGY-C&I-SH	PJ/yr	254.916	0
GAS-BLR-C&I-WH	PJ/yr	17.985	0
ELEC-BLR-C&I-WH	PJ/yr	0	4005215
ENERGY-C&I-WH	PJ/yr	14.38799	11652170
ELEC-C&I-AC	PJ/yr	15.81933	0
ENERGY-C&I-AC	PJ/yr	47.45799	4775461
ELEC-C&I-EQPT&LTG	PJ/yr	100.716	14326380
GAS-BLR-I-IH	PJ/yr	0	3445534
HOIL-BLR-I-IH	PJ/yr	0	6391562
COAL-BLR-I-IH	PJ/yr	716.1801	0

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
ENERGY-I-IH	PJ/yr	572.944	6418875
GAS-BR-I-DH	PJ/yr	43.52664	0
HOIL-BR-I-DH	PJ/yr	43.52664	0
ELEC-HD-I-DH	PJ/yr	5.440506	0
COAL-BF-I-DH	PJ/yr	519.0681	0
ENERGY-I-DH	PJ/yr	544.083	4872210
ELEC-EM&EL.CHMLS-I	PJ/yr	254.404	14326380
GAS-I-UTL	PJ/yr	98.66154	0
ELEC-I-UTL	PJ/yr	53.12545	0
LOIL-I-UTL	PJ/yr	0	84954
ENERGY-I-UTL	PJ/yr	151.787	10219910
PROPANE-I-PPCF	PJ/yr	0	943216.8
OBPPCF-I-REF	PJ/yr	436.121	0
ENERGY-I-PPCF	PJ/yr	436.121	10437410
PROPANE-TRN-AUTO	PJ/yr	5.932001	0
MTHL-TRN-AUTO	PJ/yr	0	0
ETHL-TRN-AUTO	PJ/yr	0	0
CNG-TRN-AUTO	PJ/yr	48.16943	0
LNG-TRN-AUTO	PJ/yr	0	0
GASOLINE-TRN-AUTO	PJ/yr	91.68118	0
DIESEL-TRN-AUTO	PJ/yr	113.4503	0
METHGSL-TRN-AUTO	PJ/yr	0	0.3081
ETHGSL-TRN-AUTO	PJ/yr	0	71391.87
LHYGN-TRN-AUTO	PJ/yr	0	0
ELEC-TRN-AUTO	PJ/yr	43.58651	0
ENERGY-TRN-AUTO	Mkms/yr	121083.3	28738.98
PROPANE-TRN-LT.TKS&VANS	PJ/yr	0	15.61464
MTHL-TRN-LT.TKS&VANS	PJ/yr	0	15.61464
ETHL-TRN-LT.TKS&VANS	PJ/yr	0	15.61464
CNG-TRN-LT.TKS&VANS	PJ/yr	0	15.61464
LNG-TRN-LT.TKS&VANS	PJ/yr	0	15.61464
GASOLINE-TRN-LT.TKS&VANS	PJ/yr	64.40959	0
DIESEL-TRN-LT.TKS&VANS	PJ/yr	0	15.56064
METHGSL-TRN-LT.TKS&VANS	PJ/yr	0	0.3211
ETHGSL-TRN-LT.TKS&VANS	PJ/yr	0	71391.87
LHYGN-TRN-LT.TKS&VANS	PJ/yr	0	0.54
ELEC-TRN-LT.TRKS&VANS	PJ/yr	10.16853	0
ENERGY-TRN-LT.TKS&VANS	Mkms/yr	21069.17	38542.46
AVGAS-TRN-ACRAFT	PJ/yr	0.2726	0
TJFUEL-TRN-ACRAFT	PJ/yr	45.2516	0
ENERGY-TRN-ACRAFT	PJ/yr	14.993	35124600
DSL-TRN-BUS	PJ/yr	8.719232	0
PROPANE-TRN-BUS	PJ/yr	0	875431.3
CNG-TRN-BUS	PJ/yr	0	875431.3
LNG-TRN-BUS	PJ/yr	0	875431.3
MTHL-TRN-BUS	PJ/yr	0	875431.3
ETHL-TRN-BUS	PJ/yr	0	875431.3
LHYGN-TRN-BUS	PJ/yr	0	716195.5

BASE SCENARIO

Variable Name	Units	Value	Reduced Cost
ENERGY-TRN-BUS	PJ/yr	2.267	43771660
DIESEL-TRN-MRN	PJ/yr	7.611238	0
HOIL-TRN-MRN	PJ/yr	13.26445	0
ENERGY-TRN-MRN	PJ/yr	2.753	81922570
DSL-TRN-RAIL	PJ/yr	25.37307	0
ELEC-TRN-RAIL	PJ/yr	0	0
ENERGY-TRN-RAIL	PJ/yr	6.597	43771660
DIESEL-TRN-TRUCK	PJ/yr	71.26153	0
PROPANE-TRN-TRUCK	PJ/yr	0	875431.6
CNG-TRN-TRUCK	PJ/yr	0	875431.6
LNG-TRN-TRUCK	PJ/yr	0	875431.6
MTHL-TRN-TRUCK	PJ/yr	0	875431.6
ETHL-TRN-TRUCK	PJ/yr	0	875431.6
LHYGN-TRN-TRUCK	PJ/yr	0	716198.3
ENERGY-TRN-TRUCK	PJ/yr	18.52799	43771660
ELEC-TRN-STC&SBY	PJ/yr	1.61	14326380

MODEL NAME:	Ontario Energy Optimisation Model	
SOLUTION	High Energy Demand Scenario	
OBJECTIVE FUNCTION VALUE	Dollars	3.953736000E+10

MARGINAL COST

Node Name	Units	Value
Gas Supply	$/PJ	4135000
Propane Supply	$/PJ	5937150
Coal Supply	$/PJ	2561000
Uranium Supply	$/PJ	1231000
Wood Supply	$/PJ	1728937
Syncrude	$/PJ	2564000
Refineries Dist.	$/PJ	5627000
Gas-Gasoline (Mobil)	$/PJ	8459724
Gas-Methanol	$/PJ	6777420
Gas-ethanol	$/PJ	0
Gas-Liquid Hydrogen	$/PJ	0
Coal-Gsl+Dsl (FT-SASOL)	$/PJ	9876591
Coal-Gasoline (ZnCl2)	$/PJ	4755715
Coal-Gasoline (Mobil)	$/PJ	-1532818
Coal-Methanol	$/PJ	6677967
Coal-Ethanol	$/PJ	0
Coal-Liquid Hydrogen	$/PJ	0
Wood-Methanol	$/PJ	0
Wood-Ethanol	$/PJ	0

HIGH SCENARIO

Node Name	Units	Value
Corn-Ethanol	$/PJ	1746150
Barley-Ethanol	$/PJ	3599150
Wheat-Ethanol	$/PJ	2066150
Methanol	$/PJ	4441150
Ethanol	$/PJ	5564150
CNG	$/PJ	9574875
LNG	$/PJ	11160250
Gasoline	$/PJ	6275272
Diesel	$/PJ	7167151
Aviation Gasoline	$/PJ	6275272
Turbo Jet Fuel	$/PJ	7167151
Light Fuel Oil	$/PJ	7167151
Heavy Fuel Oil	$/PJ	5765004
PCF+Petroleum Products	$/PJ	5765004
Methanol-Gasoline (MOBIL)	$/PJ	5547566
Methanol Gasoline	$/PJ	8704386
Ethanol Gasoline	$/PJ	8764450
Elec / Gas-SBC	$/PJ	12161770
Elec / Gas-SPC	$/PJ	11800800
Elec / LF Oil-CTU	$/PJ	8885782
Elec / HF Oil-SBC	$/PJ	6798782
Elec / Coal-PFC1	$/PJ	6911782
Elec / Coal-PFC2	$/PJ	7033782
Elec / Coal-AFBC	$/PJ	7317142
Elec / Lignite-	$/PJ	4007782
Elec / Uran-New Darl	$/PJ	1231000
Elec / Uran-Existing Darl	$/PJ	4201500
Elec / New Hydro (Large)	$/PJ	0
Elec / Existing Hydro	$/PJ	0
Elec / Mun. Refuse	$/PJ	0
Seasonal Peak	$/PJ	67081770
Daily Peak	$/PJ	16344780
Cycling	$/PJ	10132780
Base	$/PJ	4984000
Electricity	$/PJ	6797060
Electricity-Liquid Hydrogen	$/PJ	22371160
Liquid Hydrogen	$/PJ	0
Heat-Pump / R2000 SH	$/PJ	78950590
Heat Pump + Backups / R2000 SH	$/PJ	19355550
Wood Furnace + Backups / R2000 SH	$/PJ	19355550
Active Solar / R2000 SH	$/PJ	1343913
Heating Devices / R2000 SH	$/PJ	19355550
Heat-Pump / ISH	$/PJ	42740590
Heat Pump + Backups / ISH	$/PJ	13408050
Wood Furnace + Backups / ISH	$/PJ	13408050
Active Solar / ISH	$/PJ	1343913
Active Solar + Backups / ISH	$/PJ	18657450
Heating Devices / ISH	$/PJ	13408050

HIGH SCENARIO

Node Name	Units	Value
Heat-Pump / OBC80H	$/PJ	29970590
Heat Pump + Backups / OBC80H	$/PJ	24099320
Wood Furnace + Backups / OBC80H	$/PJ	11143050
Active Solar / OBC80H	$/PJ	1343913
Active Solar + Backups / OBC80H	$/PJ	14969070
Heating Devices / OBC80H	$/PJ	11143050
Heating Devices / Apts	$/PJ	14231800
Housing Types	$/PJ	0
Apartment / Types	$/PJ	0
Residential Space Heating	$/PJ	0
Active Solar - WH / Houses	$/PJ	91403900
Active Solar + WH Backups / Houses	$/PJ	37711370
Water Heating Devices / Houses	$/PJ	11055550
Water Heating Devices / Apts	$/PJ	9743051
Residential Water Heating	$/PJ	10543680
Heat Pump - Cooling / Houses	$/PJ	14253530
Active Solar - Cooling / Houses	$/PJ	14253530
Central Air-Conditioning	$/PJ	11187640
Residential Air-Conditioning	$/PJ	0
Heating Devices / C&I	$/PJ	14231800
C&I Space Heating	$/PJ	0
C&I Water Heating	$/PJ	9743051
C&I Air-Condioning	$/PJ	4480198
Ind. Indirect Heat	$/PJ	5361250
Ind. Direct Heat	$/PJ	3736569
Ind. Utilities	$/PJ	8917145
Ind. PCF + PP	$/PJ	7969914
Automobiles	$/PJ	24678.42
Aircraft	$/PJ	29644650
Buses	$/PJ	36826440
Marine	$/PJ	65041340
Rail	$/PJ	36826440
Trucks	$/PJ	36826440
Gasolines - Ref 2	$/PJ	6275272
Distillates - Ref 2	$/PJ	7167151
H.Oil&PCF&PP - Ref 2	$/PJ	5765004
Lt.Trucks & Vans	$/PJ	33096.55
Small Hydro	$/PJ	0
Gas Tran&Dist	$/PJ	6481441
Propane Tran&Dist	$/PJ	9574875
Methanol Tran&Dist	$/PJ	9574875
Ethanol Tran&Dist	$/PJ	9574875
Gasoline Tran&Dist	$/PJ	8704386
Diesel Tran&Dist	$/PJ	9574876
Aviation Gasoline Tran&Dist	$/PJ	9058448
Jet fuel Tran&Dist	$/PJ	9767454
Light Fuel Oil Tran&Dist	$/PJ	6661851
Heavy Fuel Oil Tran&Dist	$/PJ	8005019

HIGH SCENARIO

Node Name	Units	Value
PCF & Petrochemicals Tran&Dist	$/PJ	7969914
Electrical Tran&Dist	$/PJ	13440590
Wood Tran&Dist	$/PJ	3969937
Liq. Hydrogen Tran&Dist	$/PJ	8704373
LNG Tran&Dist	$/PJ	9574875
Refinery - 2 (High Complexity)	$/PJ	6580105
Refinery - 1 (Low Complexity)	$/PJ	6265658
Gasolines - Ref 1	$/PJ	6275272
Distillates - Ref 1	$/PJ	7167151
Heavy Oils - Ref 1	$/PJ	5765004
Electricity Imp/Exp	$/PJ	6797060
Electricity Exports - Transmission	$/PJ	9603000
Mun.Ref Elec - CY	$/PJ	2251000
Mun.Ref Elec - BS	$/PJ	563681.8
Mun.Ref Elec - Power	$/GW	-79061840
Hydro Elec - >10 MW -SP	$/PJ	159000000
Hydro Elec - >10 MW -DP	$/PJ	15340000
Hydro Elec - >10 MW -CY	$/PJ	5066391
Hydro Elec - >10 MW -BS	$/PJ	3498000
Hydro Elec - >10 MW -POWER	$/GW	0
Hydro Elec - 2-10 MW -SP	$/PJ	33540880
Hydro Elec - 2-10 MW -DP	$/PJ	8172391
Hydro Elec - 2-10 MW -CY	$/PJ	5066391
Hydro Elec - 2-10 MW -BS	$/PJ	2492000
Hydro Elec - 2-10 MW -POWER	$/GW	0
Hydro Elec - EXIST. -SP	$/PJ	-122953900
Hydro Elec - EXIST. -DP	$/PJ	-6927714
Hydro Elec - EXIST. -CY	$/PJ	40840
Hydro Elec - EXIST. -BS	$/PJ	-951015
Hydro Elec - EXIST. -POWER	$/GW	-173714200
Hydro Elec - >10 MW - Peak	$/PJ	0
Hydro Elec - >10 MW - Peak - SP	$/PJ	0
Hydro Elec - >10 MW - Peak - DP	$/PJ	0
Hydro Elec - >10 MW - Peak - Power	$/GW	0
Hydro Elec - EXIST. - Peak	$/PJ	10925340
Hydro Elec - EXIST. - Peak - SP	$/PJ	5462670
Hydro Elec - EXIST. - Peak - DP	$/PJ	5462670
Hydro Elec - EXIST. - Peak - Power	$/GW	-17897280
Electricity Imports	$/PJ	4093060

VARIABLES

Variable name	Units	Value	Reduced Cost
GAS ONT	1000 Mcf/yr	5514.015	0
GAS-MAC-BFT/EAS.OFF/ARCTIC ISL.	1000 Mcf/yr	1149628	0
PROPANE-WEST	MLts/yr	0	2256850
COAL-WEST	1000 Tns/yr	20638.05	0
COAL-US	1000 Tns/yr	47095.69	0
CRUDEOIL-FOREIGN/REGIONAL IMP.	1000 Brls/yr	232957.8	0
URANIUM-SASKAT	Tns/yr	3861.085	0

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
WOOD-ONT	1000 TNS	0	1227063
LIGNITE-SASKAT.	1000 Tns/yr	0	1971432
EXISTING HYDRO - PEAKING UNITS	GWh/yr	1516.388	-10925340
NEW HYDRO (>10 MW) - PEAKING UNI	GWh/yr	0	0
EXISTING HYDRO - ALL CATEG.	GWh/yr	22501.62	0
NEW HYDRO (>10MW) - ALL CATEG.	GWh/yr	0	0
SMALL HYDRO (2-10 MW) - ALL CATEG.	GWh/yr	0	0
CORN-ONT-ETHL	1000 TNS	0	9799148
BARLEY-ONT-ETHL	1000 TNS	0	8517322
WHEAT-ONT-ETHL	1000 TNS	0	11053050
MUNREFUSE-ELEC	GWh/yr	780.0556	0
COAL-SYNCRUDE	PJ/yr	0	1153877
GAS-GSL(MOBIL)	PJ/yr	0	0
COAL-GSL(ZNCL2)	PJ/yr	0	0
COAL-GSL(MOBIL)	PJ/yr	0	3037511
COAL-GSLDSL(SASOL)	PJ/yr	0	0
ELEC-GAS-GSL(MOBIL)	PJ/yr	0	0
ELEC-COAL-GSL(MOBIL)	PJ/yr	0	0
GAS-MTHL	PJ/yr	0	0
COAL-MTHL	PJ/yr	0	0
WOOD-MTHL	PJ/yr	0	1728937
ELEC-GAS-MTHL	PJ/yr	0	0
MTHL-GSL(MOBIL)	PJ/yr	0	0
ELEC-MTHL-GSL(MOBIL)	PJ/yr	0	0.000002
GAS-ETHL	PJ/yr	0	4409629
COAL-ETHL	PJ/yr	0	0
WOOD-ETHL	PJ/yr	0	0
COAL-CORN-ETHL	PJ/yr	0	0
COAL-BARLEY-ETHL	PJ/yr	0	0
COAL-WHEAT-ETHL	PJ/yr	0	0
ELEC-GAS-ETHL	PJ/yr	0	0
GAS-COAL-ETHL	PJ/yr	0	47762840
ELEC-COAL-ETHL	PJ/yr	0	0
ELEC-WOOD-ETHL	PJ/yr	0	40874090
COAL-LHYGN	PJ/yr	0	0
GAS-LHYGN	PJ/yr	0	0
ELEC-LHYGN	PJ/yr	0	0
ELEC-COAL-LHYGN	PJ/yr	0	32647020
ELEC-GAS-LHYGN	PJ/yr	0	35323710
SYNCRUDE-REF	TJ/yr	0	0
CRUDE-REF 1 (LOW COMPLEX.)	TJ/yr	1337099	0
CRUDE-REF 2 (HIGH COMPLEX.)	TJ/yr	83943.31	0
REF 2-GASOLINES	TJ/yr	33501.32	0
REF 2-DISTILLATES	TJ/yr	34206.78	0
REF 2-H.OIL&PCF&PP	TJ/yr	10798.33	0
REF 2-PROPANE	TJ/yr	1659.434	0
GSL 2-GASOLINES	TJ/yr	33501.32	0
DSL 2-DISTILLATES	TJ/yr	34206.78	0

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
AGSL 2-GASOLINES	TJ/yr	0	0
TJF 2-DISTILLATES	TJ/yr	0	0
LFO 2-DISTILLATES	TJ/yr	0	0
HFO 2-H.OIL&PCF&PP	TJ/yr	10798.33	0
PCF&PP 2-H.OIL&PCF&PP	TJ/yr	0	0
REF 1-GASOLINES	TJ/yr	222371.1	0
REF 1-DISTILLATES	TJ/yr	375443.8	0
REF 1-H.OIL&PCF&PP	TJ/yr	674928	0
REF 1-PROPANE	TJ/yr	8198.027	0
GSL 1-GASOLINES	TJ/yr	221991.3	0
DSL 1-DISTILLATES	TJ/yr	312376.9	0
AGSL 1-GASOLINES	TJ/yr	379.9216	0
TJF 1-DISTILLATES	TJ/yr	63066.95	0
LFO 1-DISTILLATES	TJ/yr	0	0
HFO 1-H.OIL&PCF&PP	TJ/yr	68236.75	0
PCF&PP 1-H.OIL&PCF&PP	TJ/yr	606691.1	0
GSL-IMPORTS	PJ/yr	0	1401728
DSL-IMPORTS	PJ/yr	0	509848.6
AGSL-IMPORTS	PJ/yr	0	1401728
TJF-IMPORTS	PJ/yr	0	509848.6
LFO-IMPORTS	PJ/yr	0	509848.6
HFO-IMPORTS	PJ/yr	0	1911996
PCF&PP IMPORTS	PJ/yr	0	1911996
GSL-EXPORTS	PJ/yr	0	-1338728
DSL-EXPORTS	PJ/yr	0	-446848.6
AGSL-EXPORTS	PJ/yr	0	-1338728
TJF-EXPORTS	PJ/yr	0	-446848.6
LFO-EXPORTS	PJ/yr	0	-446848.6
HFO-EXPORTS	PJ/yr	0	-1848996
PCF&PP-EXPORTS	PJ/yr	0	-1848996
ELEC-CNG	PJ/yr	0	4114667
ELEC-LNG	PJ/yr	0	2917595
CNG	TJ/yr	0	231513
LNG	TJ/yr	0	0
GSL(MOBIL)-GAS	TJ/yr	0	8226292
GSL(ZNCL2)-COAL	TJ/yr	0	7462442
GSL(MOBIL)-COAL	TJ/yr	0	0
GSL(MOBIL)-MTHL	TJ/yr	0	114024.3
GSL-COAL(SASOL)	TJ/yr	0	12702320
DSL-COAL(SASOL)	TJ/yr	0	11810440
MTHL-GAS	TJ/yr	0	6269270
MTHL-COAL	TJ/yr	0	8182816
MTHL-WOOD	TJ/yr	0	2329850
ETHL-GAS	TJ/yr	0	2811850
ETHL-COAL	TJ/yr	0	8615850
ETHL-WOOD	TJ/yr	0	4114850
ETHL-CORN	TJ/yr	0	0
ETHL-BARLEY	TJ/yr	0	0

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
ETHL-WHEAT	TJ/yr	0	0
LHYGN-GAS	TJ/yr	0	2512000
LHYGN-COAL	TJ/yr	0	7394000
LHYGN-ELEC	TJ/yr	0	29919160
GSL-MTHLGSLBLD	PJ/yr	0	0
GSL-ETHLGSLBLD	PJ/yr	0	0
MTHL-MTHLGSLBLD	PJ/yr	0	870489.3
ETHL-ETHLGSLBLD	PJ/yr	0	0
PROPANE-MOBIL(GAS)	TJ/yr	0	0
PROPANE-MOBIL(COAL)	TJ/yr	0	0
PROPANE-MOBIL(MTHL)	TJ/yr	0	0
GAS-SBC-ELEC	PJ/yr	18.56985	0
GAS-SPC-ELEC	PJ/yr	0	0
COAL-PFC1-ELEC	PJ/yr	0	110773.1
COAL-PFC2-ELEC	PJ/yr	304.5097	0
COAL-AFBC-ELEC	PJ/yr	0	0
HOIL-SBC-ELEC	PJ/yr	0	3389509
LOIL-CTU-ELEC	PJ/yr	0	5003463
URAN-NWDL-ELEC	PJ/yr	466.2307	0
URAN-EXDL-ELEC	PJ/yr	230.85	-2970500
ELEC-GAS-SBC-SP	GWh/yr	1753.819	0
ELEC-GAS-SBC-DP	GWh/yr	0	1116983
ELEC-GAS-SPC-SP	GWh/yr	0	6369034
ELEC-GAS-SPC-DP	GWh/yr	0	1404018
ELEC-LOIL-CTU-SP	GWh/yr	0	19104010
ELEC-LOIL-CTU-DP	GWh/yr	0	0
ELEC-HOIL-SBC-SP	GWh/yr	0	43517020
ELEC-HOIL-SBC-DP	GWh/yr	0	474000
ELEC-HOIL-SBC-CYC	GWh/yr	0	0
ELEC-HOIL-SBC-BASE	GWh/yr	0	4098782
ELEC-COAL-PFC1-SP	GWh/yr	0	40130010
ELEC-COAL-PFC1-DP	GWh/yr	0	246000
ELEC-COAL-PFC1-CYC	GWh/yr	0	0
ELEC-COAL-PFC1-BASE	GWh/yr	0	4134782
ELEC-COAL-PFC2-SP	GWh/yr	0	36442010
ELEC-COAL-PFC2-DP	GWh/yr	8099.339	0
ELEC-COAL-PFC2-CYC	GWh/yr	22698.42	0
ELEC-COAL-PFC2-BASE	GWh/yr	0	4172782
ELEC-COAL-AFBC-SP	GWh/yr	0	88835370
ELEC-COAL-AFBC-DP	GWh/yr	0	5312360
ELEC-COAL-AFBC-CYC	GWh/yr	0	1957360
ELEC-COAL-AFBC-BASE	GWh/yr	0	5602142
ELEC-LGTE-ELEC-SP	GWh/yr	0	127626000
ELEC-LGTE-ELEC-DP	GWh/yr	0	6063000
ELEC-LGTE-ELEC-CYC	GWh/yr	0	0
ELEC-LGTE-ELEC-BASE	GWh/yr	0	3219782
ELEC-URAN-NWDL-BASE	GWh/yr	129508.5	0
ELEC-URAN-EXDL-BASE	GWh/yr	64125	0

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-NWHY(>10MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-PEAK U.-SP-E.T.P	PJ/yr	0	0
ELEC-NWHY(>10 MW)-PEAK U.-DP-E.T.P	PJ/yr	0	0
ELEC-NWHY(>10MW)-PEAK U.-POWER	GW	0	0
ELEC-NWHY(>10MW)-SP	GWh/yr	0	336318200
ELEC-NWHY(>10MW)-DP	GWh/yr	0	22585210
ELEC-NWHY(>10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-CYC	GWh/yr	0	77217.62
ELEC-NWHY(>10 MW)-BASE	GWh/yr	0	0
ELEC-NWHY(>10 MW)-SP-ENGY TO PWR	PJ/yr	0	250918400
ELEC-NWHY(>10 MW)-DP-ENGY TO PWR	PJ/yr	0	14335220
ELEC-NWHY(>10 MW)-CY-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(>10 MW)-BS-ENGY TO PWR	PJ/yr	0	2012000
ELEC-NWHY(>10 MW)-POWER	GW	0	0
ELEC-NWHY(>10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(>10 MW)-CYC	GWh/yr	0	0
ELEC-NWHY(>10 MW)-BASE	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-SP	GWh/yr	0	283418300
ELEC-NWHY(2-10 MW)-DP	GWh/yr	0	17475210
ELEC-NWHY(2-10 MW)-CYC	GWh/yr	0	1127218
ELEC-NWHY(2-10 MW)-BASE	GWh/yr	0	2728000
ELEC-NWHY(2-10 MW)-SP-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-DP-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-CY-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-BS-ENGY TO PWR	PJ/yr	0	0
ELEC-NWHY(2-10 MW)-POWER	GW	0	0
ELEC-NWHY(2-10 MW)-SP	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-DP	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-CYC	GWh/yr	0	0
ELEC-NWHY(2-10 MW)-BASE	GWh/yr	0	0
ELEC-EX.HYDRO-PEAK U.-SP	GWh/yr	3.063408	0
ELEC-EX.HYDRO-PEAK U.-DP	GWh/yr	1513.325	0
ELEC-EX.HYDRO-PEAK U.-SP-E.T.PWR	PJ/yr	0.011028	0
ELEC-EX.HYDRO-PEAK U.-DP-E.T.PWR	PJ/yr	5.447971	0
ELEC-EX.HYDRO-PEAK U.-POWER	GW	0.967	-17897280
ELEC-EX.HYDRO-PEAK U.-SP	GWh/yr	3.063408	0
ELEC-EX.HYDRO-PEAK U.-DP	GWh/yr	1513.325	0
ELEC-EXHY-SP	GWh/yr	0	247054800
ELEC-EXHY-DP	GWh/yr	0	13966130
ELEC-EXHY-CYC	GWh/yr	22501.62	0
ELEC-EXHY-BASE	GWh/yr	0	1957980
ELEC-EXHY-SP-ENGY TO POWER	PJ/yr	0	0
ELEC-EXHY-DP-ENGY TO POWER	PJ/yr	0	0
ELEC-EXHY-CYC-ENGY TO POWER	PJ/yr	81.00587	0
ELEC-EXHY-BASE-ENGY TO POWER	PJ/yr	0	0

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-EXHY-POWER	GW	4.687	-173714200
ELEC-EXHY-SP	GWh/yr	0	0
ELEC-EXHY-DP	GWh/yr	0	0
ELEC-EXHY-CYC	GWh/yr	22501.62	0
ELEC-EXHY-BASE	GWh/yr	0	0
ELEC-MUNREFUSE-CYC	GWh/yr	780.0556	0
ELEC-MUNREFUSE-BASE	GWh/yr	0	991636.5
ELEC-MUNREFUSE-CYC-ENGY TO POWER	PJ/yr	2.808201	0
ELEC-MUNREFUSE-BASE-ENGY TO POWER	PJ/yr	0	0
ELEC-MUNREFUSE-POWER	GW	0.2	-79061840
ELEC-MUNREFUSE-CYC	GWh/yr	780.0556	0
ELEC-MUNREFUSE-BASE	GWh/yr	0	0
ELEC-TOTALSP	PJ/yr	6.324778	0
ELEC-TOTALDP	PJ/yr	34.60559	0
ELEC-TOTALCYC	PJ/yr	165.5283	0
ELEC-TOTALBASE	PJ/yr	697.0805	0
ELEC-TOTAL	PJ/yr	903.5393	0
ELEC-EXPORTS-TRAN.	PJ/yr	0	819948
ELEC-EXPORT	PJ/yr	0	0
ELEC-IMPORT	PJ/yr	0	8876940
ELEC-IMPORTS-TRAN.	PJ/yr	0	0
GAS-TRAN&DIST	PJ/yr	1217.433	0
PROPANE-TRAN&DIST	PJ/yr	9.857462	0
METHANOL-TRAN&DIST	PJ/yr	0	0
ETHANOL-TRAN&DIST	PJ/yr	0	0
GASOLINE-TRAN&DIST	PJ/yr	255.4925	0
DIESEL-TRAN&DIST	PJ/yr	346.5837	0
AV.GAS-TRAN&DIST	PJ/yr	0.379922	0
JET FUEL-TRAN&DIST	PJ/yr	63.06695	0
LFO-TRAN&DIST	PJ/yr	0	2904286
HFO-TRAN&DIST	PJ/yr	79.03512	0
PCF&PP-TRAN&DIST	PJ/yr	606.6911	0
ELEC-TRAN&DIST	PJ/yr	903.5393	0
WOOD-TRAN&DIST	PJ/yr	0	0
LHYGN-TRAN&DIST	PJ/yr	0	46271740
LNG-TRAN&DIST	PJ/yr	0	6139100
ELEC-HTP-R2SH-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-R2SH-SH	TJ/yr	0	6338965
LOIL-FCE+HTP-R2SH-SH	TJ/yr	0	7813905
ELEC-RES+HTP-R2SH-SH	TJ/yr	0	0
HT-ENERGY-HTP-R2SH-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-R2SH-SH	PJ/yr	0	0
GAS-WCBFCE-R2SH-SH	PJ/yr	0	0
LOIL-WCBFCE-R2SH-SH	PJ/yr	0	180409.8
ELEC-WDFCE+RES-R2SH-SH	PJ/yr	0	3469147
WOOD-OPTS+WDFCE-R2SH-SH	TJ/yr	0	2801005
ENERGY-OPTS+WDFCE-R2SH-SH	PJ/yr	0	0
ELEC-ASR-R2SH-SH&WH&AC	PJ/yr	0	0

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
ASR-R2SH-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-R2SH-SH	TJ/yr	0	17888360
GAS-CGF-R2SH-SH	TJ/yr	0	3424334
GAS-FCE-R2SH-SH	TJ/yr	16198.74	0
LOIL-FCE-R2SH-SH	TJ/yr	0	971187.6
ELEC-RES-R2SH-SH	TJ/yr	0	1361044
ELEC-HTP-ISH-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-ISH-SH	TJ/yr	0	398965
LOIL-FCE+HTP-ISH-SH	TJ/yr	0	1233905
ELEC-RES+HTP-ISH-SH	TJ/yr	0	0
HT-ENERGY-ISH-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-ISH-SH	PJ/yr	0	0
GAS-WCBFCE-ISH-SH	PJ/yr	0	0
LOIL-WCBFCE-ISH-SH	PJ/yr	0	180409.8
ELEC-WDFCE+RES-ISH-SH	PJ/yr	0	3469147
WOOD-WCBFCE+OPTS-ISH-SH	TJ/yr	0	574001.5
ENERGY-WCBFCE+OPTS-ISH-SH	PJ/yr	0	0
GAS-FCE+ASR-ISH-SH	TJ/yr	0	0
LOIL-FCE+ASR-ISH-SH	TJ/yr	0	667812.5
ELEC-RES+ASR-ISH-SH	TJ/yr	0	3587544
ELEC-ASR-ISH-SH&WH&AC	PJ/yr	0	0
ASR-ISH-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-ISH-SH	TJ/yr	0	0
ENERGY-ASR+OPTS-ISH-SH	PJ/yr	0	5249395
GAS-CGF-ISH-SH	TJ/yr	0	1032034
GAS-FCE-ISH-SH	TJ/yr	81382.5	0
LOIL-FCE-ISH-SH	TJ/yr	0	667812.5
ELEC-RES-ISH-SH	TJ/yr	0	3587544
ELEC-HTP-OBC80-SH&AC	TJ/yr	0	0
GAS-FCE+HTP-OBC80-SH	TJ/yr	0	0
LOIL-FCE+HTP-OBC80-SH	TJ/yr	0	597562.5
ELEC-RES+HTP-OBC80-SH	TJ/yr	0	4377544
HT ENERGY-HTP-OBC80-SH	PJ/yr	0	0
ENERGY-OPTS+HTP-OBC80-SH	PJ/yr	0	12956270
GAS-WCBFCE-OBC80-SH	PJ/yr	0	0
LOIL-WCBFCE-OBC80-SH	PJ/yr	0	180409.8
ELEC-WDFCE+RES-OBC80-SH	PJ/yr	0	3469147
WOOD-WCBFCE-OBC80-SH	TJ/yr	0	0
ENERGY-WCBFCE+OPTS-OBC80-SH	PJ/yr	0	0
GAS-FCE+ASR-OBC80-SH	TJ/yr	0	0
LOIL-FCE+ASR-OBC80-SH	TJ/yr	0	597562.5
ELEC-RES+ASR-OBC80-SH	TJ/yr	0	4377544
ELEC-ASR-OBC80-SH&WH&AC	PJ/yr	0	0
ASR-OBC80-SH&WH&AC	PJ/yr	0	0
HT ENERGY-ASR-OBC80-SH	TJ/yr	0	0
ENERGY-ASR+OPTS-OBC80-SH	PJ/yr	0	3826014
GAS-CGF-OBC80-SH	TJ/yr	0	151833.8
GAS-FCE-OBC80-SH	TJ/yr	130866.1	0

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
LOIL-FCE-OBC80-SH	TJ/yr	0	597562.5
ELEC-RES-OBC80-SH	TJ/yr	0	4377544
GAS-CGB-APT-SH	TJ/yr	0	1109774
GAS-IGB-APT-SH	TJ/yr	43471.25	0
LOIL-BLR-APT-SH	TJ/yr	0	0
ELEC-BLR-APT-SH	TJ/yr	0	4055794
ELEC-BSD-APT-SH	TJ/yr	0	5428794
ENERGY-R2SH-SH	PJ/yr	12.95899	47005550
ENERGY-ISH-SH	PJ/yr	65.106	27228040
ENERGY-OBC80-SH	PJ/yr	104.6929	11143050
ENERGY-NWA-SH	PJ/yr	22.832	14231800
ENERGY-ODA-SH	PJ/yr	11.94499	14231800
ENERGY-H-SH	PJ/yr	182.7579	0
ENERGY-A-SH	PJ/yr	34.77699	0
ENERGY-RES-SH	PJ/yr	217.535	0
ENERGY-SR(WH)-R2SH	PJ/yr	0	0
ENERGY-SR(WH)-ISH	PJ/yr	0	0
ENERGY-SR(WH)-OBC80H	PJ/yr	0	0
ENERGY-SR(WH)-HOUSES	PJ/yr	0	0
ENERGY-ASR+BKP-H-WH	PJ/yr	0	26655820
GAS-WHR+ASR-H-WH	PJ/yr	0	0
ELEC-WHR+ASR-H-WH	PJ/yr	0	2954294
GAS-WHR-H-WH	PJ/yr	98.7758	0
ELEC-WHR-H-WH	PJ/yr	0	3716044
GAS-BLR-A-WH	PJ/yr	63.1517	0
ELEC-BLR-A-WH	PJ/yr	0	5028544
ENERGY-H-WH	PJ/yr	79.02064	0
ENERGY-A-WH	PJ/yr	50.52137	0
ENERGY-RES-WH	PJ/yr	129.542	10543680
ELEC-IWAC-AC	PJ/yr	6.777	15846590
ENERGY-HTP(CAC)-R2SH	PJ/yr	0	0
ENERGY-HTP(CAC)-ISH	PJ/yr	0	0
ENERGY-HTP(CAC)-OBC80	PJ/yr	0	0
ENERGY-HTP(CAC)-HOUSES	PJ/yr	0	0
ENERGY-ASR(CAC)-R2SH	PJ/yr	0	4371087
ENERGY-ASR(CAC)-ISH	PJ/yr	0	4371087
ENERGY-ASR(CAC)-OBC80	PJ/yr	0	4371087
ENERGY-ASR(CAC)-HOUSES	PJ/yr	0	0
ELEC-CAC-AC-HOUSES	PJ/yr	6.287651	0
ELEC-CAC-AC (APT)	PJ/yr	2.874015	0
ENERGY-CAC-RES	PJ/yr	27.485	11187640
ENERGY-RES-AC	PJ/yr	47.81599	0
ELEC-RES-APP&LTG	PJ/yr	130.835	13440590
GAS-CGB-C&I-SH	TJ/yr	0	1109774
GAS-IGB-C&I-SH	TJ/yr	459143.5	0
LOIL-BLR-C&I-SH	TJ/yr	0	0
ELEC-BLR-C&I-SH	TJ/yr	0	4055794
ELEC-BSD-C&I-SH	TJ/yr	0	5428794

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
ENERGY-NWBDGS-C&I-SH	PJ/yr	306.5349	14231800
ENERGY-ODBDGS-C&I-SH	PJ/yr	60.77999	14231800
ENERGY-C&I-SH	PJ/yr	367.3149	0
GAS-BLR-C&I-WH	PJ/yr	24.9725	0
ELEC-BLR-C&I-WH	PJ/yr	0	5028544
ENERGY-C&I-WH	PJ/yr	19.97799	9743051
ELEC-C&I-AC	PJ/yr	22.79432	0
ENERGY-C&I-AC	PJ/yr	68.38299	4480198
ELEC-C&I-EQPT&LTG	PJ/yr	139.8489	13440590
GAS-BLR-I-IH	PJ/yr	0	2764341
HOIL-BLR-I-IH	PJ/yr	0	4717281
COAL-BLR-I-IH	PJ/yr	993.2924	0
ENERGY-I-IH	PJ/yr	794.634	5361250
GAS-BR-I-DH	PJ/yr	60.36848	0
HOIL-BR-I-DH	PJ/yr	60.36848	0
ELEC-HD-I-DH	PJ/yr	7.54561	0
COAL-BF-I-DH	PJ/yr	719.9118	0
ENERGY-I-DH	PJ/yr	754.6059	3736569
ELEC-EM&EL.CHMLS-I	PJ/yr	352.841	13440590
GAS-I-UTL	PJ/yr	136.8372	0
ELEC-I-UTL	PJ/yr	73.68165	0
LOIL-I-UTL	PJ/yr	0	180409.8
ENERGY-I-UTL	PJ/yr	210.5189	8917145
PROPANE-I-PPCF	PJ/yr	0	1604961
OBPPCF-I-REF	PJ/yr	604.871	0
ENERGY-I-PPCF	PJ/yr	604.871	7969914
PROPANE-TRN-AUTO	PJ/yr	9.82789	0
MTHL-TRN-AUTO	PJ/yr	0	0
ETHL-TRN-AUTO	PJ/yr	0	0
CNG-TRN-AUTO	PJ/yr	0	0
LNG-TRN-AUTO	PJ/yr	0	0
GASOLINE-TRN-AUTO	PJ/yr	165.2303	0
DIESEL-TRN-AUTO	PJ/yr	188.5805	0
METHGSL-TRN-AUTO	PJ/yr	0	0.3081
ETHGSL-TRN-AUTO	PJ/yr	0	60064.19
LHYGN-TRN-AUTO	PJ/yr	0	0
ELEC-TRN-AUTO	PJ/yr	60.5625	0
ENERGY-TRN-AUTO	Mkms/yr	168242.6	24678.42
PROPANE-TRN-LT.TKS&VANS	PJ/yr	0	13.14564
MTHL-TRN-LT.TKS&VANS	PJ/yr	0	13.14564
ETHL-TRN-LT.TKS&VANS	PJ/yr	0	13.14564
CNG-TRN-LT.TKS&VANS	PJ/yr	0	13.14564
LNG-TRN-LT.TKS&VANS	PJ/yr	0	13.14564
GASOLINE-TRN-LT.TKS&VANS	PJ/yr	89.49566	0
DIESEL-TRN-LT.TKS&VANS	PJ/yr	0	13.09165
METHGSL-TRN-LT.TKS&VANS	PJ/yr	0	0.3211
ETHGSL-TRN-LT.TKS&VANS	PJ/yr	0	60064.21
LHYGN-TRN-LT.TKS&VANS	PJ/yr	0	0.54

HIGH SCENARIO

Variable Name	Units	Value	Reduced Cost
ELEC-TRN-LT.TRKS&VANS	PJ/yr	14.12893	0
ENERGY-TRN-LT.TKS&VANS	Mkms/yr	29275.14	33096.55
AVGAS-TRN-ACRAFT	PJ/yr	0.378782	0
TJFUEL-TRN-ACRAFT	PJ/yr	62.87776	0
ENERGY-TRN-ACRAFT	PJ/yr	20.83299	29644650
DSL-TRN-BUS	PJ/yr	12.11538	0
PROPANE-TRN-BUS	PJ/yr	0	736527.3
CNG-TRN-BUS	PJ/yr	0	736527.3
LNG-TRN-BUS	PJ/yr	0	736527.3
MTHL-TRN-BUS	PJ/yr	0	736527.3
ETHL-TRN-BUS	PJ/yr	0	736527.3
LHYGN-TRN-BUS	PJ/yr	0	602555.6
ENERGY-TRN-BUS	PJ/yr	3.15	36826440
DIESEL-TRN-MRN	PJ/yr	10.57499	0
HOIL-TRN-MRN	PJ/yr	18.42953	0
ENERGY-TRN-MRN	PJ/yr	3.025	65041340
DSL-TRN-RAIL	PJ/yr	35.25384	0
ELEC-TRN-RAIL	PJ/yr	0	0
ENERGY-TRN-RAIL	PJ/yr	9.166	36826440
DIESEL-TRN-TRUCK	PJ/yr	99.01922	0
PROPANE-TRN-TRUCK	PJ/yr	0	736527.6
CNG-TRN-TRUCK	PJ/yr	0	736527.6
LNG-TRN-TRUCK	PJ/yr	0	736527.6
MTHL-TRN-TRUCK	PJ/yr	0	736527.6
ETHL-TRN-TRUCK	PJ/yr	0	736527.6
LHYGN-TRN-TRUCK	PJ/yr	0	602558.6
ENERGY-TRN-TRUCK	PJ/yr	25.74499	36826440
ELEC-TRN-STC&SBY	PJ/yr	2.237	13440590

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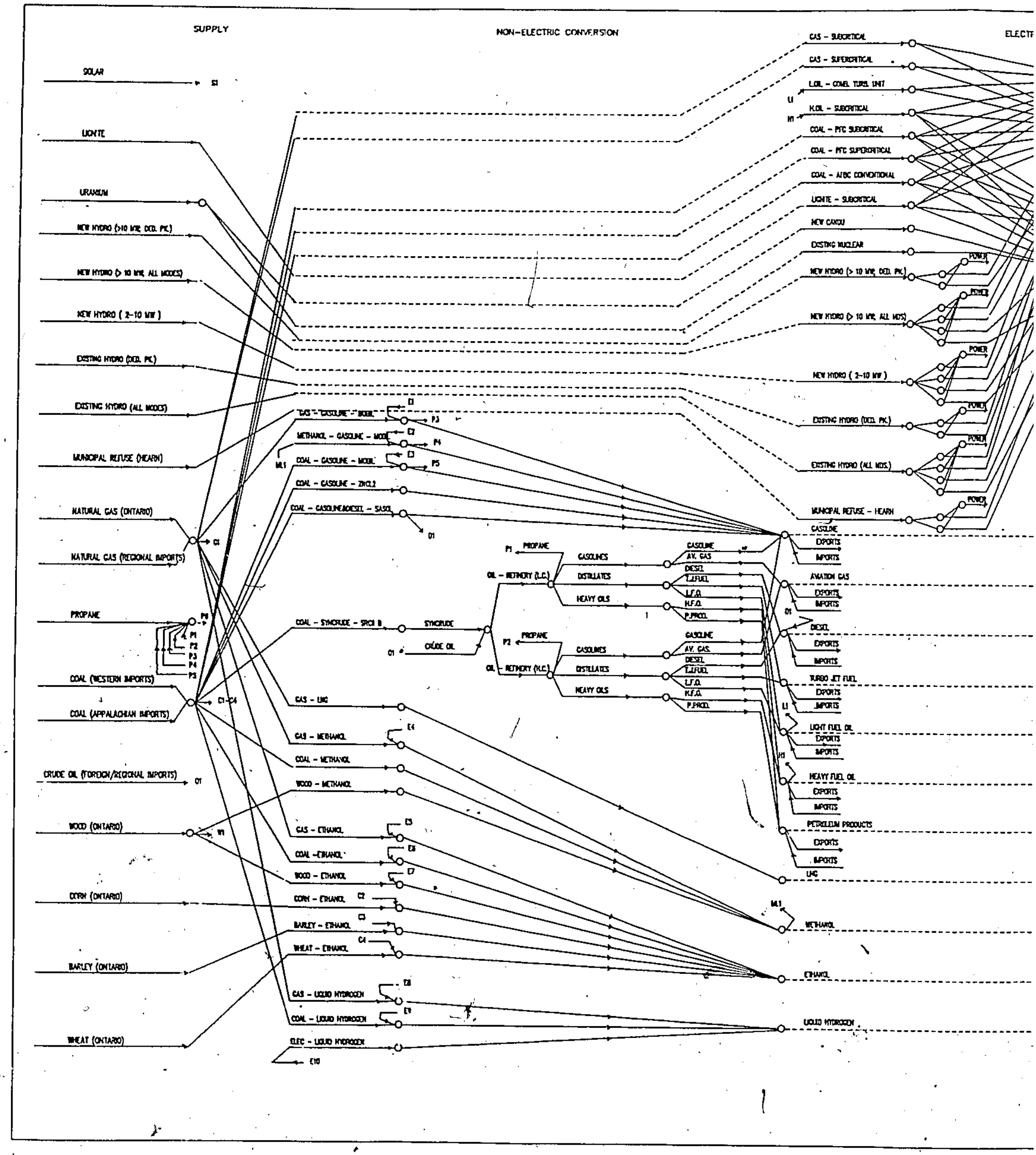
VITA AUCTORIS

1957	Born in calcutta, India on the 27th of December.
1973	Completed the Indian School Certificate examination from Sherwood College, Nainital.
1979	Graduated from Visvesvaraya Regional College of Engineering, Nagpur with a Bachelor of Engineering degree in Electrical Engineering.
1981	Graduated from Indian Institute of Technology, Bombay with a Master of Technology degree in Systems and Control Engineering.
1988	Currently a candidate for the degree of Doctor of Philosophy in Industrial Engineering at the University of Windsor, Windsor, Canada.



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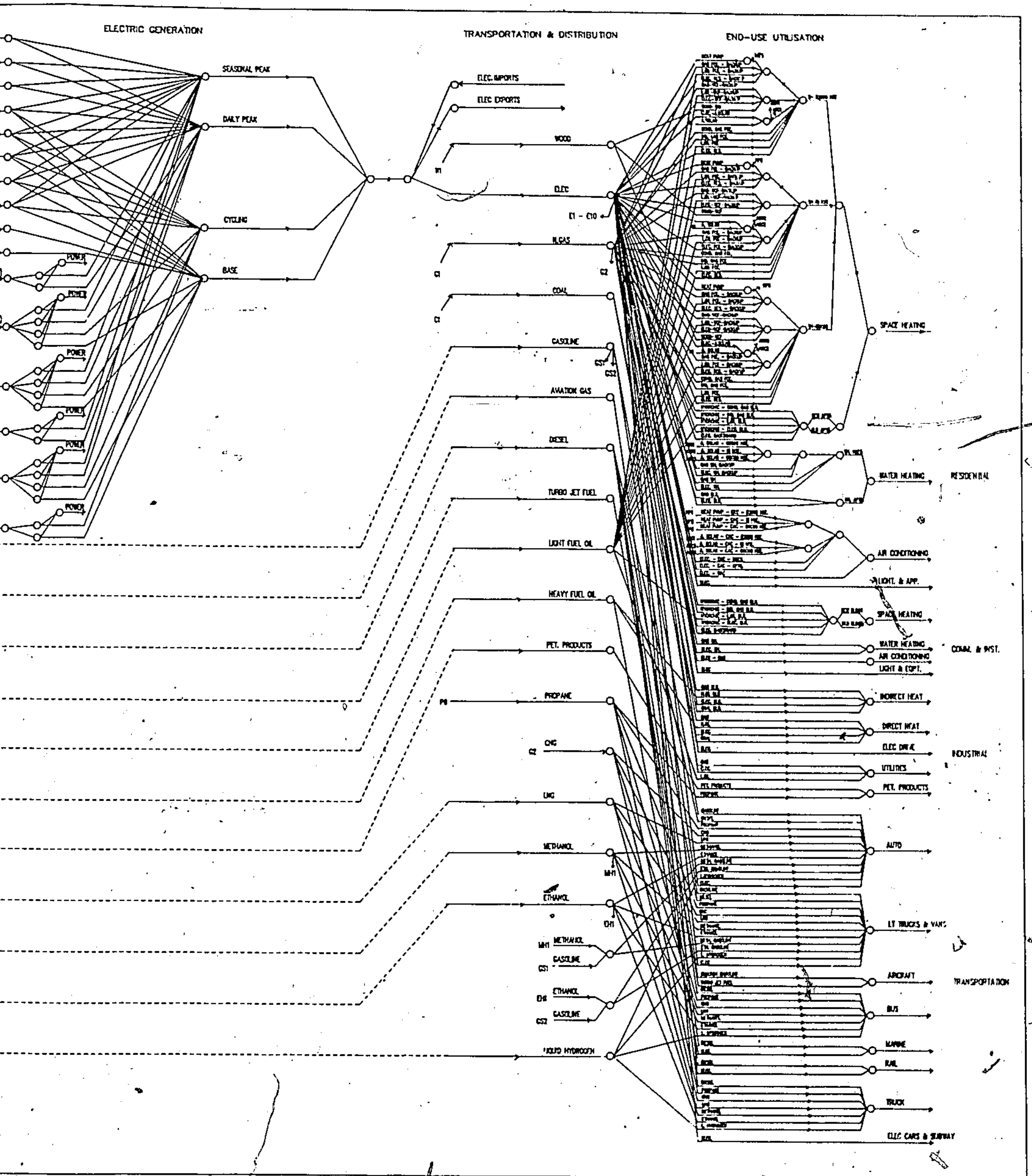

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