THE IIASA ENERGY SYSTEMS PROGRAM'S VIEW OF LATIN AMERICA'S ENERGY FUTURE: AN EVALUATION

Prepared for Kernforschungszentrum Karlsruhe

J.C. di Primio

DRAFT

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International Institute for Applied Systems Analysis
A-2361 Laxenburg, Austria Telephone: 02236/71521*0

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With an Annex by A.M. Khan and A. Hölzl

PREFACE

This report has been prepared in accordance with an agreement between the Kernforschungszentrum Karlsruhe and IIASA providing for the application of the IIASA energy models and data base to Latin America. Its objectives are an evaluation of the IIASA models as appropriate tools for studying the Latin American situation, an analysis of IIASA's Latin American results to date, and a discussion of those improvements in both the models and the data base that would be necessary to make them more suitable for understanding the particular nature of Latin American energy problems.

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1. INTRODUCTION

In the Proposal of IIASA's Energy Systems Program (IIASA-ENP) to the Kernforschungszentrum Karlsruhe (KFK) for a "Long-Term Energy Strategy Study for Latin America", the objective of the study was stated as follows: "IIASA has conducted a long-term global analysis, within which seven world regions were analyzed in a first order approximation. This means that, though much data was gathered for any one of them, the focus of the investigation was the global perspective, and no detailed consideration was done for each particular region".

The latter is more valid for the case of the regions involving less developed countries (LDCs): for them, statistical data is scarce and/or inconsistent, and must be complemented by expert knowledge and judgment. IIASA-ENP's work indicated that, under certain assumptions related to population and economic growth, Latin America projected itself into the future as a region capable of attaining the present living standards of the industrialized countries (ICs) within the time horizon of the study.

Under these circumstances, the question arose: Are IIASA projections compatible with the past-present development trends of the countries of Latin America, the natural resources, its scientific-technological and institutional features? In other words, the results of the IIASA-ENP study called for an assessment, involving the evaluation of assumptions and parameters incorporated in the modeling set, to prove if they matched with plans, hopes and aspirations, and to look in more detail into the energy demand and energy supply projections for the region.

The scope of the work was originally formulated in the following terms:

"(1) The first step would be a reevaluation of the lifestyle scenarios for our energy demand model MEDEE-2. To that end the structures of the Latin American economy should be reconsidered, developmental trends more clearly perceived and on that basis a set of goals reformulated. In that way the data base for MEDEE-2 could be adjusted so as to reflect more precisely the specific needs and premises for Latin America.

(2) Second, on the supply side some of the production profiles of the energy supply model MESSAGE would be redesigned. The intention would be to take more into account various supply opportunities characteristic for the region or part of the region. Typical examples would be here the potential for hydroelectricity and biomass production in Brazil or the heavy crudes in Venezuela.

(3) In a third step, then, the model runs for Latin America would be repeated and a somewhat more detailed regional strategy defined.

(4) Finally, we intend to test the robustness of that strategy in two ways. First, we shall disaggregate the region into two, perhaps three blocks, and run the set of models for each block, aggregate the results and compare them to the previously computed strategy. Second, a sensitivity analysis with respect to our growth assumptions will be performed, thus helping us to understand the interrelationships between economic growth, lifestyles and energy use in Latin America."

These activities have been undertaken but not completed during the allocated time. The reasons are manifold: the need to understand model construction and their specific functions as well as interplay; the necessity to conceptualize our view of the present state of development of Latin America and judge upon its possible future evolution; the realization that the region's outlook conceals the situation of individual countries, which have to be known before attempting new regional runs.

Up to the point of progress reported herein, we have respected the scope of the work, sometimes with a different emphasis due to our view of their relative importance at a given time. Some delay resulted from our way to deal with national cases: we decided that they should be done in collaboration with Latin American institutions, which could provide data and the particular understanding of their own case. The required agreements took time, but the experience was rewarding and demonstrated that cooperation was the best method to perform seriously our task.

Additional effort will be necessary to accomplish the objectives. Since the original agreement between IIASA-ENP and KFK has been extended, it is hoped to conclude our work including the additions required by such an extension, in particular the possible role of renewable energy sources.

2. IIASA-ENP MODELING SET: ITS APPLICATION TO LATIN AMERICA

Early in 1976, the IIASA-ENP started a thorough modeling effort in order to quantify its previous conceptualization of the future energy problem. A set of mathematical models was built to deal with matters of the future in relation to the economy, energy demand, energy supply and the economic consequences of implementing a given supply system. Though each of these tasks was assigned to an individual model, they were conceived to operate in harmony with information flowing from one to the other finally closing the loop. In this way, successive iterations permitted checking and adjusting the assumptions incorporated in each step of the analysis by looking at their behavior and effect on overall results. Thus, internal consistency of the modeling set was assured.

The modeling set was applied to the study of the long-range, dynamic transition of the global energy system, by compounding the results of seven regions in which the world was divided. One of these regions is Latin America.

The scope and results of this comprehensive exercise are extensively documented in the final report of the ENP, "Energy in a Finite World", forthcoming in book format in 1981 [1]. Its content is complemented by a number of publications authored by the members of the ENP, which document the evolution of ideas during the last seven years.

It is not our purpose to present herein a detailed description of the models composing the set. This has been most appropriately done by the modellers themselves. Our main concern is the evaluation of the results obtained by their application to Latin America, that is, if those results imply a reasonable future that could be achieved during the time horizon of the study and what kind of assumptions they carry on the economic, social, technological and even political domains.

In such a context, only a brief description of the models used for the regional study under consideration becomes necessary, in order to highlight their conceptual framework and the assumptions incorporated to project the future evolution of Latin America. For this reason, reference will only be made to the three models that were consistently used for the quantitative analysis of the future energy situation of the region. They are: the energy demand model MEDEE-2; the energy supply model MESSAGE; and the IMPACT model designed to evaluate the economic consequences of the gradual implementation of the energy supply system. Since a macroeconomic model for developing countries was not available, the macroeconomic module of MEDEE-2 was the limited tool used to describe economic behavior.

2.1 The Energy Demand Model MEDEE-2

2.1.1 Brief Description

The energy demand model used at IIASA is a simplification of a more disaggregated but conceptually identical model originally built at IEJE, University of Grenoble, France, to project future energy consumption patterns of an industrialized country. The principal characteristic of MEDEE-2 is that the calculation of future energy requirements are basically driven by projections of population, economic growth and various parameters reflecting behavioral patterns of society (lifestyles). The effect of particular policies affecting the energy sector, either national or the result of international interrelationships, could be in principle incorporated through the assumed influence on life-style indicators, which also can show the expected effect of variations in the energy prices. The technique used is thus one of scenarios, which must consistently represent a future development pattern.

Three main energy consuming sectors are identified in the model: transportation, industry and household/service. In addition, the macroeconomic module of MEDEE-2 describes, in an aggregate way, the production and expenditure of the gross domestic product (GDP). This description, for the starting year and the projections as well, must be provided exogenously: it constitutes, together with the projections of population growth and those corresponding to the lifestyle indicators, the scenario parameters that drive energy demand. Let us consider the way in which the calculation of energy demand is performed for each sector.

Transportation Module

Two main types of transportation are dealt with: freight and passenger transportation. The main driving forces for the determination of physical activity levels are, respectively, the growth and structure of the economy and the population growth; both determinants are qualified by lifestyle indicators.

Starting with physical activity levels, the calculation of energy demand requires the knowledge of the modal split of each transportation system, i.e., the relative contribution of various kinds of vehicles to satisfy the needs. For passenger transportation, the corresponding load factors must be specified. Projections of these parameters (modal split, load factors) have to describe a future trend consistent with a selected path of development.

Once the activity levels are obtained, the calculation of energy demand is straightforward when the specific fuel consumption of each mode of transportation involved (vehicles, pipelines) is known. Projections of the latter must also be made due considerations being given to the long lead times associated to technical efficiency improvements.

The MEDEE-2 transportation module calculates energy demand in terms of final energy, since only specific energy carriers are utilized, namely, either motor fuel or electricity.

Industry Module

The industry is divided in sectors to perform the calculation of energy demand, namely: agriculture, construction, mining and three manufacturing subsectors, each of which involves industries with similar energy use patterns.

In all cases, though, future energy demand is calculated upon the knowledge of the present (base year) consumption features expressed by means of an energy intensiveness parameter for three types of energy carriers: motor fuel, electricity, other used for heat production (useful energy in the manufacturing industries). Future energy demand is calculated for each industrial sector by introducing a coefficient of expected changes in consumption pattern, and the total monetary activity of the sector (since energy intensiveness is given in terms of energy per unit value-added).

The penetration of alternative energy sources like solar collectors or cogeneration to replace fossil fuels in the manufacturing industry is established by coefficients which affect the total useful energy demand. Conversion of useful into final energy takes into account relative fuel efficiencies (with respect to electricity).

Household/Service Module

The activity levels are in this case the housing stock and the total floor area in the service sector. They are respectively related to population growth and needs, and to the service sector contribution to economic product, whose projections consequently define their absolute future values.

This module is concerned with the calculation of energy demand for space heating, hot water, cooking and specific uses of electricity (lighting, appliances, air conditioning). Since the energy services typical of this sector can be mostly met by different fuels which can substitute one another, the first step is to calculate useful energy demand. Once the basic quantities (number of dwellings, service floor area) are known, the specific energy consumption (useful energy) for each energy service is used to determine useful energy demand. Before converting useful energy into final energy (through application of the corresponding fuel efficiencies), the penetration of alternative energy sources or the effect of energy conservation measures is established by means of indicators which define possible contributions of solar power, district heat, electricity, and heat pumps to substitute for fossil fuels, and energy savings due to better insulation.

The MEDEE-2 model has been extensively described by B. Lapillonne [2], and its application to IIASA's seven world regions by A.M. Khan and A. Hölzl [3]. We will proceed now with the description of the main scenario assumptions used during the application of MEDEE-2 to project the energy demand of Latin America until the year 2030.

2.1.2 Main Scenario Assumptions

Two scenarios were considered in the IIASA-ENP global energy study, labelled Low and High, mainly due to the selected levels of future economic growth and the sectoral distribution of GDP; for the application to Latin America they also differ because of assumptions pertaining to the transportation and household/ service sectors, which imply a general trend to increase activity levels of passenger transportation and to consume more energy (preferably electricity) in dwellings in the High scenario.

From the point of view of the future development pattern the two scenarios do not differ in terms of technological capability (energy intensiveness parameters in the industry and in the transportation sectors).

In what follows, we will present a description of the main assumptions incorporated into the scenarios.

Demography

A. Only one projection for population growth has been used. It follows the population growth trends made by Keyfitz [4].

	1975		2000		2030
Population (10^6 people)	319		575		797
Average growth rate (%/yr)		2.4		1.1	

B. The concentration of people in cities follows the past trend of rapid urbanization, UN projections until the year 2000 and their further extrapolation:

	1975	2000	2030
Urban population fraction	0.60	0.75	0.85
Fraction of population living in cities $\geq 10^5$ inhabitants	0.37	0.53	0.69

C. The average family size decreases from 5.1 persons per household in 1975 to 4.8 in 2000 and 4.15 in 2030, in line with the reduction in population growth and increasing affluence.

D. The economically active population fraction increases from 0.32 in 1975 to 0.41 in 2030, in line with the population and labor force projections of the UN until the year 2000 and their extrapolation thereafter.

Economy

A. GDP increases between 1975 and 2030 by a factor of 6.5 for the Low scenario (LS) and by 10.5 for the High scenario (HS). GDP projections are in equilibrium with those corresponding to other market economies.

	Average Annual Growth Rates (%)			
	Low Scenario		High Scenario	
	GDP	GDP/cap	GDP	GDP/cap
1975-1985	4.7	1.80	6.2	3.21
1985-2000	3.6	1.52	4.9	2.80
2000-2015	3.0	1.72	3.7	2.42
2015-2030	3.0	2.05	3.3	2.34
1975-2030	3.48	1.77	4.37	2.64

B. GDP shares of agriculture, industry and services change gradually in line with past trends, towards the pattern of the West European distribution. In particular, the share of the manufacturing industries increases whereas those of agriculture and services decreases--more in the HS than in the LS, see Table 2.1.

C. In the manufacturing sector a relatively faster development is projected for the basic materials industries (BM) (metallurgical, chemical, etc.) and the machinery and equipment (ME) industries than for the nondurable goods (ND) (food, clothing, etc.) industries, see Table 2.1.

D. Feedstocks for the chemical industry and steel production are projected to increase following the trend of the basic materials industries.

E. The GDP expenditure structure is assumed to change gradually, in line with past behavior, with the private final consumption decreasing from 70% in 1975 to 63% and 61% in 2030 for the LS and HS, respectively, while the investment is projected to remain constant at its 1975 level of 23% throughout (see Table 2.1).

F. The private final consumption structure is assumed to change gradually into the pattern of industrialized countries:

	Private Final Consumption Fraction				
		2000		2030	
	1975	LS	HS	LS	HS
i. Durable goods	0.10	0.11	0.12	0.12	0.14
ii. Nondurable goods	0.60	0.57	0.55	0.54	0.51
iii. Services	0.30	0.32	0.33	0.34	0.35

Lifestyles

Transportation

A. The car ownership ratio (population ÷ number of cars) varies inversely with GDP/cap and urbanization. It evolves as follows:

	1975	2000	2030
LS	26	14	7
HS	26	10	4

B. The average intercity distance travelled per person in one year increases linearly with the private final consumption per capita, as shown below (km):

	1975	2000	2030
LS	1850	2600	4400
HS	1850	3500	6800

C. The pattern of intercity travel changes in such a way that the shares of travel by car and aeroplane increase whereas those travelled by bus and train decrease gradually. It is also assumed that by 2030 electrification of trains will increase up to 20% from their 1975 share of 1% in the total railroad intercity traffic.

D. Load factors of buses and trains for general travel (intercity as well as urban) are considerably higher than those in Western Europe and remain so in the projections, with some improvement with time.

E. Use of private cars for urban travel is assumed to increase slowly until the year 2000, and remain constant thereafter due to congestion in cities. Fractional urban car transportation grows from 0.30 in 1975 to 0.35 by 2000 and 2030.

F. Total freight transportation increases in proportion to the assumed modifications of the value added of agriculture, mining and manufacturing industries. The share taken up by trains is projected to increase from about 18% in 1975 to 28% in 2030, with corresponding reduction in the shares of buses and barges.

Household/Services

A. The use of electricity per household (in kWh/yr) for electrical appliances is assumed to be proportional to the urbanization pattern as well as to the private consumption spent on services.

	1975	2000	2030
LS	700	1200	2150
HS	700	1700	3400

B. The useful energy requirement per person for hot water increases by 2030 between 1.6 and 2.5 times the 1975 value for the LS and HS, respectively. This follows from two assumptions: larger fraction of dwellings with hot water facilities and the average family size decreases.

C. Unlike space heating, that is required in modest amounts, air-conditioning is desirable due to climatic characteristics. It is assumed that it will rapidly increase with more affluence:

	1975	2000	2030
Fraction of dwellings air-conditioned			
LS	~0	0.04	0.12
HS	~0	0.05	0.20
Fraction of service sector area air-conditioned			
LS	0.05	0.12	0.35
HS	0.05	0.15	0.40

D. Noncommercial energy is estimated to meet about half of the useful energy requirements for cooking, space and water heating in 1975. It is assumed that the quantity of strictly non-commercial energy will remain at the 1975 level all along.

Energy Intensiveness, Efficiencies. Penetration of Electricity, Solar and Other Sources (common to both scenarios)

A. The energy intensiveness of the mining, construction and manufacturing industries with respect to the use of fossil fuels are assumed to decrease from the current level, close to that of the U.S., to 85% of it by 2000 and 75% by 2030, so as to become closer to West European data.

B. The energy intensiveness with respect to the use of electricity in the above industrial activities are assumed to remain at their current level throughout.

C. The energy intensiveness of agriculture with respect to the use of fossil fuels is assumed to increase by a factor of 5.5 by the year 2000 and to increase ten times the present value by 2030. This will lead to the current West European level of mechanization in agriculture by 2030. Similar increases are also projected in this sector for electricity utilization to account for irrigation requirements.

D. 15-20% improvements in the average efficiency of fossil fuels in meeting the heat demand of household/service and industries are projected as feasible by 2030. The utilization efficiency of noncommercial fuels is also assumed to improve with time, becoming by 2030 twice as high as in 1975.

E. The car efficiency is assumed to improve from the current levels to an average of 10.5 and 8 l/100 km for urban and intercity travel, respectively, by 2000 and remain constant thereafter.

F. 30% of new single family houses are assumed to get equipped with solar heating facilities by 2000, this fraction increasing to 50% in 2030. The same projections hold for low-rise service sector buildings.

G. Hot water requirements are assumed to be met with solar energy in the household sector to the extent of 20% by 2000 and 30% in 2030.

H. District heat is assumed to meet 3% in 2000 and 20% by 203o of the total household/service sector's space and water heating in cities ≥100,000 inhabitants.

I. Penetration of electricity, district heat, "soft" solar, cogeneration (steam and electricity) and heat pumps in the industrial heat market are projected to such an extent that fossil fuels would have to meet only 78% of the useful energy requirements for thermal uses in industry by 2030.

J. Renewable sources of energy are assumed to penetrate in the household/service sector mainly to replace fossil fuels according to the assumptions presented in Table 2.2.

2.1.3 Results

The calculation of future energy consumption based on a set of assumptions whose main components were given in the previous paragraph is first done in terms of useful energy, i.e. the energy needed to provide a service to the consumer (heat required to cook a meal, mechanical power to turn a lathe). The calculation goes further to express results in terms of final energy, i.e., the energy delivered to the user (motor gasoline, electricity), taking into account the efficiency of end-use devices that satisfy the demand for useful energy.

Table 2.3 summarizes MEDEE-2 energy demand projections for Latin America until 2030.

2.2 The Energy Supply Model MESSAGE

2.2.1 Brief description

The objective of MESSAGE is to determine a secondary energy supply strategy to satisfy the future energy demand picture quantified by MEDEE-2. To perform this task, a dynamic optimization linear program was built which takes into account the availability of primary energy sources, their estimated maximum extraction rates and the transformation into secondary energy carriers in conversion stations. Each primary energy source, except solar, is subdivided into a number of categories on the basis of the price of extraction, quality of resources and location of deposit. These primary sources are then converted into secondary energy in conversion stations using various technologies, under consideration of installation, operation and maintenance and fuel costs (excluding the cost of fuel extraction and transportation).

The objective function is the minimization of the cost of energy sources, installation of conversion facilities and their operation and maintenance, to provide the energy demand, each element discounted over time, subjected to constraints due to resource availability at specific prices and facility build-up rates. Other constraints, such as the need to minimize pollution, could be incorporated as required: these constraints, although available, were not used in the MESSAGE runs reported herein.

On the basis of the secondary energy allocation distribution, MESSAGE calculates the total primary energy requirements for the particular years under consideration.

In the equations of the model, which are roughly given below, indices are sometimes omitted to facilitate understanding. A thorough description of the MESSAGE model is given by M. Angew et al. [5].

The Objective Function

The objective function of the MESSAGE model is the sum of discounted costs of capital, operating-maintenance, and fuels (primary energy):

$$\sum_{t=1}^{n} \beta(t)\; 5\{b^T r(t) + c^T x(t) + d^T y(t)\} \quad ,$$

where

t is current index of time period
n is number of time periods
$\beta(t)$ is discount factor
5 is number of years per period
b is vector of energy resources costs
r is vector of resource activities (LP variables)
c is vector of operating/maintenance costs
x is vector of energy conversion activities (LP variables)
d is vector of capital (investment) costs
y is vector of capacity increments (LP variables)

The discount factor is calculated from an annual discount rate of 6%, applied to a constant dollar investment stream. As MESSAGE is intended to minimize societal costs this discount rate is to be understood as a pre-tax one.

The cost of increments to capacity still operating at the end of the planning horizon is corrected by a "terminal valuation factor", tv:

$$tv(t) = (1 - \beta^{5(n+1-t)}) \quad ;$$

for example, the terminal valuation factor for the last time period is

$$tv(n) = 1 - \beta^5 \ .$$

Resource Constraints

The following resource constraint is defined for each resource and for each category:

$$\sum_{t=1}^{n} 5r(t) \leq Av \quad ,$$

where

r(t) is annual extraction in period t
Av is availability of resource

Resource Requirements

The following equation is specified for each time period and for each resource:

$$\sum_{j=1}^{J} r_j(t) \geq \sum_{1} \quad v_1x_1(t) + 5w_1y_1(t) - 5w_1y_1(t-6) \quad ,$$

where

j is index of resource category
J is number of resource categories
v_1 is specific consumption by production activity x_1
w_1 is inventory requirement for capacity increment y_1

Capacity Equations

The following equation is specified for each technology and for each load region supplied by this technology:

$$x_j \leq Cap \times h_j \times pf \quad , \qquad \left(Cap(t) = \sum_{\tau=t-5}^{t} 5y(\tau)\right) \quad ,$$

where

j is index of load region
Cap is capacity
hj is load duration of load region j
pf is plant factor

Demand Constraint

The following equation is specified for each time period, for each demand sector, and for each load region:

$$\sum \eta_{ij} x_i \geq DM_j \quad ,$$

where

j is index of demand sector
η_{ij} is conversion efficiency (or equal to 0 if x_i does not supply demand sector j)
DM_j is annul secondary energy demand

Build-up Constraints

The following equation is specified for some (primarily new) technologies and for each time period:

$$y(t) \leq \gamma y(t-1) + g \quad ,$$

where

γ is growth parameter
g is constant, allowing for start up

2.2.2 Main Assumptions

The assumptions incorporated in the model for running the Latin American case are presented through the self-explanatory Tables 2.4-2.7.

2.2.3 Results

Tables 2.8 and 2.9 summarize the most important results provided by the model.

2.3 The Energy-Economy Interaction Model IMPACT

2.3.1 Brief Description

Once an optimal energy strategy is identified, it is necessary to understand the requirements for corresponding direct and indirect energy investments.

IMPACT belongs to the set of energy-oriented dynamic input/output models, explicitly accounting for lags between the start of investment and the putting into operation of production capacities. It consists of linear and nonlinear equations that describe the following for each year of the period concerned: balance of production of individual products and services and their consumption in operating and building the energy systems and related branches; the conditions for introducing extra capacities in energy-related branches; investment and WELMM (Water, Energy, Land, Materials and Manpower) requirements.

For each given strategy, the model determines:

- Investment in energy system development;
- The required putting into operation of capacities in energy-related branches of industry and corresponding (indirect) capital investment;
- The required output of different types of materials, equipment, and services to provide operational and construction requirements of the energy system and related branches;
- Direct and indirect WELMM requirements.

All these indicators are evaluated for each year of the period considered.

The model describes the building up of production capacities as a direct part of the energy supply system (ESS) and its related branches. In this way lead times of construction and related consumption of equipment and material are taken into account. This is done by identifying input/output relations between the following sectors of the economy important for the energy supply systems:

iron ore mining
primary iron and steel manufacturing
fabricated metal products
nonferrous metal or mining
nonferrous metals manufacturing
chemical products
plastic and synthetic materials
petroleum products
stone, clay, and glass products
lumber and wood products
miscellaneous materials
engines and turbines
electrical equipment
mining equipment
oil field equipment
construction equipment and machineries
material handling equipment
metalworking equipment
instrument and control equipment
transportation equipment
special industry equipment
general industry equipment
fabricated plate products
miscellaneous equipment
export goods I
export goods II
construction in energy sectors
construction (nonenergy)
transport (nonenergy)
maintenance and repair construction

The Equation System of IMPACT*

The direct requirements of the ESS for products of energy-related sectors are expressed as

$$Y_e(t) = A_1\bar{X}_e(t) = \sum_{\tau=t}^{t+\hat{\tau}} F_1^{(\tau-t)}\bar{Z}_e(\tau) \quad ,$$

where

$Y_e(t)$ is the vector of direct investment and operational requirements of the ESS for products of energy-related sectors in the year y

$\bar{X}_e(t)$ is the vector of annual energy production in the year t

$Z_e(t)$ is the vector of required additional capacities of the ESS in the year t

A_1 is the matrix of contribution coefficients of energy-related sectors to the construction and operation of energy production per unit of activity

$F_1^{(\tau-t)}$ is the matrix of contribution coefficients of energy-related sectors in the year t to putting into operation the additional capacities of the ESS in the year t $(t \leq \tau \leq t + \hat{\tau})$

$\hat{\tau}$ is the vector of the time lag introduced by construction times

Total (direct and indirect) material and equipment requirements of the ESS are expressed as

$$X_1(t) = A_2X_1(t) + A_3X_2^{in}(t) + Y_e(t) \quad ,$$

where

A_2 is the matrix of input/output coefficients

A_3 is the matrix of materials and equipment requirements coefficients per unit of investment in energy-related sectors

*Matrix notation is used throughout the section. The letters t or τ in parenthesis denote vector-valued time functions. A bar denotes an exogenously given input.

$X_1(t)$ is the vector of output in energy-related sectors
$X_2^{in}(t)$ is the vector of indirect capital investments in energy-related sectors

Direct capital investment in the ESS is expressed as

$$X_2^d(t) = \sum_{\tau=t}^{t+\hat{\tau}} F_2^{(\tau-t)} \bar{Z}_e(\tau) \quad ,$$

Indirect capital investment in the ESS is expressed as

$$X_2^{in}(t) = \sum_{\tau=t}^{t+\hat{\tau}} F_3^{(\tau-t)} Z_1(\tau) \quad ,$$

Total (direct and indirect) capital investment in the ESS is expressed as

$$X_2^{(t)} = X_2^d(t) + X_2^{in}(t) \quad ,$$

where

$F_2^{(\tau-t)}, F_3^{(\tau-t)}$ are, respectively, the matrices of capital investment coefficients in the year t to put into operation the additional capacities of the ESS and energy-related sectors in the year t

$Z_1(t)$ is the vector of new additional capacities in the energy-related sectors in the year t

$X_2^d(t)$ is the vector of direct capital investment in the ESS

Vector $Z_1(t)$. with vector components $Z_1^{(1)},\ldots,Z_1^{(k)}$, must satisfy the following conditions:*

$$Z_1^{(i)}(t) = \begin{cases} \min\limits_{\tau\leq t} [X_1^{(i)}(t+1) - X_1^{(i)}(\tau)] & \text{if this value is positive;} \\ 0 & \text{otherwise} \end{cases}$$

for every $i \,\varepsilon\{1,2,\ldots,k\}$.

Vector notation is used in the model for simplicity reasons. This equation is therefore written as

$$Z_1(t) = \max\left[\min_{\tau\leq 1}\left(X_1(t+1) - X_1(\tau)\right);0\right] .$$

The model also includes an equation for calculating the direct and the indirect expenses of the WELMM resources. This equation is written as

$$X_3(t) = A_4\bar{X}_e(t) + A_5X_1(t) + A_6X_2^{in}(t) + \sum_{\tau=t}^{t+\hat{\tau}} F_4^{(\tau-t)}\bar{Z}_e(\tau) ,$$

where

$X_3(t)$ is the WELMM expenditures in the year t
A_4 is the matrix of direct operational WELMM coefficients

*In order to take into account *installed* capacity requirements, this expression can be replaced by

$$Z_1^{(i)}(t) = \begin{cases} \min\limits_{\tau\leq t} \left[X_1^{(i)}(t+1) - \dfrac{X_1^{(i)}(\tau)}{(1-p)^{t-\tau+1}}\right] & \text{if this value is positive;} \\ 0 & \text{otherwise} \end{cases}$$

for every $i \,\varepsilon\{1,2,\ldots,k\}$ where p is the rate of replacement.

A_5 is the matrix of indirect operational WELMM coefficients of energy-related sectors

A_6 is the matrix of indirect constructional WELMM coefficients of energy-related sectors

$F_4^{(\tau-t)}$ is the matrix of direct constructional WELMM coefficients in the year t to put into operation new energy capacities in the year t

Equations for evaluating air and water pollutant emissions of the ESS and the energy-related sectors can be written analogically.

The drivers for IMPACT's relations are $\overline{X}_e(t)$ and $\overline{Z}_e(t)$; these exogenous variables can be obtained from an energy supply model (e.g., the IIASA MESSAGE model).

An algorithm has been developed for solving equations iteratively. This algorithm, as well as other details of IMPACT's structure, logic, and scope are described in [6].

2.3.2 Main Assumptions

The knowledge of the economic behavior in LDCs is not well documented, and the attempt to deal with a detailed analysis of a country's economy is of very recent data. At the time the IMPACT model was applied to understand the direct and indirect consequences of the energy sector on the economy as a whole, only some basic input data was available for India (more recently similar information has been published in the cases of Mexico and Brazil).

For this reason, IMPACT runs had an aggregated and provisory character, since they were done using the Input/Output table of India and capital/output ratios pertaining to developed countries.

2.3.3 Results

Under the above described conditions, the results of IMPACT for LDCs were used only as indication of likely trends. It has been shown that the capital requirements of developing countries must drastically increase in the future from today's standards (approximately 2% of GDP is allocated to the energy sector) towards expenditures between 6% and 7% by 2030. For Latin America, in particular, the maximum share of total energy investment in GDP fluctuates between 6.5% and 8% in the scenarios.

In addition, IMPACT estimates WELMM requirements associated with the implementation of the energy sector. Besides the growing demand of capital for investments, preliminary WELMM results point to the hardships that skilled manpower requirements will pose in the future.

TABLE 2.1. Summary of Economic Indicators

	1975	Low Scenario 2000	Low Scenario 2030	High Scenario 2000	High Scenario 2030
A. GDP/cap ($ 1975)	1066	1597	2797	2212	4478
B. GDP Shares (%)					
i. Agriculture	12	10	7	8	5
ii. Mining, construction, and energy	11	11	14	12	14
iii. Manufacturing	25	28	29	30	33
iv. Services	52	51	50	50	48
C. Structure of Manufacturing Industries (%)					
i. Basic materials	31	34	36	36	35
ii. Machinery and equipment	26	33	39	35	42
iii. Nondurable goods	43	33	25	29	23
E. GDP Expenditure (%)					
i. Private consumption	70	65	63	64	61
ii. Government expenditure	11	12	14	13	16
iii. Investment	23	23	23	23	23
iv. Exports	-4	0	0	0	0

TABLE 2.2. Assumed Penetration of Renewable Sources of Energy (fraction of useful heat demand)

Demand Sector	Nature of Demand	2000	2030
Households			
Cities	Cooking, space and water heating	0.40	0.60
Towns (>100,000 persons)	Cooking, space and water heating	0.60	0.80
Villages (urban and rural)	Cooking, space and water heating	0.75	0.90
Service Sector			
Cities	Space and water heating	0.20	0.40
Towns	Space and water heating	0.30	0.60
Manufacturing Industries	Low temp. steam/hot water	0.40	0.80
	High temperature steam	0.30	0.60
	Furnaces	0.06	0.12

TABLE 2.3. Commercial Final Energy Results (GWyr)

	Base Year	Low Scenario				High Scenario			
	1975	1985	2000	2015	2030	1985	2000	2015	2030
By Sector									
Transportation	104.7	171.6	303.8	473.3	726.2	195.4	409.5	712.7	1153.7
Industry	118.8	198.7	328.9	497.6	719.1	234.3	483.8	814.8	1230.7
Household/Service	30.9	54.5	100.0	147.7	210.3	56.7	111.2	172.0	255.7
Total commercial (incl. feedstocks)	254.4	424.8	732.7	1118.6	1655.6	486.4	1004.5	1699.5	2640.1
By Energy Form									
Fossil substitutable	92.1	151.0	231.9	302.7	367.9	171.6	312.6	451.1	578.4
District heat	0.0	0.3	1.8	6.6	19.9	0.3	2.5	9.5	30.3
Soft solar	0.0	0.3	3.6	10.6	22.1	0.3	4.1	13.8	32.6
Electricity	24.4	43.5	85.4	150.3	255.9	50.5	119.3	228.1	401.7
Motor fuel	114.7	186.7	330.4	516.2	785.7	212.5	444.2	772.4	1238.7
Coal (metallurgical)	6.4	11.7	21.4	36.3	51.3	14.0	32.7	61.6	90.2
Feedstocks	16.8	31.2	58.2	95.9	152.8	37.2	89.1	163.0	268.2
Total commercial (incl. feedstocks)	254.4	424.8	732.7	1118.6	1655.6	486.4	1004.5	1699.5	2640.1

TABLE 2.4. Estimates of Ultimately Recoverable Resources by Cost Category for Latin America

Cost Category[a]	Resource: Coal 10^9tce	Coal TWyr	Oil 10^9toe	Oil TWyr	Natural Gas 10^{12}m^3	Natural Gas TWyr	Uranium 10^3tU
1	11	10	13.4	19	14.5	17	56
2	12	11	57.1	81	10.2	12	3544
3	-		77.6	110	11.9	14	-

[a]Cost categories represent estimates of costs either at or below the stated quantity of recoverable resources (in constant U.S. dollars of 1975).

	Category 1	Category 2	Category 3
Oil and natural gas	12$/boe	12-20$/boe	20-25$/boe
Coal	25$/tce	25-50$/tce	-
Uranium	80$/kgU	80-130$/kgU	-

TABLE 2.5. Estimated Resource Availability of Renewable Energy Sources (commercial use only)

	Maximum Production Capacity (GWyr/yr)	Capacity in 2030: Low Scenario (GWyr/yr)	Capacity in 2030: High Scenario (GWyr/yr)
Hydroelectricity[a]	583	355	355
Wood from forests	2090	458	704

[a]The figures refer to primary energy equivalent at an efficiency of about 37%.

TABLE 2.6. Cost Assumptions for Major Competing Energy Supply and Conversion Technologies.

	Capital Cost (1975$/kW)	Variable Cost (1975$/kWyr)	Final Product Cost (1975$/kWyr)
Electricity Generation			
Coal with scrubber	550	23	154
Conventional nuclear reactor (e.g. LWR)	700	50	136
Advanced reactor (e.g. FBR)	920	50	143
Coal, fluidized bed	480	36	152
Hydroelectric	620	8.5	85
Oil-fired	350	19	256
Gas-fired	325	16	216
Gas-turbine	170	17	241
Solar central station	1,900	28-60	297
Synthetic Fuels			
Crude oil refinery	50	3.7	75
Coal gasification ("high Btu")	480	40	125
Coal liquefaction	480	40	125

NOTES: The figures for electricity generation and synthetic fuels are assumed to apply, mostly, to *both* developed and developing regions. The costs are assumed to apply, as averages, over the 50-year planning horizon.

Capital cost: Capital costs per kW of capacity. Assumed to represent average capital costs (paid at once) for standard facilities of 30-year lifetime; intended to include owner's costs (interest during construction, land lease, etc.). Escalation is not included. Extraordinary other costs (litigation, unspecified social costs) are not included.

Variable costs: Operating and maintenance plus fuel cycle costs (not including fuel costs) per kWyr of product (electricity or synthetic fuel).

Final product cost: Static cost per kWyr of secondary energy (electricity or synthetic fuels) *including* fuel costs. Fuel costs are taken to be the cheapest category of the corresponding fuel. The cost figures in this column are not the dynamic figures in MESSAGE; here they serve only the purpose of quick comparison. The data on plant life (30 years, hydro 50 years) and on the load factor (70% hydro and 57% solar) enter the calculations, as does the discount rate (6%). For a time interval of 5 years and a plant life of 30 years, the formula for the annualized capital cost is

$$\text{cap} \cdot \frac{\beta^5 - 1}{(\beta^{30} - 1)\ \beta^{2.5}\ 5} \qquad (1)$$

where β is the one-year discount factor ($\frac{1}{1.06}$ here) and cap is the total capital cost. In order to get the levellized capital costs per kWyr of output, (1) must be divided by the load factor. For example, a LF of 0.7 yields a levellizing factor of 0.101.

Hydroelectric: The high, but so far unexploited potential of hydroelectric in Latin America led to a specification of two capital cost categories for hydro in this region; the second category including additional costs reflects transmission from remote sites.
Solar central station: Including storage costs allowing an annual average load factor of 57%. Variable costs include an estimate for long distance transmission costs, and are lower in high insolation developing regions.

TABLE 2.7. Start-up and Build-up Constraint Assumptions for New Energy Technologies

	Increment, As % of Previous Period's Expansion	Start-up Capacity GW/yr	Commercially Available After
Conventional nuclear reactor (e.g. LWR)[a]	120	0.4	today
Fast breeder reactor[a]	120	0.4	2000
Coal, fluidized bed	140	0.4	1995
Coal liquefaction	140	2	2000
Coal gasification	140	2	1995
Solar electric	140	0.5	2005

[a]For nuclear technologies, a total (LWR plus FBR) build-up constraint is also imposed.

NOTE: The numbers are transformed into constraints for the MESSAGE model as follows: The asymptotic increment and start-up parameters refer to γ and g, respectively, in

$$y^t \leq \gamma y^{t-1} + g \qquad (1)$$

where y^t is the annual addition to the capacity of the respective technology in time period t (y^0 being a boundary condition).
In addition to these build-up constraints, there is a constraint on the build-up of total nuclear capacity.

TABLE 2.8. Primary Energy or Equivalent (GWyr), Low Scenario

Resource	Base Year 1975	1985	2000	2015	2030
Gas	48	71	81	113	182
Oil	228	331	533	787	1136
Coal	16	45	105	175	195
LWR	1	15	43	42	103
FBR	-	-	-	26	112
Hydro	45	75	143	245	355
Solar	-	-	4	11	22
Renewables	-	18	64	128	206
Commercial	338	555	973	1527	2312
Noncommercial	109	109	109	109	109
Total	447	664	1082	1636	2421

TABLE 2. 9. Primary Energy or Equivalent (GWyr), High Scenario

Resource	Base Year 1975	1985	2000	2015	2030
Gas	48	92	157	265	438
Oil	228	376	730	1193	1809
Coal	16	55	140	185	185
LWR	1	15	82	206	430
FBR	-	-	-	26	112
Hydro	45	75	143	245	355
Solar	-	-	4	14	33
Renewables	-	19	83	183	317
Commercial	338	633	1339	2317	3679
Noncommercial	109	109	109	109	109
Total	447	742	1448	2426	3788

3. THE IIASA-ENP ENERGY PICTURE OF LATIN AMERICA

3.1. The Situation in 1975

When put into a worldwide perspective, commercial primary energy consumption in Latin America is comparatively modest: Table 3.1 shows that with 8.1% of world population the region's energy budget amounted only to 4.2% of global energy requirements. In per capita terms, the figures indicate that every latin-american has access to about 50% of the world average but roughly to twice as much as the energy consumption of the LDCs as a whole.

Table 3.2 shows how the primary energy demand of 1975 was covered by the contribution of various sources. More than 2/3 of the total were taken care of by liquid fuels: from the seven regions in which the world was divided for the IIASA study, Latin America is the most dependent on oil derivatives.

If we consider the way in which final energy (i.e., the type of energy available to the consumer) was allocated to the various sectors of the economy (Table 2.3), it becomes clear that transportation was the most important user of liquid fuels. Less than 10% of the commercial final energy was provided by electricity. With nuclear power being of no regional significance, the generation of electricity was shared rather evenly by hydro and thermal power stations, as shown in Table 3.3.

The pattern described above is substantially modified when the so-called non-commercial fuels are brought into the picture. These energy sources are mainly constituted by firewood and vegetable waste from forests and crops, and basically used in the rural household sector. IIASA estimation of the energy content of such fuels is represented by 108.7 GWyr in 1975, a substantial amount when compared with the total energy consumption. These fuels are directly utilized without losses due to conversion, transportation or distribution; consequently, the figure expresses primary as well as final energy.

Non-commercial fuels in Latin America are partially subject to trade, but the extent of this commerce is hardly found in statistics. Their inclusion in the energy balance substantially changes the sectoral distribution of the total final energy budget because they are primarily allocated to the domestic uses. This view confuses both the general economic and energy situations: the first is distorted since firewood and vegetable waste are not accounted for in monetary terms, and the second is affected because the relative high share in terms of primary and final energy conveys the impression of an importance that is lacking at the users level due to the very low efficiency of utilization. But non-commercial fuels play a social role, since they measure the unavailability of energy to the most deprived sector of the population that is compelled to substitute with hardship for commercial fuels which are expensive or simply not there.

Non-commercial fuels utilization tends to decrease during development. The region's trends of the last 25 years (1950-75) show that their share of the total energy requirements has steadily decreased; in the case of firewood, for example, it has come down from around 50% in 1950 to approximately 19% in 1975. During the same period commercial primary energy consumption increased at a rate of about 7%/yr, whereas that of firewood has risen only at 1.5%/yr. IIASA-ENP approach to deal with the energy situation of LDCs has been to assume that the trends discussed above will continue and consequently the relative share of truly non-commercial fuels steadily diminishes during the period of the study. For such reason, only the commercial energy market will be used for comparisons.

3.2. Energy Reserves and Estimated Resources

In order to analyze the possible future situation of the energy sector, an estimation of natural resources is essential. This means the knowledge of reserves of primary energy carriers as well as an evaluation of potential resources availability during the period under consideration. The term "reserves" is generally accepted as indicating that part of the resource base that is rather accurately identified and is considered recoverable under actual technological and economic conditions. "Resources" include reserves as well as deposits whose existence is surmised on the basis of scientific evaluation with a certain degree of probability. Estimation of resources are done in the framework of likely future technological progress and the assessment of price situation trends. As a consequence, both reserves and resources are continuously changing in magnitude.

Table 2.4 shows the estimations done at IIASA by the Energy Resources Group about the potential supply of conventional energy carriers as related to production costs. In general, the "economically recoverable" coal reserves are included in the first category. For oil and gas, category 1 involves known reserves but also a fraction of the resources remaining to be discovered.

The knowledge of uranium resources is rather limited at present, in particular due to lack of intensive prospection. The recoverable reserves of about 60 thousand tons of uranium represent only a small fraction of IIASA estimates for the ultimately recoverable resources of 3.6 million tons at prices below 130$/kg U. This last figure compares well in magnitude with the most recent estimations for South and Central America (excluding Mexico), 0.7 to 1.9 million tons [7].

The potential of renewable resources, such as hydro power, solar energy, wind, biomass, etc., has been only globally assessed for the IIASA analysis, with the exception of commercial hydroelectricity generation. For Latin America, the total installable hydroelectric capacity has been estimated by Armstrong [8] at the level of 432 GW (20% of world potential) which operating at 50% capacity factor would generate 216 GWyr(e)/yr. In 1975 only 15.05 GWyr(e) were produced by this source, i.e. around 7% of the estimated maximum.

Finally, the existing woods and forests of the region are quite large: more than 10 million km^2 of land are covered out of a total continental surface of 21 million km^2 [9]. As shown in Table 2.6, the maximum possible production capacity attributed by IIASA to the annual regeneration of such energy resource corresponds to an energy content of about 2 TWyr/yr.

3.3 Projections of Future Energy Demand and Supply

The application of the energy demand model MEDEE 2 to explore future energy consumption in Latin America required the knowledge of many parameters describing the present economic situation, the technological stand and the lifestyles. They were obtained from a thorough evaluation of available statistical data. In addition, an assessment had to be made of the possible future change of these indicators; therefore, a definitive judgement on the Latin American development pattern was necessary. The evaluation of past trends, today's reality and present aspirations conformed a view of its future which involved steady economic development toward a "western European" pattern. Further industrialization, prudent use of regional natural resources and energy conservation were some of the main ingredients envisaged to obtain a consistent set of projections.

The results of MEDEE 2 for the base year 1975 accurately reflect the present pattern of Latin American energy demand which was described in paragraph 3.1. In paragraph 2.1.2 we described the main assumptions incorporated to the model for the projections and Table 2.3 showed future final energy demand until 2030.

Additional assumptions on resource availability, their extraction rates and other technological and economic constraints were necessary to explore a strategy for the allocation of primary sources to satisfy the annual levels of energy demand projected by MEDEE 2. In paragraph 2.2.2 we have shown those assumptions. Tables 2.8 and 2.9 indicated the distribution of primary energy carriers proposed by MESSAGE, the energy supply LP cost optimization model.

When we look at the energy situation of Latin America presented by the results of the IIASA exercise, projected commercial primary energy requirements seem modest in the distant future (2030)when compared with the world picture obtained in the same study by global integration: 2.3 TWyr to 3.7 TWyr define a consumption level in two scenarios which represent for each of them around 10% of world requirements. But by then the present gap in primary energy per capita utilization between Latin America and the ICs with market economies will have significantly closed (Table 3.4).

From the MESSAGE runs it comes out that liquid fuels will continue to have a predominant role in covering the energy budget in years to come. In the High scenario, the contribution of oil declines to 54.5% in the year 2000 and to 49.2% in the year 2030 from the 1975 share of 67.5%. These trends are similar in the Low scenario. This is certainly related to the influence of the transportation sector, where no saturation effects were detected due to the expected increase in freight movement and the necessary relaxation of load factors in vehicles for passenger travel coupled with the population expansion. But oil dependence is projected to diminish under the assumptions that liquid fuels will be increasingly used as a premium for transportation and the petrochemical industry, and progressively be replaced for thermal uses by other sources, mainly renewables.

With regard to the utilization of renewable sources the basic assumption is an aggressive policy implemented for their commercial use. This means the introduction of extended wood and forest management to harvest about one-third of the total regional wood and forest regeneration (i.e., about $3.5 \cdot 10^9$ tons of air-dried wood) and process it further, mainly by transformation into charcoal with a conversion efficiency of 45%, in order to simplify handling and distribution. The share of solar energy in its variety of forms is only limited in view of the expected long lead times for technology development and commercial application. The contributions of wind and small hydro to the electricity generation have been included under the total hydropower potential. "Soft" solar, the use of passive and active methods to produce hot water and low temperature steam, has also been taken into account, and "forced" into the cost optimizing program, as was the case with the products of biomass.

The share of electricity in final energy consumption can be seen to grow from under 10% at present up to 15-16% by 2030. In this context, the hydroelectric generation is assumed to be implemented to the level of 24.4% in the year 2000 and 60.9% by 2030 with respect to the maximum generation capability, thus accepting the inclusion of the most expensive type of hydropower requiring long distance transmission lines.

With the limitations imposed on the further use of fossil fuels for electricity generation, the projected increase in the utilization of electricity must be taken care of by hydro-power and nuclear energy, since solar energy (STEC, photo-voltaics) is not expected to provide a substantial contribution within the 55 years considered. For the year 2000, the nuclear installed capacities oscillate between 23 GW(e) in the Low scenario and 43 GW(e) for the High Scenario. These figures encompass a range well in accordance with the present knowledge of national plans. The extended implementation of nuclear power appears in Latin America after the turn of the century.

In contrast with the great importance of liquid fuels, conventional solid fuels seem used in modest proportion. But coal supply must increase by a factor of about 10 by the year 2000 with respect to 1975 in order to meet the projected applications. The use of truly non-commercial fuels is assumed to decrease progressively, for example to a share of 7.5% of total primary energy by the year 2000 and to 2.9% in 2030, in the High scenario.

TABLE 3.1 Base Year Data (1975)

	World	Latin America	All Developing Countries
Population(10^6)	3946	319	2786
GDP(10^9 US$75)	6175	340	1190
GDP/cap(US$75/cap)	1565	1066	427
Commercial Primary Energy Consumption (GWyr)	7998	338	1253
Primary Energy/cap (kW/cap)	2.03	1.06	0.45

TABLE 3.2 Primary Energy Consumption Latin America, 1975

	GWyr	%
Solid Fuels	16.1	4.8
Liquid Fuels	209.4	61.9
Feedstocks	18.8	5.5
Natural gas	48.0	14.2
Hydro(+Nuclear) Electricity	46.2	13.6
Commercial	338.5	100
Non-commercial (of which firewood)	108.7 (83.7)	
Total Primary Energy	447.2	

TABLE 3.3 Installed Capacity and Generation of Electricity, 1975

Installed Capacity, GW(e)	66.33
Thermal	34.69
Hydro	31.30
Nuclear	0.34
Generation, GWyr(e)	28.43
Thermal	13.09
Hydro	15.05
Nuclear	0.29

TABLE 3.4 Primary Energy per Capita (kW/cap)

		IIASA Scenario			
		High		Low	
Region	1975	2000	2030	2000	2030
A. ICs with Market Economies	6.16	8.48	12.16	6.95	8.23
B. Latin America	1.06	2.33	4.62	1.69	2.90
C. Ratio A/B	5.8	3.6	2.6	4.1	2.8

4. THE COMPONENTS OF THE ASSESSMENT PROCESS

A basic requirement to accomplish the objective of the work reported herein is to identify the issues that must be treated. Since we must look at the future of a developing region, it is therefore unavoidable to deal with the process of development. In an academic sense we have no expertise on this matter but have been "doing" development in a developing nation for a good part of our professional life. As the character of Molière would assert "We have been talking prose most of our lives without really knowing it". This situation requires to spell out our conceptual view of the issues involved which, perhaps because of the particular personal experience, will emphasize certain features with preference to others generally accepted as the conventional wisdom of development theory.

The conclusions we shall extract from this excursion should be compared with the development pattern assumed by the IIASA-ENP study. This, in turn, calls for a previous analysis of past-present world development performance, in the light of which we should try to assess where Latin America stands at present and where it seems to move into as time goes by.

These considerations should allow us to analyze the appropriateness of IIASA-ENP's modeling set to project the long-term energy situation of the region. In this context, the main question is: Do the assumptions that support the input data of the models (especially MEDEE-2) imply a development process that we can consider a reasonable, acceptable perception of the possible future evolution of Latin America?

5. THE DEVELOPMENT ISSUE

5.1 What Is Development?

Since the time when the existence of poor nations was recognized as a problem of worldwide relevance shortly after the Second World War, and the word "development" was coined to identify the need to change their situation, the process has been, more often than none, equated to economic growth. And, consequently, the development situation of countries and regions has been measured by a macroeconomic yardstick, namely, gross national product (GNP) or its respective per capita value.

Some economists argue that a distinction should be made between "economic growth" and "economic development", the former defining a process of simple increase (more of the same), while the latter involving structural change of the economy (something different if not something more) [10]. The past history of today's developed countries gives considerable support to the concept of economic development since they evolved towards their present situation in the wake of substantial changes in the structure of their productive system.

The question comes immediately to mind: Were those just economic changes? In answering we must accept that the concept of development has kept on extending its significance, and the structural changes mentioned above cannot be regarded only as a modification which affects the economy without leaving an impression on the social and political domains. Thus, it is our view that the process of development involves structural changes pervading the economic, sociocultural, scientific-technological and political fields, which dynamically interact during the journey of a society's transformation to a new, hopefully, better one. Ohlin [11] asserts: " A reasonable suggestion might be that "development" is a shorthand term to describe something not previously recognized, such as an all-embracing social change for the better, not confined to mere growth of production but encompassing every kind of social improvement".

5.2 Development in Practice

At the beginning, attention was focussed on the similarities between developing nations; the common denominator is poverty: economic resources are scarce, and this situation constrains a breakaway. Thus, in these terms, the identification of a developing society's features is a rather simple matter: poor nations remain poor because they are poor [12]. What seemed necessary was to help them get away from the vicious circle of poverty, the objective of development being then the steady increase of wealth. How to accomplish this? Simply, by following the example of today's industrialized countries in the way they chose during their development.

The approach schematically given above is typical of the earlier economic development theories. They also recognized that, in order to implement them, something must be done to increase the economic basis of backward societies above a threshold which was supposed to hinder self-sustaining economic growth. This consideration fostered the conviction that external aid is the only way to eliminate the constraint imposed by the insufficient saving capacity of a poor nation; and that such aid should be maintained for an extended period to allow the achievement of a "take-off" situation.

Though this basic conception was put into practice, the results obtained proved that not all is money. During the last 30 years some developing countries have substantially improved in economic terms, but others have advanced but a little, and as a result the increasing differences between them have produced a further division of the developing nations into the so-called Third and Fourth World.

Everybody has learned from this experience. During more recent years other characteristics have been incorporated to define the features of developing countries, the focus of attention being shifted to social issues. Of these, the utilization of the labor force--unemployment, underemployment--and the distribution of income are essential factors related to the actual running of the economy and to the understanding of how the benefits of production are (or are not) made available to the majority of the population.

The attention to social problems is also reflected in the modern concern on the situation of the poorest sector of the population, the one with no access (and often no hope) to the essential requirements for bare existence, hundreds of millions of people according to current statistics. Many scholars (economists, sociologists, scientists at large) and civil servants are convinced that development is largely concerned with the satisfaction of "basic human needs", the fundamental requirements of food, shelter, medical care and education. As a consequence, today's concept of development embraces the consideration of the quality of life.

The present emphasis on socio-cultural and even psychological features is in line with the complexity and diversity of situations that must be dealt with when development objectives and their implementation ways and means are under serious consideration.

5.3 Implications and Constraints

If we go back to the point of view briefly stated in section 5.1, the consequence is that when we want to plan for or assess future development an essential requirement is to identify the characteristic features of a given society that constitute the driving forces for future change and upon which development objectives must be established. The next step is to recognize society's choice of a development path.

Pertinent questions related to the proposed sequence are of the following type: 1) What are society's hopes and aspirations? Do they concentrate on the achievement of wealth or are they mainly concerned with the attainment of a more just, equitable social situation? 2) How should the objective be pursued? Under the influence of foreign guidance or stressing independence and self-reliance?

In the context of our approach, the identification of objectives that respond to legitimate social requirements and the corresponding policy to implement them are heavily correlated issues. They should allow decisions upon priorities for development: for example, what comes first, a high GDP growth rate or the redistribution of income?

Generally, these priorities are written down, albeit implicitly, as official development plans put forward by governments. They essentially contain a description of short-term economic goals, the sectoral distribution of national product and the social changes which are expected. Society's reaction to development plans is normally slow and generally comes upon as the result of the appraisal of their consequences. Sometimes the reaction is of such a nature that swift changes in orientation, i.e., in the assignment of priorities, are required, when governments get the message that the plan is in flagrant contradiction with the hopes and aspirations of a vast majority of the population. But the norm is that reaction often stems from elitarian and/or illustrated minorities, where analysis of development plans is promoted by sectoral interests, either practical or academic. The effect of this activity on the preparation and execution of development plans is generally limited to its formulation, in no small measure due to the fact that planning requires quantification of parameters that represent actual activities. For example, an official development plan can emphasize that the main objective pursued is to improve the quality of life (as a rather long-term strategy); but, how could success or failure be measured on a continuous way? Thus, what generally is done is to propose the attainment of a certain goal of GNP growth, implicitly conveying the idea that its fulfillment will result in general economic and social betterment. It is a rule rather than an exception that the socio-cultural factors related to development could not be written down as specific commitments: the assignment of proportionally higher funds for education or medical care does not automatically insure that the plan's implementation will succeed in achieving the nonmeasurable expectation if no definite reforms of the corresponding system's structures are simultaneously enforced.

What we are trying to convey here is the difficulty of the endeavor: i) respond to society's hopes with an explicit document; ii) select objectives and clearly put forward priorities; iii) assess the balance between aspirations and practical realization, attending to sectoral interests.

In present developing countries, constraints for the selection of development objectives and their implementation come from both external and internal forces, which have resulted from the changing international environment and were not present during the development of the current industrialized countries.

We will enumerate the main factors which, in our times, conform the new frame of reference:

(i) The demographic explosion that is expected to happen during the next 50 to 100 years, overwhelmingly in the developing countries. The options open to them will be limited by the synergistic effect of large migrations, in particular to urban centers with weak infrastructures, and the increasing demand for jobs, food, shelter, education, energy.

(ii) The communications explosion, that has shown to the poor that they coexist with the rich in an essentially finite world. The actual existence of rich societies shows the variety of opportunities available to the affluent. The social behavior and lifestyle of the latter have been equated to the requirements for (and not to the consequences of) attaining wealth, unmistakably showing the objectives and methods that must be chosen to succeed.

(iii) On the other hand, the new awareness regarding "limits to growth" possibly imposed by the apparent shortage of natural resources conveys the idea that it would be hard to repeat an experience of development based upon cheap resources (particularly oil), previously viewed as practically inexhaustible.

(iv) The division of the world into a great number of nation-states with their borders and respective zones of influence, which favors competition for resources and markets, limits the possibilities of the less endowed, fosters the international division of labor and hinders the conception and implementation of worldwide/regional cooperation.

(v) The predominance of the industrialized countries and their transnational corporations in the development and ownership of science and technology. Developing countries have, at the best, weak scientific-technological infrastructures, incapable of keeping pace with the technological product of developed countries. In one world where technological innovation can be considered the deus ex machina behind development [13], the institutionalization of such infrastructure is a prerequisite for progress. Technological and, consequently, economic options of the developing world are basically constrained by this situation, which has been described in political terms as "dependence".

(vi) A final dimension we cannot omit to comment upon is of political nature. In an essentially interdependent world, the development issue is heavily interlinked with political matters. Developing countries have largely become aware of the fact that international affairs are a definite constraint to their ability in defining development objectives and in choosing their own ways. In this context, mention must be made of key subjects such as technology transfer and the issue of self-reliant development, which belong to the conceptual framework that must be basically understood before any dialogue between developing and industrialized countries could make constructive progress. Unfortunately, these issues have been poorly treated from a factual point of view and since confusion exists, they are dealt with rather rethorically. For instance, much effort is devoted nowadays to design a "code of conduct" for the transfer of technology from ICs to LDCs: if agreement could be achieved on its content, this will not change the capability of LDCs to use the new knowledge "open" to them. In order to be technologically "self-reliant", basic institutions must be created and protected from political erosion.

This enumeration is certainly not complete. But we think that it is able to show the modern complexity of the development issue. Some of the constraints are external to a given developing society and therefore must be viewed as part of reality, since the reluctance to accept the facts of life could only produce frustration: yes, there are richer countries, there is a political and economic pressure coming from outside, there are others which own the body of knowledge essential for independent decision. An enlightened development planner would recognize the existence of these factors as a part of the actual framework in which objectives can be accomplished, and in doing so will be able to envisage an appropriate strategy.

But some of the constraints are endogenous, they belong to what can be called the capability of society to recognize internal shortages. We have mentioned above the scientific-technological infrastructure, a wide concept that involves complex interrelated systems: literacy and education; basic and applied, public and private R&D; public and private management ability; promotion of inventive and innovative activities. Besides, capacity of control of each system and coordination of all, which means existence of bodies of knowledge at the academic, private and official levels.

The constraint imposed by the lack or weakness of such an infrastructure grows in pace with economic growth and the resultant structural changes. If we could envisage that the process of national development occurs in stages [14] perhaps the last stage necessary is the one in which society becomes conscious of its true capability of realization and finally could use this knowledge to select the most convenient, self-reliant way for future action. This stage is characterized, in our view, by the formation and coordination of institutions of two types: one conforming to the scientific-technological infrastructure, the other relating the former to the objectives of its society, permitting understanding and assessment of what implementation is possible in the light of the existing capability.

Without such institutionalized bodies, it is hopeless to deal, for instance, with the subject of technology transfer. How could a primitive technical society make adequate decisions in this field, which in the long term must affect forthcoming--and more often than not irreversible--structural changes, if it is not able to understand its own limitations? There are examples of policy decisions taken to "modernize" through the indiscriminate acceptance of advanced technology, without a previous evaluation of society's capability of realization that have resulted in more dependence and less self-reliance. The problem has been conceptualized by referring to "appropriate technologies" for the development of LDCs: in our view, the level of appropriateness is a measure of society's capability of realization, so what is appropriate today could be harmful tomorrow.

In summary, the present framework for development is qualitatively and quantitatively different from the one within which the development of today's industrialized countries took place. Its concerted effect is one of cultural influence and guidance by example, a mermaid's song leading into a promising future. Yet without more attention being paid to the endogenous problems, self-reliant development becomes utopian. The consequence is that most developing countries are eager to industrialize according to schemes similar to those shown by current developed societies, compete with each other for foreign technology and markets and, simultaneously, continue with their own arms race.

5.4 Past-Present Development Performance

We must have some quantitative notion of development performance. In order to deal with the subject, we need a yardstick. We have previously shown that the concept of development is complex, a number of interrelated factors pertain to it. But they cannot be measured by a single, universal indicator. The secular behavior of world development has been only registered through macroeconomic parameters, in particular GNP/cap. It is true that literacy and health indicators have been collected, but little is known about their long-term behavior and their correlation with economic development. Through the concomitant effect of medical and communications progress in relatively recent times, some endemic diseases have been practically erradicated in developing countries: this fortunate result has not changed substantially their economic development patterns, though in some cases have worsened the situation due to previously unexpected population growth. On the other hand, the index of literacy only tells us how many can read, but very little about the repercussion on national product.

Different views have been reported by economists and social scientists on the advantages and limitations of the current monetary indicator, GNP/cap, as an adequate representative of development. But it is the only yardstick generally accepted and available for long-term explorations. We will use it to look into the past-present evolution patterns.

5.4.1 Worldwide Trends

It is instructive to have first a glimpse at the secular changes characteristic of the economic growth of today's industrialized nations in their way towards affluence.

Kuznets [15] tells us that, since dates concentrated between the 1830s and 1870s, total economic product of the 15 to 18 presently developed countries grew (until 1963-67) at an annual average rate of 3%, population at about 1% and per capita product at around 2%. These long-term rates of growth were far greater than those previously observed in Japan and the older developed countries of Europe: in the preceding centuries, population in Europe was growing at a rate that cumulated to about 17% per century, and estimations on per capita economic product indicate that it was growing with a multiplication factor of 1.25 to 1.50 per century, as opposed to the factor characterizing the fast growth secular period of 6 to 30 (50 for Japan).

If we look at the post-World War II period of 1950 to 1975, economic growth continued at an even accelerated pace, this time including a good number of developing nations. For instance, the per capita GNP growth rate of Latin America was 2.6% per year and that of the developing countries as a whole (excluding the People's Republic of China) reached 3.0% per year, a value comparable (but lower) than the annual growth rate of 3.2% of the highly industrialized countries [16].

This performance should not be taken at face value. First, it is shown through very aggregated averages which cannot reveal wide differences between countries. In the case of the LDCs, for example, the figure is built upon the high OPEC nations annual per capita growth rate of 4.8% and the low economic growth of the South Asian countries of 1.7%. Secondly, reference should be made to the absolute values of GNP/cap to which they correspond, covering the whole spectrum of low, medium and high income classification of the LDCs. In the low income bracket there are nations which in 1975 had a per capita national income lower than that estimated for most of the current developed countries at the time they started their modern growth (more than US$ 200 at 1965 prices).

The record of the economic growth of LDCs in the period 1950 to 1975 shows three main features: (1) the rapid average growth rate; (2) the wide diversity of experience; and (3) the increasing disparity between richer and poorer LDCs. In what concerns Latin America, the region belonged in 1975 to the higher-income class, with a representative average GNP/cap figure of US$ 1066 at 1975 prices, around three times higher than that corresponding to East Asia, the People's Republic of China and the average of all LDCs, and seven times that of the poorest region (South Asia), increasing the disparity already existing in 1950 [16]. Since the diversity of experience is a general phenomenon, it must be stated that not every Latin American country could be included in the class of higher-income nations.

In the same way that disparity has been growing within LDCs, it has also increased between them and the ICs. Consequently, the gap in GNP/cap, which has been increasing for the last 100 to 150 years, continued to widen.

5.4.2 The Development Pattern of Latin America

In the light of the previous paragraphs, it should now be possible to describe the present development stand of Latin America and the path it is following to achieve its objectives.

Another way to look at the diversity of experience shown by the development trends of LDCs in the period 1950 to 1975 is emanating from the distinction of the type and origin of their economic structure [17]. In this context, Latin America belongs to a group that possesses essentially modern economic structures. These have evolved from active interaction with the market economies of the North during the 19th and 20th centuries, which has shaped the present pattern of the region's economy. Due to this interaction, Latin America has adopted the development path of the Western world, with a growing tendency in the last 20 years to pursue the goals of a consumer society. In other words, the consequence is the pure imitation of the consumption patterns of the developed countries [18].

The behavior is reflected in the characteristics of the productive system and in the lifestyles. The former resulted from the need to channel production through the market: it has suffered continuous transformations for a lengthy period as a result of the region's participation in international trade and the gradual growing demand of the internal requirements. Initially concentrated in processing agricultural and cattle raising products for export (an activity which has not been abandoned), the productive system has been modified during a period in which manufacturing industries grew for import-substitution reasons and lately to be active in the world market. In the wake of this transformation, an infrastructure has been shaped that in many aspects responds to the purpose and sometimes possesses the standards of the ones existing in ICs [19].

It seems that during the lengthy period of independence (more than 150 years) Latin America has not concentrated in soul searching, looking for social identity, but has accepted the rules of the game coming from the conception of an international division of labor.

The Latin American lifestyles reflect also those typical of the Western culture, at least in its big urban centers, where standards of living come from abroad. A heavy tendency towards centralization is seen not only in the political systems, but is reflected in social behavior, with a marked inclination towards urbanization. The attraction exerted by the cities is basically due to employment opportunities, with higher and regular salaries that allow access to the products of civilization. Unfortunately, for many only the most superficial forms of consumption become available, not only due to income limitations but also to overburden of the cities' infrastructural systems.

Most of the features of a modern developed society can be seen in the cities of Latin America, however: transport, communication, entertainment, schools and universities, public and private industry and commerce. Sometimes it is difficult to distinguish them from European or North American settlements, if it not were for the presence of suburban areas showing the result of an uneven income distribution. But the most important difference is, perhaps, the failure of the infrastructure to cope satisfactorily with an increasing demand for goods and services.

In conclusion, the past has shaped the present development pattern of Latin America. Though concerned minorities have looked and are still looking into the internal causes of the social tensions that often surface in Latin American societies, the identification of the development driving forces remains masked by the power of the imitative process that has defined objectives and selected the policies for economic development. If this situation will continue during the next 50 years cannot be foreseen. Since it has evolved in the wake of a steady secular transformation, we will provisorily accept it has depicted a likely alternative of future evolution.

6. THE APPLICABILITY OF THE MODELING SET DEALING WITH THE ENERGY FUTURE OF LDCs

We have briefly considered the issue of development because the assessment of the assumptions for scenario projections must be done in the framework provided by our conceptualization of the subject. If the society's structural changes are at stake during future development, then the model in charge of projections, in particular the one dealing with future energy demand, must have the ability to describe them in a consistent and reasonably accurate way.

In what follows, we will analyze the adequacy of the models for the study of the Latin American energy future.

6.1 Energy Demand: MEDEE-2

We are not going to document the values assigned to the roughly 180 parameters which constitute the input data of the model for each projected year. This task has been accomplished by A.M. Khan and A. Hölzl [3] in a paper that we include as Appendix I. Our endeavor is to analyze the conceptual construction of the model and its applicability to handle the situation of LDCs, in particular Latin America.

As a fundamental body of its input data, MEDEE-2 requires a description of future development quantified through a number of parameters on population growth, economic development and the associated lifestyles. Upon this information the model determines activity levels; the subsequent step is to calculate the implication of activities on energy demand.

In summary, one can describe MEDEE-2 as an accounting tool which i) must be fed with the projection of future development (this involves a scenario-writing process) and ii) calculates demand.

We will now consider in sequence the two functions mentioned above, without losing sight that some parameters pertain to both categories.

i) The scenario-writing process involves the consistent explicit formulation of future development objectives, which must be reflected in the values assigned to the relevant parameters. Of these, the lifestyle indicators clarify the aggregated view of society obtained in terms of population growth and economic development. When we reflect upon them, we find that they correspond to the way of life characteristic of an industrially advanced society.

Let us use some examples to prove this assertion. When we look at the way MEDEE-2 treats passenger transportation, the modal split correctly describes people's mobility in an industrialized country. In a LDC, travel occurs with a different modal split: there, human and animal energy play still an important role. It can be properly objected that the aim of the model is the determination of energy demand for commercial fuels, i.e., people walking, riding bicycles, carts and horses do not count for that purpose. But the knowledge of the difference in the modal split is necessary, at least, to understand future substitution requirements when more advanced transportation systems would be perhaps introduced, if the modal split of the ICs will constitute the solution people will definitely choose in the future. When one looks at the multitudes moving in the cities of India, it is difficult to envisage that a fundamental replacement by a modern efficient mass transportation system could be implemented in years to come; and, more importantly, if such a solution will be chosen, taking into account the magnitude of the enterprise in relation to available funds and infrastructure.

Perhaps this example could be considered irrelevant, since it seems not to deal with the core of the problem: how much motor fuel and electricity are actually used and will probably be needed? But the example points, in our view, to the nature of the assumptions that are implicit in the model and relate the future energy demand to a definite socio-economic structure.

The consideration of the housing stock and the requirements for comfort is possibly more appropriate. The analysis of space heating is dealt with in MEDEE-2 with a degree of detail necessary for a developed society living in a region with cold winters; it is, though, unnecessary for tropical regions. In these, air conditioning could require huge amounts of energy in the future, but this item is treated rather briefly in the model, and assumed to be taken care of with electrical equipment.

Besides the lifestyle indicators, the complex industrial activity of the manufacturing sector is analyzed in a rather aggregated way. In all cases, the level of production is not given in physical quantities, but in monetary terms. Thus, the assumptions on future economic structural change become crucial factors. A more disaggregated analysis in terms of physical production, the technological present situation and future perspectives of particular industries could contribute to a better treatment of energy demand in LDCs.

Finally, a number of simple econometric equations have been used to project long-term physical activities: steel production, feedstocks for the petrochemical industry, freight transportation, miscellaneous (military and international) motor fuel consumption, future increments in the labor force.

(ii) In section 2.1.1 we have already discussed the way in which energy demand is calculated in MEDEE-2.

A relationship between energy and economy has been used to calculate energy demand in the industrial sector. A parameter has been chosen for this purpose that determines the initial (base year) energy used per dollar value added. A factor of change implies how future evolution is projected.

In our view, the energy-economy parameter is made up of two contributions: one dealing with the specific energy consumption associated with one (or various, presumably similar) industrial process(es), and the other relating overall production to the monetary measure of the input to obtain it (value added). Therefore, two main descriptions are done via one parameter, respectively referring to process efficiency and industrial productivity.

Process efficiency depends, in turn, on the technology used: it should be comparable in LDCs and ICs when a certain activity is done using the same technology (this is not the case, e.g., for the agricultural sector). But what makes any difference between the two categories of nations has to do with the quality of the infrastructure and the consequent efficiency of labor, normally lower in LDCs. On the other hand, industrial productivity depends in great measure on the capabilities of management in association with the quality demanded from the market. Again, these factors are less exacting in LDCs.

As a result, the projection of future industrial energy demand in LDCs is a difficult task, since the parameters designed to introduce future change must reflect a number of factors related, mostly, to the assumed temporal implementation of the industrial infrastructure and its linkage to economic structural changes. They are, in our view, too aggregated to reproduce the deep transformation one should expect.

Another problem we see in MEDEE-2 for application to LDCs is the way used to account for the penetration of alternative sources. And this is connected, essentially, to the use of renewable sources. The so-called noncommercial fuels are introduced only in the household sector, though it is known that they are used also in certain industries (e.g., bagasse in the sugar cane industry). These noncommercial fuels are important, sometimes overwhelmingly so in the lower income countries; there use proportionally diminishes in the wake of development, when they are being replaced by conventional commercial fuels. Thus, the renewable sources will represent the contribution to the commercial energy sector of an important part (biomass) of the present noncommercial fuel use. This transformation is not seen by the model, where the incorporation of renewable sources is not allocated to each sector. On the other hand, only the use of charcoal is envisaged, a limitation that does not account for, e.g., an eventual production of alcohols as carburants.

With reference to energy demand savings due to conservation, they are mostly based on the effect of better insulation (space heating) and of process efficiency improvements in the industry. The latter could largely contribute to reduce energy demand in LDCs, provided we understand better how developing societies use energy. It has to be kept in mind that the energy budget of LDCs is definitely too low to envisage any substantial saving by conservation measures: perhaps, they could lead to a shift in the sectoral distribution rather than to a reduction in consumption.

In summary, it seems to us that the applicability of MEDEE-2 to LDCs is more difficult for the user the lower the income of a country/region, i.e., the less developed it is, for reasons that pertain to the ability in describing the development pattern and the energy sector as well. For the case we are considering here, that of Latin America, MEDEE-2 could be reasonably applied, though some modifications will permit adjusting a tool that must be recognized as the most suitable, avoiding the straightforward extrapolations of past trends implicit in econometric models.

Those modifications should take into account: the features of energy use in the rural-suburban versus the truly urban sector, especially in what concerns present utilization of noncommercial fuels and future replacement by fossil and renewable sources; the climatic and institutional patterns which cannot be dealt appropriately with the model; the convenience of dealing in detail with the few basic industries that make the utmost contribution to the economy; and the possible effect of fuel prices on curving or changing energy demand levels, at least for the short to medium term projections.

6.2 Energy Supply: MESSAGE

The input data of MESSAGE has to be expressed in terms of secondary energy. The transformation of MEDEE-2 results, which are given as final energy, must be done externally: it is based upon consideration of transportation and distribution losses, but for the projections also involves important assumptions on the respective shares of substitutable fuels. Those are based on the availability, convenience of use and likely price evolution of oil, gas and coal, in consequence a combination of judgments on matters of policy. Projections of this type are difficult, in particular for the case of developing countries where: (i) domestic resources' availability is poorly understood, not the less due to lack of systematic exploration and (ii) internal prices are the result of external decisions and of own social policy (protectionist measures).

The program optimizes the total cost of implementing a supply system based on the knowledge of the installation, operation, maintenance and fuel costs of central conversion units under specific constraints. It is not certain that such costs are the same in developing countries as in developed nations, which provide most of the technologies used, as well as components, equipment and spare parts. The program deals with a certain number of conversion units, which can be labelled conventional; the unconventional use of soft solar or renewable sources do not compete for the market with the others, their contribution is accepted by the program as it comes from the energy demand and, consequently, they cannot substitute conventional fuel: for instance, charcoal cannot displace coal, though in developing countries this substitution is common even in the industrial sector.

With reference to the installation associated costs (in constant U.S. dollars of 1975), either for the existing plants or for their replacement and extension in the future, they are assumed to remain constant during the whole time horizon of 55 years. Though such swift assumption could be justifiable for the case of today's commercially proved technologies--it could be accepted that cost variations will occur, due at least to changing prices of materials and labor, but that they would affect nearly equally all industries, maintaining then the relative existing differences--it is more difficult to admit that this will be the case for known but commercially unsettled technologies, like the fast breeder reactor and the synthesis of liquid fuels, or for technologies that currently are at the R&D level, like nuclear fusion or "hard" solar (STEC).

This point of costs becomes harder to handle if it is assumed that developing countries will cope with the implementation of the future supply system using their own industrial capability, minimizing in the course of the years the present dependence on know-how and components.

The MESSAGE model has been run basically for a reference case, provided by the results of MEDEE-2's Low and High scenarios. Alternative cases, like the nuclear moratorium (of particular interest to LDCs where nuclear power is in the initial stage) and the nuclear enhanced plus methanol production case have been mainly analyzed for the developed regions. Preliminary runs of the nuclear moratorium alternative for Latin America indicate, for example, that fossil fuels have to replace the missing contribution of nuclear power for electricity production: other sources, like hydropower and STEC do not change their share (which, in any case, is zero for STEC) due to installation overall cost of the solar system and to load curve constraints in the case of hydropower.

It is reasonable to assume that LDCs would try to enforce maximum utilization of indigenous resources. For instance, Brazil is promoting the use of ethanol production from sugar cane as replacement of conventional motor fuel on the basis that, even if the cost of such decision proves not to be economically competitive, perhaps the social benefits emanating from land and labor utilization could convincingly justify it. Therefore, it seems important to look for alternatives that maximize benefits other than purely economic. If this can be done with MESSAGE, the exploration of possible cases would enlarge our understanding of the price a developing nation must pay for the implementation of certain social or political decisions.

In summary, we can establish that MESSAGE is a powerful tool to look at alternatives of energy supply in Latin America, provided some constraints are modified, e.g., installation overall costs, competition of renewable sources. Its application would certainly be improved when its extension (currently underway and labelled

MESSAGE-2) becomes operative: the incertitude stemming from the projection of shares of substitutable fuels would be diminished, and the possibility of incorporating renewable source technologies will allow the evaluation of their substitution capabilities.

6.3 The IMPACT Model

IMPACT runs for the developing regions were of rather provisory nature. Their results should be taken with certain reservation since the input data describing each region's economy with the required degree of detail (input/output table, capital/output ratio) were not available. The preliminary runs involved the use of India's I/O table and the capital/output ratios typical of developed countries. Nevertheless, it was shown that the economic requirements (direct + indirect costs) for implementing the energy supply systems will rise to 7-8% of GDP, and consequently be higher than the corresponding burden in industrialized countries of around 5% of GDP.

It is impossible for us to visualize what will be the economic impact of the energy sector on the Latin American economy. The required input for two countries is now available, thus we can confidently expect that computer runs of the modified IMPACT model could give an indication, at least, of the effect for a country.

In general terms, we should expect high economic consequences in the light not only of the costs involving the energy supply system and the supporting industry, but also taking into account the fuel import requirements of non-oil producing countries. In 1975, Brazil imported 80% of its oil consumption, representing a bill of approximately 3.5 billion dollars, around 2.8% of that year's GDP. And the situation has further deteriorated.

A better understanding of individual countries' situations is then a basic requirement to gain understanding of the regional picture.

7. THE ASSESSMENT

In the previous sections we have presented with the necessary detail the information obtained within IIASA-ENP's global study on the future energy picture of Latin America and also developed the conceptual frame of reference which we considered necessary to evaluate the significance of numerical results as well as their implications. That framework was built upon our view of the development process, in whose light past-present and future Latin American development trends were viewed; and also on the analysis of the appropriateness of IIASA-ENP's modeling set to handle the energy situation of LDCs, in particular that corresponding to the region under consideration.

In the course of this work we have reached some conclusions. First, we have indicated that the development pattern of Latin America has been heavily influenced by its lengthy interaction with the Western market economies, this influence shaping a development path based on emulation: this can be seen through the planners objectives, the lifestyles predominating in the big urban centers and the tendency followed by human settlement patterns. This behavior and its implications form the basis of the IIASA-ENP approach to project the region's future development. Secondly, a critical analysis of the modeling set has shown to us that, in principle, it is suitable to the purpose, though adaptation to take into account the characteristic features of climate, resources, industry, infrastructure and energy use of Latin America will increase its flexibility as a tool for the exploration of alternatives.

In a separate paper [20] we have presented a preliminary analysis of IIASA-ENP's results, without advancing any judgment on the adequacy of the supporting assumptions and on the region's capability to implement the energy supply system corresponding to each scenario. This constitutes our present task. But we have estimated there that the regional results gave a rather optimistic picture, basically showing that the comparatively low integrated level of energy demand of the High scenario could easily be satisfied by the abundant regional oil resources. We qualified then this conclusion by referring to the Latin American countries with limited oil/gas resources and hinted that the regional seemingly comfortable outlook might be an illusion based upon the implicit assumption that Latin America is a coherent whole. This premise was unavoidable when interest focussed on the inter-regional balance within the global study, but is conflicting with national reality, since it assumes an unprecedented level of regional integration for the common solution of energy problems in each and all composing countries.

As stated above, our present task is to look further into scenario assumptions. Does a particular scenario reflect best the Latin American expectations and capabilities? Is it necessary to analyze national cases, in order to illuminate diversity as well as similarity? The answer to these questions will allow us to progress in the understanding of the Latin American energy future and give the clue for further explorations.

The relationship between energy and development is illustrated by the effect of cheap energy sources on the economic (technologically-based) structural changes of the post-World War II period in developed countries. This effect of a minor component in the formation of GDP, the energy sector, recalls to a chemist the function performed by a catalyst in a chemical reaction. For today's developing countries the availability of energy could mean a bit more than the difference between wealth or stagnation.

It is for this reason that we will interpret the results of the IIASA-ENP scenarios using two essential factors for a self-induced, self-reliant development, namely growth of product and society's capability of realization.

7.1 The Growth of Regional Product

We have seen that the macroeconomic yardstick used to measure the past-present (1950 to 1975) development trend of Latin America indicates a reasonable performance, as well as a change in the structure of the economy, showing the increasing importance of the manufacturing sector. The attainment of a per capita regional product over US$ 1000 in 1975, the highest among the developing regions, has not prevented that the income distribution pattern of 1950 was maintained or even worsened during the 25 years, in spite of the fact that the GNP of some countries has grown during few years at annual rates over 10%. These rates have fostered optimism in leading political circles, and in turn constitute the basis of future development plans objectives (not only in Latin America, but also in LDCs at large).

The goals for economic growth put forward by a group of developing countries are rather ambitious: they consider an annual GNP growth rate of 6% during the next two decades as a modest aim. Some countries of Latin America estimate necessary that the future economic product should grow at annual rates of the order of 7% or higher. These high expectations have not been confronted with the cautious considerations of ICs' economists on the likely global economic behavior after the 1973/74 oil crisis. If it is true that developing countries are not taking into account such analysis, perhaps it is because they consider themselves either capable of avoiding the effect of world interdependence or able to enforce a new international economic order preferably responsive to their requirements. Whichever the reasons, these expectations do not match with any of the IIASA-ENP's projections of future economic growth. The general trend of the latter is the ever decreasing GDP growth rates as time goes on. Two main factors contribute to this assumption: projected decreases in population growth and the increasing scarcity of basic resources. In what concerns the economic product growth rate for developing regions the assumption was made that the major stimulant for growth will be international trade dominated by the ICs.

We have documented on page 8 the projections used by the IIASA-ENP for the future economic growth of Latin America. When taken together with expected population growth, which was based on the assumption that the region's reproduction rate will become unity shortly after the turn of the century, the values of GDP/cap growth rates of the High scenario reflect best--at least for the medium-term until the year 2000--the objectives of Latin American countries.

It seems to us that the achievement of high economic growth could help to relax the social tensions provoked by inequitable income distribution. On the other hand, rapid increase in national product will facilitate the implementation of measures to increase productivity and strengthen the infrastructure required to support structural changes. Therefore, we conclude that the High scenario projections of economic growth represent a necessity for future Latin American development, whichever the path society will choose for further progress.

7.2 Society's Capability of Realization

The implementation of the future energy picture presented by IIASA-ENP's study, reflected in the detailed structure of energy supply by technology provided by MESSAGE, is related to two essential factors: capital and technology.

The problem posed by the reduced availability of capital does not only affect the level of possible investment: it also constrains technological progress. In addition, a relevant issue is how capital stock is allocated by government and the private sector as well. Latin American governments are heavily engaged in industrial activities, particularly in those related with energy production and distribution: as a consequence, a big bureaucratic system has evolved consuming an elevated share of government expenditure. On the other hand, capital availability is, in turn, constrained by negative balance of payments and the amount of the external debt, which has alarmingly grown in recent years, particularly after the oil crisis of 1973/74.

These monetary problems cannot be forgotten. However, we will be mostly concerned here with the second factor.

We will use an example to illustrate the point we have in mind in relation to the role of technology. The cost optimization procedure incorporated into the energy supply model indicates that in order to meet a share of the electricity demand projections of the Low and High scenarios, 23 and 43 GW(e) of nuclear power capacity must be installed respectively by the year 2000. As a reference, the IIASA-ENP Region III (OECD countries except North America) had in 1975 an operative installed capacity of 22.5 GW(e).

The figures given above must be explained within an appropriate frame. We assume that the nuclear power installation will be based on a self-reliant approach, involving full commitment of the region's technological capacity. This assumption corresponds to the factual situation and implies responsibility in the management, direction and control of all the activities related to the installation of nuclear power stations and the necessary facilities pertaining to the nuclear fuel cycle, plus their operation and maintenance.

What is not meant is that the process must be completely endogenous, i.e., that it has to start with the conception of an indigenous design or that the construction of major components must be done entirely in the region: the technology of nuclear power has been commercially proved worldwide and is available at a cost. What we imply, however, is the existence of a body of knowledge that permits decisions upon the best solutions in accordance with national requirements, fostering the gradual increase in the participation of local know-how and capability.

When we look at the present (1980) situation of Latin America with respect to the incorporation of nuclear power, only one country has today a commercial unit linked to the grid. Few other reactors are under construction, and a prudent estimation of regional plans to extend nuclear energy utilization indicates that between 20 and 30 GW(e) might be operating by the year 2000. What are the requirements to attain these objectives?

The nations involved must create and/or strengthen a scientific-technological infrastructure capable of handling all the sides of the complex problem. The ramnifications of such infrastructure escape the apparent main objective, since they are related with the adequacy of each country's higher education system to provide necessary replacement and increase in numbers of qualified personnel, the appraisal of what the local industry is capable now and the planned promotion of its future activities, the existence of appropriate institutions for separate tasks (for instance, one dealing with execution of the nuclear program, other responsible for control and licensing) including government and private bodies that are able to follow smoothly the development of the program and can, consequently, contribute to its better assessment within a fluid coordinated interaction.

In our experience, the institutional barrier is a major constraint to self-induced progress. It represents what we embodied with the term society's capability of realization: its lengthy and arduous implementation depends on many societal and political issues that, at first sight, have nothing to do with the technical world. However, it is our contention that the ability to develop technology is checked by the maturity achieved by the institutions that represent and measure that capability.

Apparently, we have been carried away from the consideration of the technological factor. But the development of technology is fundamentally linked to the understanding a society has of its own capabilities and limitations. This is finally interwoven with the human factor. Under these circumstances we feel that the projections of nuclear power of the Low scenario are achievable goals, well in accordance with the long lead times required to incorporate modern technology in LDCs.

We have dealt in our example with the introduction of a rather new, sophisticated technology. Let us assume that the implementation of such a supply system would be minimized. It must then be replaced, if the future energy demand level is accepted as representing a likely possibility. The replacement could be based upon the existing technologies or new methods must be developed. For the particular case under consideration, electricity production, fossil fired power stations are under the constraints of climbing fuel prices and expected future fuel shortages (for oil/gas, less for coal). The hydropower potential of Latin America has been barely exploited: it provides an escape from immediate technological pressure, but it does not solve the energy supply problem in the long run. New technologies must be developed: the same requirements posed by the incipient nuclear power industry will be valid in this case. It becomes clear that the region cannot postpone the fundamental necessity of improving its presently weak scientific-technological-institutional infrastructure.

These considerations, and the comparison of future energy demand levels with present consumption in ICs lead us to consider that the Low scenario requirements involve an energy supply system that will put a lower stress on the region, thus allowing more time to deal with the challenges of the future.

7.3 Conclusions

In the previous sections we have reported on IIASA-ENP's view of the Latin American energy future. In terms of the IIASA-ENP exercise, such picture could be put into perspective when compared with the present situation of the developed countries with market economies that conform with region III (OECD countries except North America). From Table 7.1 it can be extracted that the long term Latin American stand, as measured by gross averages (GDP/cap and Primary Energy Consumption/cap), resembles the one characteristic of region III at present.

In our attempt to evaluate the significance of numerical results in the light of our perception of the particular developing society we have reached a number of partial conclusions that now must be conceptually synthesized.

First, we have seen an apparent comfortable long term energy situation, due to the relatively low level of per capita primary energy consumption and the abundance of natural resources, particularly fossil fuels and renewables. But we have pointed out that this picture might be out of touch with reality; therefore, the analysis of some country situations becomes necessary to clarify the regional view.

Secondly, using our judgment that truly development has to be self-motivated and self-reliant, we assessed pro and cons of the two IIASA-ENP scenarios: the High scenario being more in line with actual economic performance, development planning and aspirations, was considered as necessary (though not necessarily optimum or achievable). On the other hand, the energy projections of the Low scenario indicated that the requirements for implementation of the energy sector were more in accordance with our estimation of the actual capability of realization, thus reducing the stress on the economy and stretching the time required for the incorporation of advanced technologies. This conclusion emphasizes again the importance of country analysis, since the existing diversity of economic structures and degree of industrialization between the countries of Latin America will likely increase; the more advanced countries will also have to face different situations according to their particular natural resource endowment and the energy policies they happen to choose.

Putting together high economic growth and reduced energy consumption objectives seems contradictory in the light of known energy-economy relationships. But if we recognize the degree of uncertainty associated with long term projections we could envisage the two scenarios as providing a range of possibilities within which reality might happen to be.

It is our view that IIASA-ENP scenarios are based on a likely evolution of the development process of Latin America. They are consistent with past trends and the present situation and take into account influences emanating from world interdependence; they have produced rather realistic results of energy demand. The situation changes when we look at the energy supply side. It is apparent that the strategy obtained could be modified if certain assumptions are changed. Under the pressure of today's energy situation, the attention of many countries is being focused on the search of alternatives for the best possible utilization of their natural resources.

The lesson of the exercise reported here is that we need more information from some national cases and regional cases as well. The first would be easier to interpret, and would hopefully provide a better insight in the quality of the data used to run the regional study. New regional runs must be done with the view on exploring alternatives in the supply system. The choice of alternatives should be realistic, pointing to the best use of all kind of resources, natural and human as well. We envisage regional studies involving nuclear moratorium, high hydropower and enhanced use of renewables to illuminate the constraints posed by commitments on the economic and technological sectors. For example, if a policy of radical incrementation of hydropower is analyzed, what will be the effects on the use of other sources, the electrification policies and the sectoral structural changes? How much time would be gained, how much capital would be necessary, would some economic resources be left to deal with the future projected requirements? In general, if policies rather than costs are optimized, what will be the price to be paid?

The capability to develop technology will play a fundamental role in the future of the region. Which is the most "appropriate" way to deal with technological progress, what technologies seem most adequate in what periods of time?

We conclude asking more questions than providing answers. The modeling set modification process which is underway at IIASA-ENP will help to answer them and allow a better understanding of the regions's future energy picture. It would also permit us to see more clearly the relevance of international aid: of economic nature and by means of technology transfer and joint ventures to strengthen the existing infrastructure. But regional results have shown that the integration of Latin American countries to deal with the energy problem is a major component for success.

7.4 Complementary Work

We have initiated two national energy studies, those of Brazil and Mexico, working in cooperation with country organizations. The first runs of the energy demand model have been done using input data directly or indirectly incorporated to national plans. The projected growth rate of GDP is, in both cases, higher than the values used in the IIASA-ENP High Scenario. The availability of the regional outlook allows one, in consequence, to judge upon the consistency of the national scenarios, in particular when also compared with the 1975 energy consumption pattern of developed countries and regions.

We have extracted a better insight of the regional situation through the exploration of these national cases which, in an initial stage at present, should be completed by runs of MESSAGE and IMPACT. In particular, the growth rate of electricity consumption is higher than envisaged by the IIASA-ENP scenarios, possibly showing the latter's underestimation of electricity utilization, mainly in the industrial sector. Also, through the interaction with national organizations, we have received new statistical data, whose study will permit a better assessment of many parameters and assumptions to be incorporated into the modeling set.

The role of renewable sources is envisaged quite differently in Brazil and Mexico, the latter relying on its rich endowment of fossil fuels, whereas the former fostering a policy of oil replacement and electrification. We estimate the possibility of an adequate evaluation of that role in the wake of future national and regional runs.

TABLE 7.1 Regional Comparison

	Latin America			Region III	
		2030			2030
	1975	Low Scenario	High Scenario	1975	Low Scenario
Population (10^6)	319	797	797	560	767
GDP (10^9\$75)	340	2230	3570	2385	6656
GDP/cap (10^3\$75/cap)	1.07	2.80	4.48	4.26	8.68
Primary energy (TWyr/yr)	0.34	2.31	3.68	2.26	4.54
P.E./cap (kW/cap)	1.06	2.90	4.62	4.03	5.92

8. RECOMMENDATIONS

In doing the evaluation reported herein, we have just touched upon many subjects of relevance for an understanding of the future development of Latin America and its relationship with the energy sector.

The established relationship with country organizations has barely started. However, it indicates strong interest in the application of IIASA-ENP's methodology and findings to their national cases, in order to produce a consistent basis for decision-making. We can only recommend that such links be strengthened if future actions in the field of energy of LDCs are contemplated.

On the other hand, it has become clear to us that the issue of development is at the intersection of multidisciplinary studies, which are necessary to reveal the significance of important components: the economic growth as a tool to foster equity, the development of technological capability (know-what and know-how), technology transfer, the linkage between society's ability to understand its predicaments and the existence of appropriate institutions. Since it is our view that the future of world harmony is threatened by the way the relationships between LDCs and ICs will be affected by their respective views, initiatives and actions on the development of the LDCs, we consider it important to focus attention on the industrialization problems of LDCs and the connected issue of technology transfer. Both will shape the future utilization of energy. And both would be tools either for progress or for frustration.

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APPENDIX TO SR-80-2/DRAFT

EVOLUTION OF FUTURE ENERGY DEMAND TILL 2030 IN DIFFERENT WORLD REGIONS AN ASSESSMENT MADE FOR THE TWO IIASA SCENARIOS

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Preface

Assessment of future global energy demand has been an essential and important element of the recently completed first phase of the IIASA Energy Systems Program. This report outlines the essential features of the final energy demand assessment in six out of the seven world regions considered in the IIASA study.

The analysis has been based on a model called MEDEE-2 which was adopted at IIASA for projecting the medium to long term energy demand at the level of world regions. The approach used in MEDEE-2 involves development of fairly detailed scenarios reflecting the expected evolution of socioeconomic activities and technological developments in different world regions over the next five decades during which parameters related to such activities and developments are expected to undergo considerable change.

Effort has been made here to describe how the estimates were obtained of the average base year (1975) values of MEDEE-2 parameters conceptualising the present energy consumption pattern at the regional levels considered, and to list the important relevant sources of information. The major assumptions and considerations behind the projected values of such parameters till the year 2030 have also been spelled out at length. Finally, the energy demand projections for various sectoral activities in different world regions are discussed in relation to their levels in 1975. It is hoped that all this information will prove to be of some help to future researchers in this field.

Acknowledgement

Many members of the IIASA Energy Systems Program have helped during the course of work described in this report. The authors would like to acknowledge all such help and useful discussions with various members of the Program although it would be difficult to name all of them individually. Still, we feel that our special thanks are due to:

P. Basile and V. Chant for many useful suggestions at various stages of this work and for carrying out a critical evaluation of the MEDEE-2 results in economic terms in general, and in relation to expected rising costs of different fuels in particular. Such an evaluation and feed-back from it were very necessary to remove certain inconsistencies in the results at early stages of the MEDEE-2 runs.

B. Lapillonne, who established the base year data set for the United States (about 90% of Region I), and also helped establish the base year values for Region III (Western Europe, Japan, Australia and New Zealand).

H. Maier, A. Papin and Y. Sinyak for providing useful information on Region II (Soviet Union and Eastern Europe) and for reviewing the energy demand projections for this region.

J.C. di Primio for advising on various aspects of the study on Region IV (Latin America) in particular, and on important considerations relevant to all the developing regions in general.

Finally, we are most grateful to Prof. W. Häfele, Leader of the Energy Systems Program at IIASA, for his guidance, suggestions and encouragement throughout the course of this work. In fact, without his advice and critical assessment, this work could not have been completed in its present form.

Abstract

An assessment is made of the evolution of energy demand in different world regions over the next five decades using an energy demand model called MEDEE-2. The 1975 pattern of energy consumption in each region is analyzed in terms of useful and final energy requirements of a large number of activities in three broad sectors of the economy viz. industry, transportation, households/services. Projections of useful and final energy demand to the years 2000 and 2030 are obtained by considering the plausible evolution of these activities together with feasible improvements in technological factors and likely changes in the life styles of the populace. The detailed scenario assumptions underlying these projections are spelled out and the rationale behind these assumptions is explained. The energy conservation embodied in these projections is elaborated and the shares of various energy forms in the projected sectoral energy demand trajectories are discussed. The assessment shows that the final energy demand of the market-economy developing world regions will, until 2030, increase by a factor of 7-12 as compared to that in 1975, whereas the corresponding increase in the developed world regions will be by a factor of 1.8-2.6. The projected final energy demand levels in various world regions are about 20-50% lower than those expected on the basis of historical final energy-to-GDP elasticities of the 1950-1975 period.

SUMMARY

This report describes the essential features and the results of a final energy demand assessment made at the International Institute for Applied Systems Analysis (IIASA), covering six of the seven world regions considered in the recently completed global energy study of IIASA's Energy Systems Programme. The assessment was made using the scenario development approach embodied in a model called MEDEE-2 which was adopted at IIASA for projecting the medium to long term energy demand at the level of world regions. In this approach first the base year energy demand of different sectors in a region is analysed in terms of useful/final energy requirements of a large number of activities in each sector and then this demand is projected for later periods by identifying the plausible evolution of various socio-economic activities and by estimating the probable technological improvements and life style changes in the coming decades.

The starting point for the present assessment was a set of basic scenario assumptions concerning population growth and economic development (measured in terms of GDP growth). Two different scenarios have been analysed; these are labelled as High and Low with respect to two different sets of assumptions implying relatively high and relatively low economic growth rates in the various regions consistent with a plausible range of world economic growth

during the next 50 years. The population growth rate assumptions are common to both the scenarios.

The assessment described in this report involved estimation of the base year (1975) values of some 180 parameters for each region and projection of the values of these parameters to the years 2000 and 2030 in a manner consistent with the basic scenario assumptions and incorporating feasible technological improvements and plausible life style changes. The estimated base year values of the various parameters are listed, the method of their estimation is described and the sources of information are spelled out. Similarly the projected values of these parameters have also been listed and the reasoning underlying these projections is described. The projected requirements of final energy for various sectoral activities are discussed and the extent of conservation incorporated in the projections has been spelled out.

Some of the main results of this assessment are:

1. By 2030 the final energy demand in the developed regions (IIASA Regions I - North America; II - The Soviet Union and Eastern Europe, and III - Western Europe, Japan, Australia etc.) will increase by a factor of 1.8 - 2.6 as compared to that in 1975, whereas the corresponding increase in the three developing regions considered in the present assessment (viz. IIASA Regions IV - Latin America; V - Africa (except Northern Africa and

South Africa) and South East Asia, and VI - Middle East and Northern Africa) will be by a factor of 7 -12. The projected demand in the various regions will, however, be lower than that estimated on the basis of historical final energy - to - GDP elasticity of each region by 16 to 40% in the Low Scenario and 23 to 54% in the High Scenario.

2. The per capita final energy consumption in the developed regions (I, II, III) will increase from a level of 2.8 - 7.9 kW in 1975 to a level of 3.9 - 11.6 kW by 2030, whereas that in the developing regions (IV, V, VI) will increase from 0.2 - 0.8 kW to 0.5 - 4.6 kW over the same period. Among the developing regions the largest increase will take place in the resource-rich Region VI and the smallest increase will occur in the resource-poor Region V.

3. The sectoral shares in final energy demand in various world regions will not undergo major changes during the next 50 years so that the regional differences in the sectoral distribution of final energy will persist. In particular the transportation sector in the developing regions and the household/service sector in the developed regions will continue to have relatively higher shares in the final energy demand than those commanded by the corresponding sectors in other Regions.

4. The share of electricity in final energy will increase everywhere -- from 10 - 13% in 1975 to 20 - 23% in 2030 in the developed regions, and from 4 - 10% in 1975 to 15 - 17% in 2030 in the developing regions.

5. The specific liquid fuel requirements as motor fuel or petrochemical feedstocks will, in 2030, account for a 34 - 43% share of final energy in the developed regions and 45 - 57% in the developing regions. The corresponding shares in 1975 in the developed and the developing regions were in the range of 24 - 37% and 32 - 52% respectively.

6. Manufacturing activities will continue to dominate the industrial final energy demand (i.e. the demand of manufacturing, mining, agriculture and construction sectors) in all regions. The share of manufacturing in the industrial final energy demand in 2030 of different regions will be in the range of 76 - 90% as compared to 62 - 92% in 1975.

7. The share of automobiles in the transportation energy will decrease in the developed regions and increase in the developing regions. The most notable change will occur in Region I where this share will decline from 67% in 1975 to 19 - 29% in 2030. The shares of automobiles in the transportation sector's final energy demand of different regions will, in 2030, lie in the range of 8 - 36% as against 6 - 67% in 1975.

8. Soft solar devices will be able to meet in 2030 about 1 - 3% of the useful thermal energy requirements of the manufacturing sector and 5 - 13% of those of the household/service sector in the developed regions. The corresponding shares in the developing regions will be in the ranges of 4 - 5% and 2 - 12% respectively.

9. Inspite of gradually increasing penetration of electricity, heat pumps, soft solar and district heat in the heat markets of the manufacturing and household/service sectors, fossil fuels will continue to be the most important source of useful thermal energy in these sectors in all regions except Region II. The shares in 2030 of substitutable fossil fuels in the developed Regions I, III and the developing regions will be in the range of 80 - 90% for the manufacturing sector and 55 - 85% for the household/service sector. The corresponding shares in Region II will be about 30 and 25% respectively due to continued heavy reliance on district heating systems in this region.

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1. Introduction

IIASA's Energy Systems Progam deals with the medium- to long-term aspects of global energy supply and demand. It concentrates on a period of 15-50 years from now, during which the world energy system will have to undergo a major transition. This transition will result from a large increase in world population, the expected industrialization and relatively fast economic growth of the developing countries and the worldwide scarcity of the hitherto cheap conventional forms of energy, particularly of fossil oil and natural gas. The major findings of the first phase of this study have recently been reported in a book entitled "Energy in a Finite World--A Global Systems Analysis" (Energy Systems Program Group, 1981). This paper reports on an assessment of final energy demand in various world regions that was carried out as a part of the above program by using an energy demand model called MEDEE-2 (the structure of MEDEE-2 is described in detail by Lapillonne, 1978a).

In IIASA's energy systems study, the world was divided into seven regions, as is illustrated in Figure 1. (For a complete listing of the countries in each region see Appendix I.) The grouping of countries in these regions was based not necessarily on their geographical proximity but mostly on considerations of similarities in social, economic and demographic structures, and on prospects of economic growth and availability of energy resources. The work described in this report covers only the first six of the seven world regions shown in Figure 1. The energy demand assessment for Region VII (China and Centrally Planned Asian Economies) was not carried out with MEDEE-2 due to the lack of data. Instead a simplified model called SIMCRED (Parikh 1978) was used for this region; this assessment and its results are, in general,not discussed in this report.

The long-term projection of energy demand and supply in various world regions can be made only in the light of mutually consistent projections of population, economic growth, availability of energy, material and other resources, some perception of technological innovation and development, and in the wake of various physical, social and environmental constraints. In order to obtain a consistent picture, one has to look at all these factors both individually and collectively, and try through an iterative procedure to eliminate internal inconsistencies.

Such an analysis was carried out at IIASA using a set of mathematical models as its major analytical tool (Basile, 1980). The flow of information between these models is schematically shown in Figure 2. It starts out with some initial scenario definitions of the economic and population growth rates in the various world regions. Then the demand of final energy in each region is evaluated with the energy demand model MEDEE-2 projecting changes in economic structure, life-styles, technical efficiencies, etc., that could be expected under the basic scenario conditions. The energy supply model MESSAGE then leads to optimum supply strategies consistent with the availability of energy resources and subject to various constraints encompassing technological, environmental and other related issues. Consideration of the interregional energy trade calls for iteration of the MESSAGE runs for various regions until a globally consistent picture emerges. The economic impacts of the regional supply strategies are then analysed in the energy-economy interaction model IMPACT, and the corresponding implications together with the estimates of energy and fuel prices obtained from the MESSAGE runs are used to modify, if necessary, the scenario definitions of regional economic growth and the projections of some of the parameters used in the MEDEE-2 runs of the preceding iteration of the modelling loop. This procedure is repeated until the demand and supply projections are considered to be "reasonable" and consistent.

This report is concerned mainly with the assessment of final energy demand, based on a MEDEE-2 analysis, for the IIASA Regions I through VI. In order to provide a proper appreciation of the assessment procedure, we will also describe, although briefly, the energy accounting and the analytical approach followed in the MEDEE-2 analysis*. This will be followed by a discription of the input data actually used for the base year (1975), of the values assigned to the scenario variables for the years 2000 and 2030 in the various world regions, and of the assumptions underlying these projections. The results of the MEDEE-2 analysis will then be discussed in terms of the projected energy requirements for various sectoral activities and the extent of "conservation" incorporated in these projections.

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* The computer program actually used for the assessment is described by Hölzl (1980).

2. Some Definitions:

In discussing the issues related to energy demand and supply, a distinction has to be made between different forms of energy usually referred to as primary energy, secondary energy, final energy and useful energy. The difference between these various forms is illustrated in Figure 3.

Primary energy* (at the lower left of Figure 3) represents the energy content of extracted raw fuels, e.g., crude oil or natural gas at the wellhead, coal at the minemouth. Some primary fuels need to be refined or converted to secondary energy (in oil refineries or power plants) with typically rather large conversion losses (at least 60% losses in the case of coal converted to electricity), while others can be transported and used directly as secondary energy. Secondary energy, after transmission and distribution through major networks (e.g. oil/gas pipelines, delivery trucks, high and low voltage lines), becomes final energy. Electricity at the output, or busbar, of a power station is secondary energy; electricity at the home wallplug is final energy. Final energy is energy delivered to final consumers--oil delivered to burners in the basement, or to industrial boilers. Final energy is what the consumer buys. What one actually benefits from is useful energy--the heat that warms living rooms, for example. Produced photons, heated air, kinetic energy are useful energy. All conversion processes from primary energy through useful energy involve varying amounts --

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*Primary energy also includes fossil fuel equivalents of, for example, nuclear energy and hydropower converted to electricity, and the energy obtained from new sources such as solar, geothermal, wind, ocean thermal gradients, charcoal or fuelwood from forests, planned wood plantations, biogas, etc. Except where noted, primary energy excludes noncommercial use of fuels such as firewood, farm wastes and animal wastes.

of losses due to conversion and/or transmission, storage and distribution as shown in Figure 3. The useful energy is also ultimately rejected to the environment, after providing the required energy services in combination with other inputs such as capital, know-how and labour. The amount of useful energy needed for obtaining a given amount of energy services depends on the relative magnitudes of these other inputs (Häfele, 1977), and this is what leads to the ultimate potential of energy conservation.

The energy demand projections discussed in this report were made only in terms of useful and/or final energy forms The evaluation of secondary and primary energy requirements based on these demand projections, was made in the MESSAGE model runs and has been described in (Energy Systems Program Group, 1981).

3. The MEDEE-2 Model for Energy Demand Assessment

3.1 Methodological Approach

MEDEE-2 is a simulation model for evaluating the energy demand implications of economic and lifestyle scenarios for the long-term evolution of countries or regions. It is a simplified version, described in Lapillonne (1978a), of a more general approach developed by Chateau and Lapillonne (1977) at the IEJE, University of Grenoble, France. MEDEE-2 is based on a disaggregation of total energy demand into a multitude of end-use categories such as heating or cooling of dwellings, urban/intercity passenger transportation by mode, steam generation etc. When the useful energy demand of a given end-use category can be provided by various energy sources (e.g. fossil fuels, district heat, electricity or solar systems), the energy demand is calculated first in terms of useful energy* and then converted into final energy terms based on assumptions about the penetration of various energy sources into their potential end-use markets and about their end-use efficiency.

For nonsubstitutable uses (e.g. motor fuel for automobiles or electricity for electrolysis, lighting and appliances such as washing machines and refrigerators), energy demand is calculated directly in final energy terms. Table 1 gives an overview of the end-use categories considered in MEDEE-2. For each end-use category, energy demand (useful or final) is related to a set of determining factors, which may be macroeconomic aggregates, physical quantities, or technological coefficients. The energy demand projections result from the evolution assumed for these factors. Because of this high level of disaggregation and the relatively few structural assumptions built into the model, it can be viewed as an accounting framework of the energy uses in a country or a region.

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*For this assessment, useful energy for thermal processes is expressed as equivalent requirements of electricity.

Figure 4 shows the scheme for projecting useful and/or final energy demand used in MEDEE-2. The starting point is a scenario which defines an environment of population growth, economic development and energy availability and prices envisaged for the future. These general scenario parameters must be disaggregated in terms of economic structure (GDP expenditure and formation and production of certain very energy-intensive basic industry products), demographic structure and life-styles (labor force participation, urban/rural split, household size; type and size of dwellings and their energy-using equipment; travel distances, automobile ownership, preferences for certain modes of travel); and technological structure (energy intensiveness of industrial sectors, dwelling insulation, fuel economy of vehicles etc.). Once this disaggregation is done, calculation of energy demand for each end-use category is straightforward.

For certain thermal uses (space/water heating, steam generation etc.), energy demand is calculated in useful terms. Several energy sources (fossil fuels, electricity, district heat, solar systems, heat pumps) can be used to meet this demand. While the potential markets for each source are defined in the model, the user must specify the expected penetration of the various energy sources in their potential markets and their efficiency.

Transportation

Three types of transportation are distinguished in MEDEE-2: passenger, freight, and international and military transportation. Passenger transportation is broken down into urban and intercity categories.

For international and military transportation only the use of liquid fuels is considered feasible. Data for this category are often difficult to find, and the motor fuel demand of this type of transportation is therefore treated simplistically as a function of GDP.

The demand for domestic freight transportation (measured in net ton-kilometers) is calculated as a function of the GDP contribution by the agricultural, mining, manufacturing and energy sectors. The modal split, i.e., the allocation to the various modes (rail, truck, inland waterways or coastal shipping, pipeline) must be specified exogenously, as well as the energy intensity (per ton-kilometer) of each mode. Except for rail, where electricity and coal can also be used as an energy source, only liquid fuels are assumed to be used.

Passenger transportation is treated in more detail because it accounts in most countries for a major share of energy consumption.

Total demand for intercity passenger transportation (measured in passenger-kilometers) is calculated in MEDEE-2 from data on population and average distance travelled per person per year. Automobile travel is calculated from data on population, automobile ownership, average distance travelled per automobile per year, and an average load factor (passenger-kilometer per vehicle-kilometer). The remainder is allocated to public transportation modes (rail, bus, airplane) according to exogenously specified shares. The corresponding vehicle-kilometers are calculated from average load factors for each mode. The energy intensities (per vehicle-kilometer) also have to be specified. As for freight transportation, except for railways, only liquid fuels are assumed to be used.

Total demand for urban transportation is related to the population in large cities* where mass transportation is feasible. It is calculated from data on the average distance travelled per day and per person in urban areas and on the total population living in these areas. The energy consumption related to this demand is determined from exogenously specified shares of various modes (private automobiles and mass transportation powered by motor fuel or electricity), together with average load factors and energy intensities of each mode.

All energy demand in the transport sector is calculated only in terms of final energy.

Industry

Under this label in MEDEE-2, all economic activities except for those of the service sector are included. Specifically, these are agriculture, construction, mining, three manufacturing subsectors and energy (electricity, gas and water). The energy consumption of the energy sector (and some other energy-related activities that can be isolated) is neglected because it is

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* Cities with more than 50,000 inhabitants in Regions I, III, and those with more than 100,000 inhabitants in the developing Regions IV, V, VI. For Region II all urban population has been included in this category.

related to conversion activities as calculated at a later stage by the MESSAGE model.

Three types of end-use categories are considered: specific uses of electricity (for lighting, motive power, electrolysis, etc.); thermal uses (space and water heating, low/high temperature steam generation, furnace operation); and motor fuel use (mainly for motive power in nonstationary uses such as in agriculture, construction and mining).

Because it is mostly impossible to obtain energy balances in such detail, all present uses of electricity in industry are considered "specific" (in the sense that they are unlikely to be replaced by other energy sources) and all fossil fuels except for motor fuel, are assumed to be consumed for thermal uses. This implies that electricity penetration into thermal uses must be interpreted as incremental penetration above the levels reached today.

For the energy demand calculations, knowledge of the activity level (value added) and energy intensities (per unit value added) in each sector is required. Energy intensities must be specified in terms of final energy for motor fuel and electricity and in terms of "electricity equivalent" for thermal uses. The breakdown of thermal uses (space and water heating, low and high temperature steam generation, furnace direct heat is assumed to be constant. If the breakdown is not known for each subsector, an average split must be specified.

The energy consumption of manufacturing industries depends on the activity level and on the energy demand per unit of output in each sector. Since the sectors are highly aggregated and therefore inhomogeneous, the energy intensity may change with a modified product mix as well as with increased process integration and other operational improvements. Besides, the energy use pattern changes as a result of substitutions of other energy sources for fossil fuels, especially with regard to thermal uses.

For thermal uses, the penetration of electricity, district heat, cogeneration, heat pump and soft solar technologies must be estimated. The remaining energy demand is assumed to be met by fossil fuels, and is converted to final energy demand using exogenously specified end-use efficiencies for heating systems, boilers and furnaces (these must be given relative to electricity). Electricity can penetrate into virtually all thermal uses; the potential market of the other alternatives is restricted to steam and low-temperature uses.

The demand for coke and for petrochemical feedstocks is calculated separately in MEDEE-2, since they account for a major share of total industrial energy consumption. Coke demand is related to pig iron production, which in turn is related to steel production; and petrochemical feedstock demand is directly related to the value added of basic materials industries.

Households and Services

It is well known that in the presently developed countries space heating accounts for the major share of energy consumption in the household sector, and that with improved insulation this energy demand could be reduced considerably. Especially buildings constructed after the world's awakening to the energy crisis in 1973 have or will have better insulation. To capture this difference, pre-75 and post-75 buildings are treated separately in MEDEE-2. In addition, three types of dwellings are considered: single housing units with central heating, apartments with central heating and dwellings with room heating only. This is done in order to capture the large difference in the average heat loss of these dwelling types.

The change in the housing stock of the residential sector is determined from data on average family size and population, on demolition of existing dwellings by type and on construction of new dwellings by type. Allowance is made for the reduction of heat loss in old dwellings through retrofitting; the heat loss of post-75 dwellings is calculated from data on the average size and the specific heat loss (per m^2) for each type of dwelling.

Energy demand for water heating, cooking, air-conditioning and the electricity consumption of secondary appliances (such as washing machine refrigerator, freezer, dish washer, clothes dryer, vacuum cleaner) is calculated from exogenously specified ownership fractions and/or average annual consumption rates.

The change in the building stock of the commercial/service sector is calculated from data on the average floor area per worker and labor force and on the demolition of existing floor area. Allowance is made for improving the insulation of old buildings. Besides thermal uses (space/water heating), two other end-use categories are distinguished, namely air conditioning and specific electricity uses, for which penetration and/or average consumption rates must be given.

The energy demand calculations for this sector are generally made in terms of "electricity equivalent". For air-conditioning, electricity is considered the only energy source; this is also true for heat pumps. In all other instances, the penetration of alternative sources, such as electricity, district heating, heat pumps, or soft solar technology, must be estimated; the remaining energy demand is assumed to be met by fossil fuels and converted to final energy demand using exogenously specified end-use efficiencies. The potential market for district heat is restricted to large cities, and the potential market for solar is restricted to post-75 single housing units in the case of space heating; penetration of solar technology for thermal uses in the commercial/service sector is also assumed to be feasible only in low-rise buildings.

3.2 Input Data Requirements

There are some 180 parameters in the input data files of MEDÊE-2 serving to capture such essential features of the economy, demography, technology, lifestyle and various social and industrial activities of a country or region that have or, in the foreseeable future, are likely to have a bearing on the amount and pattern of its final energy consumption. These parameters are constants or variables. Constants are understood to comprise initial values as well as coefficients held constant in the model calculations. Variables are time-dependent parameters for which scenario values have to be assigned for each model year.
A complete listing of all the parameters and their definition is

given in Appendix II. This list refers to the specific computer program (Hölzl, 1980) used in the present assessment.

4. Two Scenarios: Basic Elements

The future evolution of world energy demand will be governed essentially by three basic elements: population growth, economic growth and technological developments. The last two elements among these, which are to a certain extent interdependent, will also be influenced by the relative availability (or scarcity) of energy as a source of power and its prices.

The starting point for IIASA's energy demand projections 1975-2030 is the definition of two scenarios (Chant, 1980) describing the evolution over time of population and economic growth in the seven regions of the world described in Figure 1. The population projections common to both scenarios are based on Keyfitz (1977). These scenarios are labelled High and Low in terms of two different levels of world economic growth, which are conceived to cover a range of plausible economic developments in the regions in a mutually consistent manner.
The figures for economic growth projections have been arrived at after several iterations through the modeling loop of Figure 2 until the energy prices and the investment requirements of the energy sector obtained for the various world regions were considered to be consistent with their envisaged

economic growth rates. (See Basile, 1980, Chant 1980, Energy Systems Program Group 1981, for a more detailed discussion.) Tables 2, 3 and 4 simply list the projections of population and GDP in various world regions that serve as basic inputs to the energy demand assessment to be discussed. The population projections for the world as a whole as well as by groups of developed (I, II and III) and developing (IV, V, VI and VII) Regions are plotted in Figure 5. Note that the period of consideration is one in which the world population is expected to undergo a major transition, with a predominant increase occurring in the areas of the presently developing economies.

Depletion of energy resources, increasing production costs and rising prices of energy commodities traded internationally over the next 50 years are qualitatively accounted for in this assessment. (For a detailed discussion with respect to the two IIASA scenarios, see Energy Systems Program Group, 1981). These issues influenced the projections of some scenario parameters of the MEDEE-2 model, and occasionally required a modification of the values used in a previous iteration of the modeling loop of Figure 2. For our present purpose, it should suffice to point out two important results of the assessment. The biggest difficulty in energy supply, which is to be felt worldwide, will be to meet the demand for liquid fuel. Further, by 2030, the average final energy production costs will increase to about 2.9 to 4.2 times the 1972 values (with the corresponding prices probably increasing to 2.4 to 3.0 times the 1972 prices) in the various world regions (Chant, 1980).

5. Application of MEDEE-2 to IIASA Regions I to VI

5.1 Base Year Data/Inputs

As is evident from the description in Section 3, assessment of future energy demand following the MEDEE-2 approach requires base year data of a large number of parameters as well as projected values of these parameters that are consistent with the basic scenario elements (Section 4) for each world region. For some of these parameters, statistical information detailed by countries or by groups of countries is available from UN, IBRD, FAO, IRF, OECD, ECE, etc., while for others the information is either limited to only a few countries (mostly contained in national statistical bulletins) or is not documented at all.

Overall, the data base situation is considerably more satisfactory for the developed Regions I, II and III than it is for the developing Regions IV, V and VI. Therefore, in the case of the developing regions more than of the developed regions, we had to rely on extrapolation of regional averages from information on just a few countries (sometimes only on one) in a given region, or on estimates we made on the basis of scattered material in the literature and from discussion with knowledgeable persons from countries in these regions.

In spite of these difficulties, we feel that the base year data for all the regions represent fairly well the regional average situations prevailing in 1975. One should keep in mind, however, that the purpose of this exercise was to conceptualize the present energy demand pattern in each world region and to arrive at projections of the demands for specific and intersubstitutable energy forms. This was achieved considering the likely evolution of various socio-economic activities in line with the basic assumptions of the two IIASA scenarios. This report documents the complete set of input data for the base year (1975) for each world region as it was used in the IIASA analysis (Energy Systems Program Group, 1981). It is hoped that some of these data will be refined in due course, within IIASA or in similar studies outside the Institute, as improved and/or more complete information becomes available. With these comments we now proceed to describe briefly how the base year data related to various groups of parameters were obtained.

The starting point for this exercise was to determine primary energy consumption in the form of both commercial and noncommercial fuels. These data are listed in Table 5. The data on commercial energy consumption in Regions II, IV, V and VI are based on World Energy Supplies (UN, 1977a; 1978a), and those of Regions I and III are derived basically from OECD Energy Statistics (OECD, 1977). For noncommercial energy, the data on fuelwood are based on World Energy Supplies (UN, 1977a; 1978a), and those for agricultural and animal wastes on the estimates by Parikh (1978) coupled with information on agricultural production given in FAO (1977). The noncommercial energy use in Regions I and III, as compared to the use of commercial fuels, is insignificantly small and has been neglected.

The MEDEE-2 calculations lead to only final energy and not to primary energy. Thus, for adjusting the various base year parameters to match the actual energy consumption, one needs to know the final consumption in terms of electricity as well as in nonelectric energy forms. Such information is readily available for Region I, for most of Region III and for part of Region II (Eastern Europe) in OECD (1977) and ECE (1977). The missing information on these and other regions is obtained by assuming appropriate conversion (primary to secondary) and distribution (secondary to final) losses typical of different fuels, as well as an appropriate fuel mix for thermal electricity (and, in the case of Region II, district heat) generation in the various regions. The final energy estimates for the base year are listed in Table 6.

Information on the sectoral distribution of final energy in Region I, in the Eastern European part of Region II, and in the OECD section of Region III is also available in OECD (1977) and ECE (1977). Similar information on the developing regions is derived partly from sectoral primary energy consumption data for certain countries (Brazil, Mexico, India, Pakistan, Egypt, Saudi Arabia) (Vieira, 1978; WAES, 1976; Parikh, 1976; Henderson, 1975; Pakistan, 1977; Elshafei, 1978; Saudi Arabia, 1977) and partly by adjusting the less certain MEDEE-2 parameters to match the total final energy demand*. These estimates are summarized in Table 7

*A recent publication by OECD (1979b) giving information on energy consumption data for sectoral activities in sixteen developing countries was not available at the time of the assessment.

In the following, the base year input parameters (see Appendix II for definitions) for MEDEE-2 are discussed by groups covering: (1) demography, (2) macroeconomics, and (3) energy consumption by the industry, transportation and household/service sectors. They are listed in Table 8, and the corresponding sources of information are given below. In order to obtain the appropriate regional values, additional calculations and/or extrapolations were necessary in most cases.

5.1.1 Demography: (parameters in Group 1 of Table 8)

The sources of information for the various parameters were as follow:

Variable		Reference
PO	:	UN (1977b; 1978b)
PLF	:	UN (1976a)
PARTLF	:	US (1976a) and Canada (1975) for Region I
		CMEA (1976) for Region II
		ILO (1976) for Region III
		FAO (1977) for Regions IV, V, VI
POLC	:	UN (1976b) for Regions IV,V,VI; Paxton (1976) fo Regions I and III; CMEA (1976) for Region II
PRUR	:	UN (1976b)
CAPH	:	ECE (1978a) for Regions I, II, III
		UN (1974) for Regions IV, V, VI

5.1.2 Macroeconomics (parameters in Group 2 of Table 8)

The sources of data were the following:

Variables		Reference
Y	:	UN (1977c), World Bank (1977), OECD (1979a)
All other data	:	UN (1977b) for Regions I, II, III UN (1977c) and data supplied by Arab Fund (1979) for Regions IV, V and VI

5.1.3 Energy Consumption in Sectors

I. Industry (Agriculture, Construction, Mining and Manufacturing)

(i) Parameters in Groups 3.1a and 3.1b in Table 8.

The data for Region I are based on estimates for the U.S. made by Lapillonne (1978b) who used the information given in WAES (1976) and Doblin (1978). The values estimated for Region III are based on the data for Austria (Foell, 1979), France (Lapillonne, 1978c) and the U.S. The estimates for Region II were made partly on the basis of data contained in Vigdorchik (1976) and USSR (1976) and partly by intercomparison with Regions I and III. For Regions IV and V, the values were in general derived by combining the sectoral energy consumption data of a few countries (viz. of Brazil (Vieira, 1978) for Region IV, and of India (Parikh, 1976) and Pakistan (1977) for Region V) for recent years and the corresponding value-added contributions to respective national GDPs (UN, 1977c). The data for Region VI were estimated by adjusting the values obtained for Egypt from the energy consumption data given by Elshafei (1978) in the light of those for Regions IV and V.

The energy intensity values for agriculture (EI. AGR. MF and EI. AGR. EL) in Regions IV, V and VI, were also adjusted taking into account the extent of farm mechanization and irrigation (FAO, 1977) in these regions. The energy intensity of mining in Region VI was estimated from the data given by Chapman and Hemming (1976) and Saudi Arabia (1977).

(ii) Parameters in Group 3.1c and 3.1d in Table 8

These parameters are used to project future changes in energy intensity of various industrial activities relative to the base-year values. Each of the parameters is by definition equal to unity in the base year.

(iii) Parameters in Group 3.1e in Table 8

At the time the present set of model runs was carried out, detailed information on these parameters was available to us only for the U.S. (APS, 1975; Lovins, 1977), but we had some partial information on the USSR (Vigdorchik, 1976). This is the basic information used for the estimates of these parameters in all regions, although some adjustments were made to account for the different climatic conditions in the regions. Detailed information recently published for the U.K. in (Leach, 1979) indicates slightly higher values for STSHI and STI, but the differences are not significant for the present results.

(iv) Parameters in Group 3.1f in Table 8

Among these parameters, relating to the penetration of alternative energy sources into the thermal energy market, ELPIND is by definition zero for the base year.

HPI, SPLT and SPHT are zero in 1975 in all regions, and consequently EFFHPI and FIDS are ineffective. IDH has a large value for Region II (Vigdorchik, 1976), but was considered negligible for other regions. ICOGEN applies, as a significant base year parameter, to Region III only where cogeneration is used appreciably in certain countries (in particular UK, FRG, Sweden). EFFCO and HELRAT are significant only when ICOGEN has a non-zero value. The listed values for these parameters are based on Leach(1979).

EFFIND represents the average value of the fossil fuel efficiency for all fossil fuels (oil, gas, coal) and all thermal processes (low temperature heat, steam, furnace heat). It is difficult to specify a regional value of this parameter as the combustion efficiencies of gas, oil and coal differ greatly among each other and since the shares of these sources vary between countries. EFFIND, therefore, is largely of indicative value. The fossil fuel efficiency values in the literature(e.g., Eurostat, 1978; Beschinsky and Kogan, 1976), expressed relative to the efficiency of electricity, vary between 30-80% for the developed regions; they are in the lower range for high-temperature processes and in the upper-range for low-temperature processes. The values are generally expected to be lower fo the developing regions, where the equipment is not the most modern and is also often not well maintained. The efficiency would be the lowest in Region V, where coal is still used in large proportions. The values listed for EFFIND in Table 8 were estimated (and, if necessary, adjusted) in the light of the above consideration.

(v) Parameters in Groups 3.1g and 3.1h in Table 8

As indicated in Appendix II, the parameters of Group 3.1g are the fixed coefficiencies C(1) and C(2) of the expressions C (1) + C (2) × X relating the quantitative production of petrochemical feedstocks (based on liquid fuel only) and steel to the value-added contribution of the basic materials industries in each region. In principle, these coefficients can be determined on the basis of the actual production data over the last few years, if in the scenarios the past trends are assumed to continue. Alternatively, one could define the coefficients independently of the past data and only adjust them to the base-year production values.

In the present set of MEDEE-2 runs, CFEED(1) is assumed to be zero in all the regions except for Regions II and VI, and CFEED(2) was determined solely on the basis of the 1975 values. For Regions II and VI, the coefficients were fixed in a similar manner: they were assumed to constitute an increasing proportion of the petrochemical component in the value added of basic material industries of Region II and a declining proportion in Region VI. Coefficients CPST(1) and CPST(2) were determined likewise for all regions, except for Region II, by assuming CPST(1) to be zero. For Region II, the two coefficients were adjusted to the base-year data under the assumption that the proportion of the steel-making component of the basic material industries decreases with time. The base-year productions of liquid fuel-based petrochemical feedstocks and of steel in the various regions were estimated basically from the data given by the following sources:

Feedstocks Production	OECD (1977) for Regions I, III UN (1977a; 1978a) for other regions
Steel Production	UN (1977b) for Regions I, II, III UN (1975; 1977d) for Regions IV, V, VI

The parameter IRONST was estimated for all the regions from the data on pig-iron and steel production (UN, 1975; 1977b; 1977d).

The EICOK and BOF estimates for Regions I and III are based on the data for the U.S. and Japan (Doernberg, 1977) and France (Lapillonne, 1978c). For Region II, such estimates were obtained by comparison with the values for Regions I and III and taking into account the coke production data given in (UN, 1977b). For Regions IV, V and VI, BOF was assumed to be unity in 1975, whereas the estimates for EICOK were based essentially on the data on pig-iron production and coke consumption of a few countries (UN, 1975; 1977d; Vieira, 1978; Parikh, 1976; Elshafei, 1978).

II. Transportation

(i) (Parameters in Group 3.2a in Table 8)

The coefficients CTKFRT(1) and CTKFRT(2) for Region I have been taken to be the same as were derived by Lapillonne (1978b) for the U.S., on the basis of the historical data for 1950-1975 (U.S. 1976a,b). For Region II, these coefficients were estimated by assuming a slower growth of freight transportation activity in relation to the growth of value-added from the nonservice sectors and by adjusting them to match the base-year data on freight transportation (CMEA, 1976) and GDP formation. For Regions III, IV, V and VI, CTKFRT(1) was assumed to be zero; the values of CTKFRT(2) were worked out on the basis of estimated total freight transportation activity in 1975 in each region and the corresponding GDP formation data. Freight transportation on trains is given in detail in (UN, 1977b). Information on freight transportation by truck, barge and pipeline for several countries in each region was gathered from various national statistics and other sources, in particular IRF (1976), WAES (1976), Europa (1976) and WFB (1974). This information served to estimate the total freight transportation activity in groups of countries in each region, the latter values were then extrapolated to the regional level by GDP weighting. Often, data on freight transportation were not given in ton-km but had to be estimated from information on total tons transported, number of vehicles, vehicle-km, average distance travelled per vehicle, lenghts and diameters of pipelines, etc.

Coefficients CMISMF(1) and CMISMF(2) refer to motor fuel consumption for miscellaneous transportation activities including military and international transportation. In MEDEE-2, these activities are assumed to vary linearly with GDP. Data necessary for estimating these coefficients are generally not available except for the U.S. in Region I. The coefficients for Region I used here are based on the estimates made by Lapillonne (1978b) and are in agreement with the information given in WAES (1976). For other market economy regions, CMISMF (1) is assumed to be zero, as for Region I, and the values of CMISMF(2) have been chosen in the light of information on international travel/freight transportation and keeping in view the expenditures (as fraction of GDP) on military activities in different regions relative to that in the United States (U.S., 1976a). For Region II, it is assumed that the present per-capita level of motor fuel consumption for these activities is comparable to that in Region I. It is further assumed that the absolute demand for such activities will grow more slowly than GDP, in view of the relatively faster growth of GDP expected for this region among the developed regions. We realise that our input values of CMISMF(1) and CMISMF(2) for various regions are particularly uncertain, but this has been due to the present limitations of data availability.

(ii) (Parameters in Group 3.2b in Table 8)

These parameters refer to fractional shares of different modes in total freight transportation. The parameters in parentheses represent certain subcategories of the preceding mode. The values for these parameters were obtained simultaneously with those of total freight ton-km discussed earlier in connection with the CTKFRT coefficient, and the same sources of data apply. Subcategory TRUL was not considered separately except for Region I.

(iii) (Parameters in Group 3.2c in Table 8)

The values of the first four of these parameters for Region I are the same as those derived by Lapillonne (1978b) on the basis of data given in U.S.(1976a), ATA (1975) and FEA(1974a). Estimates of these parameters for Region III were obtained on the basis of data given in WAES (1976), Goen(1975), Japan (1978), CEC (1978) and Lapillonne (1978c). The values chosen for Region II are similar to those for Region I as the average distance per freight movement is similar. The values used for Regions IV, V and VI are identical with those for Region III.

Parameter DTRUL applies only to Region I, where local truck movements are considered separately from long-distance hauls. The value of parameter DPIP is based on information given in ECE (1976). Energy consumption due to pipeline transportation is significant only in Region VI, and was neglected for other regions.

Not included in Group 3.2c are the efficiencies of electric and steam-operated trains. These efficiencies were internally fixed within the model as 1/3 and 3 times, respectively, the efficiency of diesel trains.

(iv) (Parameters in Groups 3.2d to 3.2g in Table 8)

The parameter values for Region I in these four groups were obtained on the basis of data in U.S. (1976a), Hirst (1974a,b), IEA (1976), ATA (1975), FEA (1974a), WAES (1976), Hittman (1974) and are, in general, the same as were used for the U.S. study in Lapillonne (1978b). The information for Region III was derived on the basis of Goen (1975), Japan (1978), WAES (1976), UN (1977b), IRF (1976) and by comparison with the data for Region I. The input data for Region II are based partly on UN (1977b), CMEA (1976), USSR (1976), Styrikovich (1979) and partly on intercomparison with Regions I and III.

For Regions IV, V and VI the main sources of information were, in addition to a few national statistical publications, UN (1977b), IRF (1976), Europa (1974), WFB (1974) and Arab Fund (1979). Some of the information available was limited to a few countries in each of the developing regions, and was extrapolated to obtain representative regional values also on the basis of other parameters and under consideration of similarities between countries or groups of countries.

For most regions, except for Region I and partly Region III, load factors and urban travel were estimated essentially on a judgemental basis in consultation with some experts from various regions. The load factors for the developing regions were chosen to correspond to trains and vehicles of similar average sizes as are used in Region III. This was necessary in order to make use of the vehicle efficiency data established for Region III as the corresponding information for Regions IV, V and VI was not readily available.

III. Households and Services (Parameters in Group 3.3a to 3.3e in Table 8)

Detailed information on the distribution of energy consumption in the household and service sectors is generally scarce, except for the U.S. and a few countries in Region III. Still, a large number of parameters are needed to conceptualize the patterns of energy consumption in these sectors and to project the future energy demand by assuming a plausible evolution of various activities in relation to the projected population and economic growth. The values for the parameters in Table 8, Group 3* are based on available data wherever possible, on extrapolations from the data of certain countries, and on more general studies related to energy consumption in this field.

Specifically, the values of these parameters for Region I are based on the estimates made by Lapillonne (1978b) for the U.S. on the basis of data given in U.S. (1976b), FEA (1974b), SRI (1972), SPP (1975), and Hirst and Jackson (1977), Beller (1975), WAES (1976), Salter (1976), and on additional data given for Canada in WAES (1976). The corresponding estimates

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*except for subgroup 3.3c, which is only relevant for the prejections.

for Region III were made by extrapolation from the information in some Region III countries given in CEC (1978), Lapillonne (1978c), WAES (1976), Foell (1979), and by comparison with the values found for Region I -- taking into account similarities and differences in lifestyle and technology as described in various comparative studies between the U.S. and Japan, the FRG, Sweden in Doernberg (1977), Goen (1975) and Schipper and Lichtenberg (1976). For Region II, some values were established from UN (1977b), ECE (1978a), ECE (1978b), CMEA (1976), USSR (1976); others were derived by comparison with Regions I and III and by cross-checking against the useful energy balance by process and energy source given for the USSR in Vigdorchik (1976), against the final energy consumption statistics given in ECE (1977), Melentiev (1977) and Petro Studies (1978), and against typical efficiencies as are given in Eurostat (1978) and Beschinsky and Kogan (1976).

For the developing regions, our estimates were based on the geographical locations of these regions, sizes of dwellings in various countries (IBRD, 1976), scattered information on the pattern of energy use in the domestic sector and on the sectoral distribution of energy consumption in various countries (e.g. Makhijani and Poole 1975, Parikh 1978, McGranahan and Taylor 1977, WAES 1976, Vieira 1978, Parikh 1976, Henderson 1975, Revelle 1976, Pakistan 1977, Elshafei 1978)*; discussions with persons from these regions, and intercomparison with data for other regions.

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*Some useful information is also given in a recent publication by Cecelski et al (1979).

The values for DW-75 listed in Table 8 correspond to the data on population (PO) and average household size (CAPH). The value of CPLSER is determined on the basis of the value of 'PYSER' and the fraction of labour force employed in the service sector. Information on the share of the service sector in the labour force was derived from the data in IBRD (1976), CMEA (1976), and ILO (1976).

Parameter TAREA-75 corresponds to the service sector area in 1975. For Regions I and III, it represents the area of establishments related to trade and catering, business and social and governmental services. For other regions, this definition was not applied due to the complete lack of data. Instead the values used for this parameter are, in combination with those of some other parameters, only a way to conceptualise the present energy requirements of the service sector.

The parameters in Group 3c of Table 8 are intended exclusively for projections and do not serve to describe the pattern of energy consumption in the base year.

5.2. Detailed Scenario Projections

The projection of final energy demand in the two IIASA scenarios is based on the formulation of detailed scenarios describing plausible evolutions of the variable parameters of MEDEE-2 listed in Appendix II. There is no universally accepted method for projecting the evolution of various socioeconomic indicators and related technological parameters over a period of several decades. The econometric approach based on extrapolations from past trends usually works well for short-term projection, but cannot be usefully applied over such long intervals. Fifty years is a short period in the history of mankind, but a fairly long time when one considers that during such a period in the coming years certain economies will, in all likelihood, change their status from developing countries to one of the present-day developed countries, while some others may be forced to reorientate substantially their economic structures and the lifestyles of their populations in the face of a growing scarcity of natural resources (including energy) and under tightening environmental constraints.

In our opinion, the past trends, although useful as a general guideline, cannot be relied upon heavily for making medium- to long-term projections in a rapidly changing world situation. This goes notwithstanding the fact that there is an acute shortage of disaggregated relevant data; sufficiently detailed data are available only for a few countries (mostly developed) and, even then, such data have been compiled only in recent years. The approach followed here is, therefore, one of scenario assumptions, developed on the basis of judgements guided by past trends, interregional and intercountry comparisons whenever appropriate, estimated relationships reflecting the interdependence between various economic and social activities, and estimated prospects of technological developments. Of course, these scenario assumptions and the resulting sectoral and subsectoral energy demand projections are not deterministic; they should simply be considered as guidelines for understanding the nature of future energy demand.

The detailed scenario assumptions to be described in this section are the final set of MEDEE-2 inputs we arrived at after going through the iterations of the IIASA modelling loop described earlier (see Section 1). In the final stages of these iterations, the energy demand (total as well as for some broad sectors, such as transportation, household, agriculture and industry) was also analysed (Chant 1980) in terms of the elasticities implied (energy price elasticity, income elasticity, elasticity of substitution) to insure consistency of the aggregate results.

The values of variable scenario parameters of MEDEE-2 used in the present assessment are listed for the years 2000 and 2030, along with those for 1975, in Tables 9.1-9.3. The parameters are presented in several groups to help understand the assumed variations of somewhat similar parameters within each region and also to allow interregional comparisons. (Although the values for the intermediate years 1985 and 2015 were also specified in the actual model runs, these are not listed here for the sake of brevity). In the following paragraphs we will make some general comments about the considerations underlying the assignment of specific values to the parameters in these different groups.

5.2.1 <u>Demography</u> (Table 9.1)

The parameter projections in this group are based on Keyfitz (1977) and on extrapolation of past trends and the available UN projections for the next 10 to 25 years (UN 1974, 1976b).

5.2.2 Macroeconomics (Table 9.2)

In order to project the GDP formation structure and the composition of the value added by manufacturing industries for the developing regions (IV, V, VI), we have sought guidance from the observed evolution patterns in the historical data (covering the period 1960-1975) for a number of individual countries and groups of countries at different stages of development (see UN 1977b,c), from the analysis of past data (for 1950-1970) for several countries made by Chenery and Syrquin (1975), and from the short-term development plans of a few countries.

The main features of the assumptions made concerning GDP formation in these regions are the following: the share of agriculture decreases while still allowing a slow gradual improvement in per capita agricultural GDP with increasing per-capita total GDP; the share of manufacturing increases with the increase being relatively higher in the High Scenario than in the Low Scenario; and the service sector share increases in Regions V and VI (where it was quite low in the base year), but decreases slightly in Region IV. The mining sector contributes only 2%-3% to the GDP of Region IV and V all along, whereas its share in the GDP of Region VI is projected to decrease from 51% in 1975 to 9% in the High scenario and about 18% in the Low scenario by 2030. The value added by the mining sector in this region is mainly governed by the oil and gas extraction activities; it has been adjusted accordingly in each scenario to correspond to the envisaged production rate necessary for meeting both the domestic consumption and the export demand. It is also assumed that Region VI will undergo major industrialisation within the next 10-25 years with the help of its oil revenues. With respect to the composition of the manufacturing industries, our projections are based on the hypothesis that the countries at a low level of industrial development have a high share of consumer goods industries, but as the industrial infrastructure develops more emphasis is placed first on expanding the basic material and later on promoting the sophisticated machinery and equipment industries. This hypothesis is based on the observed pattern of manufacturing activities in various countries at different stages of development.

The situation is different in the developed Regions I and III. There the GDP formation structure, as it appears on the aggregated level considered in MEDEE-2, remained practically unchanged during the period 1960-1975, whereas in Region II the only significant change in this period was a decline of the agricultural share* from 32% to 15% and an increase in the industry (mining, manufacturing and energy sectors) share from 41% to 57%.

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*These shares are based on values of GDP which do not include nonproductive services, e.g., social and administrative services. If the contribution of such nonproductive services is also included in GDP the shares of sectors will be somewhat different. It was estimated that the inclusion of nonproductive services in GDP of 1975 would lower the shares of agriculture and manufacturing by a factor of 1.35, i.e. to 11% and 38%, respectively. These numbers can be compared to the GDP shares in market economy regions.

The shifts in the structure of GDP formation assumed in the light of a retarding overall economic growth can be qualitatively described as follows: For Region I, the service sector share is assumed to increase slightly and the manufacturing share is assumed to decrease roughly by the same amount (the change is insignificant in the Low scenario); GDP formation structures assumed for Regions II and III gradually shift toward the pattern of Region I as these regions proceed to a higher level of economic development. All three regions are assumed to give higher emphasis to the development of machinery and equipment industries than to the basic materials and consumer goods industries. Only minor shifts are assumed in the GDP shares of construction and energy sectors in all the regions. The share of agriculture in GDP is assumed to decrease in all three regions in line with past trends; however, this decrease is large only in the case of Region II, whose share was large in the base year and which is projected to have a higher overall economic growth in each scenario than either of the two other developed regions.

5.2.3 Energy Consumption in Sectors

I. Industry (Table 9.3.1)

We have assumed that there will not be any significant changes in the energy intensity of agriculture and construction in the developed Regions I and III. This is because it was difficult to estimate the net effect of two oppositely acting factors: the likely improvements in the efficiencies of equipment used in these sectors, and a probable further, albeit small, increase in the mechanisation of such activities. In Region II, the energy intensity of agriculture and construction activities are assumed to decrease slightly, given a sometimes inefficient use of the relatively heavy equipment employed at present. Over the long run, therefore, efficiency improvements are expected to more than counterbalance the effect of increasing mechanisation. As the mining sector in Regions I, II and III is not considered separately but as part of the manufacturing and energy sector activities its energy intensity is not given explicitly.

At the present time, agricultural activities in all the developing regions are largely carried out using traditional methods based on human and animal labour. More or less the same is true for construction and nonpetroleum mining activities, at least in the countries of Regions V and VI. One may expect increasing mechanisation of such activities with further development and a correspondingly greater demand for quality and quantity of sectoral products. In the case of agriculture, for example, considerable and rather rapid mechanisation is necessary in order to obtain higher outputs from the limited resources of arable land supplying a rapidly growing population with more and better food. The projected changes in energy intensity are based on our estimates of the energy requirements of field equipment (tractors and other appliances) and of irrigation water-pumping units, under the assumption that by 2030 agricultural activities in the developing regions will be mechanised to an extent comparable to the present level of mechanisation of the developed countries. Mechanisation is also assumed to increase in the construction activities in Regions V and VI, but to relatively lower levels than those found in the developed regions. As for the mining sector, the changes assumed take into account differences in the nature of mining activities and in the working conditions in the various regions, and reflect a likely future improvement.

It may be mentioned here that there are considerable uncertainties in the base year data of energy intensity of agriculture, construction and mining activities of almost all regions, both developed and developing. The assumed changes in the energy intensity of these sectors should, therefore, be considered as qualitative indicators of a likely trend.

MEDEE-2 considers manufacturing activities by only three broad categories: basic materials industries, machinery and equipment industries, and consumer goods (nondurable) industries. Each category covers the manufacturing of a variety of products so that its composition is not uniform for all the regions; and even within a single region the composition cannot be assumed to remain constant all the time. The energy intensity of each category is thus affected by changes in composition as well as by changes and improvements in technology. The parameters of group 3.1d in Table 9.3.1 are intended to project the changes in energy intensity of each category covering both the above aspects.

The data on energy consumption of various manufacturing industries in different countries over the last 15-20 years (e.g. for U.S., France, F.R.G., Austria, see Doblin (1978), Lapillonne (1978c), Schaefer et al. (1977), Foell (1979)) reveal a gradual reduction in energy intensity over time. This is, in general, due to a reduction in the use of fossil fuels (per unit of output), while the specific use of electricity (per unit of output) by most of the industries has actually been increasing.

The past increases in the use of electricity in the above countries were generally due to increasing automation. As automation in the developed regions has already reached a high level and as, different from the past decades, electricity prices are expected to rise in the coming years, it is assumed that the use of electricity (per unit of output) for specific purposes will also decrease in the future, although not as fast as the use of fossil fuels. For the developing regions, where automation is expected to continue to climb, the energy intensity of manufacturing activities with respect to specific uses of electricity is assumed constant.

The projected changes in energy intensity of manufacturing activities in various regions are based, in general, on considerations of the present status of the technology in each region, rates of increase in industrialisation (high growth allows more rapid incorporation of new technologies) and the prospects of technological improvement in line with past trends.

Thermal energy requirements of industry are, at present, normally met by direct use of fossil fuels (coal, oil, gas). The only exception is Region II, where a large fraction of the industrial steam demand is supplied by district heat systems based on both cogeneration plants and large boilers. This development has been due to central planning and considerable concentration of industry into just a few industrial centers. Application of such district heat systems in Region II is expected to grow further, because of the economic use of low-grade fuels in such systems. Other regions are also expected to employ such centralised heat supply systems to some extent, even though their industries are relatively more widely scattered. Similarly, the decentralised use of cogeneration systems in industrial plants is expected to increase in Region III and to be applied in other regions. Other energy saving technologies, such as soft solar devices and (electric) heat pumps, are practically not in use now in any region; they, too, are expected to be applied more heavily as the capital cost of such systems reduces with R&D and mass production. Electricity use for thermal processes is assumed to increase only modestly above present-day levels; although it is a very clean, efficient and easy-to-handle form of energy, the high losses incurred in the conversion from primary fuels to secondary energy would be in conflict with the need to conserve primary fuels. Despite the penetration of alternative energy sources assumed, a large share of the thermal energy for industry will have to come from the direct use of fossil fuels even by 2030, so that improvements in efficiency of fossil fuel appear mandatory. Some such improvements have been assumed to materialise in line with past trends.

The present use of coke per ton of pig-iron produced varies considerably from country to country. So far, the lowest consumption was achieved by the Japanese steel industry where the consumption decreased to about 390 kg per ton of pig-iron in 1972 (see Doernberg, 1977). However, after the oil crisis, coke consumption in Japan again increased as fuel oil injections were lowered; in 1975 the consumption was 440 kg per ton of pig-iron. Despite this short-term reversal in the trend of the Japanese steel industry, we have assumed that future technological improvement will permit reduction in coke use to about 400 kg per ton of pig-iron in the various world regions. The changes assumed for other parameters related to steel production are based on discussions with technologists and on interregional comparison.

II. Transportation (Table 9.3.2)

The evolution of the modes of freight transportation assumed to occur in the various regions is based on consideration of past trends, regional characteristics, interregional comparison, existing infrastructure and relative costs of expanding road or railway networks as well as need to promote less energy intensive modes of transportation in the future. These essentially judgmental projections were developed in the light of the above considerations. No change has been addumed (except for Region II) in the energy intensiveness of various freight transportation modes. This does not mean that efficiency improvements will not occur but that their effect will largely be counterbalanced by lower capacity utilization resulting from the need of quicker service.

Data for passenger transportation in the U.S., covering the period 1950-1974 (U.S. 1976a), indicates that the total distance travelled per person and per year has been increasing somewhat faster than the increase in per-capita private consumption expenditure. Such a rapid increase has apparently been due to the greater number of cars and the rapid expansion of air travel in recent years. With car ownership practically saturated, any further increase in the average distance travelled per person and per year will mainly depend on a further increase in air travel. This is a shift away from the past trend and towards a gradual development of saturation effects in personal travel in this region. In Regions II and III as well as in the developing regions, car ownership is still far from saturation and air travel is low; both of them are expected to expand in the future, resulting in a high growth of passenger transportation activity. However, some saturation effects in Region III may become apparent towards the end of the study period. The past U.S. trend has been taken as a general guideline for projecting passenger travel in the developed Regions II and III, although some adjustments were necessary in view of the differences in travel distances, settlement patterns, and other local conditions. As for the developing countries, intercity travel (parameter DI) is assumed to increase roughly in proportion to the per-capita private consumption expenditure. The relative increase in urban travel is assumed to be lower than that in intercity travel for all the regions, except for Region III where the current trend of suburban expansion is expected to continue.

Among the parameters related to car travel (Group 3.2e), car ownership (i.e., the inverse of parameter CO) is assumed to increase in the developing regions in proportion to both GDP/capita and the fraction of population living in urban areas. Relatively lower growth rates of car ownership are assumed for the developed regions where saturation effects are expected to play a varying role. The share of cars in urban travel is assumed to decrease or remain constant in the developed regions due to the promotion of mass transit systems. In the developing regions, the increase in car ownership would favour a heavier use of cars for urban travel, but road congestion in the overcrowded cities would have the opposite effect. Thus a significant increase in the use of cars for urban travel is assumed only for Region VI, where enough resources are available to modernise the road network. Load factors of cars are expected to decrease with increasing car ownership almost everywhere, particularly in the developing regions. Some use of electric cars for urban travel, to varying extents in different regions, is also envisaged in the future.

The scenario assumptions about various modes of intercity and urban travel (Groups 3.2e and 3.2f) are based on considerations similar to those discussed in connection with modes of freight transportation. Additional factors, such as personal convenience, flexibility, and speed of travel were also accounted for by the mass transit modes chosen and the share of airplanes in intercity travel is assumed to increase everywhere. The share of intercity buses, on the other hand, is expected to decrease in all regions except in Region II. The load factors of mass transit modes (except for airplanes) are assumed to remain constant in Regions I and III, where they are already quite low. In all the other regions, they are assumed to decrease from the present, high, level to relatively more comfortable standards as the service will certainly be improved with further development in these regions.

The specific energy consumption of cars is expected to go down in all the regions, due to rising gasoline prices and the initiation (or contemplation) of fuel economy standards in several countries. The assumed drop in future fuel consumption is most strongly pronounced in Region I, whose present automobile fuel consumption is very high, compared to that in other regions. Significant reductions in the energy intensity of airplanes are also expected in Regions I and II, in view of the importance of domestic air travel in these regions. Some such reductions in other regions, though probable, have not been taken into account, since the share of air travel in intercity travel in Regions III through VI is much smaller than in Regions I and II. The specific energy consumption of other passenger transport modes in Regions I and III and the respective load factors were held constant in the present assessment. Actually, one should expect vehicle efficiencies to improve and the load factors to decline further; since the two effects would thus partly balance each other they were not considered separately. In the developing regions a trend towards larger vehicles was assumed to offset improvements in vehicle efficiencies. In Region II, improvements in these modes were considered after discussions with experts from this region, where reliance on mass transit and trains in particular, counts more heavily than in the other regions.

III. <u>Households and Services</u> (Table 9.3.3)

As was mentioned in Part III of Section 5.1.3, a large number of parameters are used in MEDEE-2 to conceptualise the likely evolution of energy consumption associated with various activities in the household/service sector. The scenario assumptions concerning the changes in the values of the various parameters in 2000 and 2030 in relation to those in 1975 are detailed in Table 9.3.3 for both the High and the Low scenarios. Some general considerations underlying these assumptions and largely applicable to all the regions are:

(i) a continued trend towards a relatively more comfortable living (e.g. by larger houses, more centrally heated dwellings, more air-conditioning, a larger use of hot water, additional electrical appliances in households, etc.) and provision of better amenities in the service sector (viz through increased supply of space/water heating, air-conditioning, lighting and electrical equipment) with increasing levels of GDP/cap;

(ii) increasing shares of electricity with time (and affluence) in the provision of thermal energy requirements (cooking, space/ water heating) of households and services, in line with past trends;

(iii) increasing emphasis on improved insulation of buildings (both new and old) in regions where space heating is an important energy consuming activity;

(iv) gradual introduction of soft solar devices for space and water heating in both households and service sector buildings leading to a considerable buildup by 2030;

(v) some improvement in the fossil fuel efficiencies of various thermal devices and, in addition, gradual introduction of heat pumps in places where electricity is to be used for supplying thermal energy;

(vi) introduction or increased use of district heat in regions where settlement patterns and energy requirements favour district heating systems;

(vii) saturation of energy requirements of certain activities, e.g. of cooking energy per dwelling, or of useful thermal energy per m^2 of floor area under given climatic conditions.

Although regional characteristics, such as climatic conditions, people's cooking and living habits, construction styles of buildings, etc., have to be taken into account in projecting the likely evolution of various parameters, considerable insight, at least in respect of regions at lower levels of GDP/cap, may be obtained by comparing the base-year data (or estimated base year values of various parameters) of different regions at various stages of development. Our projections of scenario parameters draw heavily upon such interregional comparisons.

Noncommercial fuels play an important role in meeting the household energy requirements of the developing regions, particpularly of Regions IV and V. (Among the developed regions, only Region II has a significant contribution of noncommercial fuels.) Although the use of such fuels, particularly that of firewood obtained by indiscriminate cutting of forests, has been increasing in the developing regions in the recent past, we believe that measures will soon be adopted to check the deforestation problem in these regions. Accordingly, it has been assumed that the use of noncommercial fuels in the various regions (including Region II) will not be significantly different in 2000 and 2030 from what it was in 1975. However, the efficiency in using such fuels is assumed to increase in the developing regions by as much as a factor of 2, due to the introduction of better stoves and other devices in rural areas.

5.3 Projected Final Energy Demand

This section is devoted to the salient features of the final energy demand projected for the years 2000 and 2030 in the various world regions, resulting from the detailed scenario assumptions spelled out in Tables 9.1-9.3 and briefly reviewed in the preceding section.

The evolution of final energy demand in Regions I through VI in the High and the Low scenarios is shown in the projections in Table 10, also incorporating the share of electricity in final energy demand. It is worth noting that the demand for final energy rises much more rapidly in the developing regions than in the developed regions. In the High scenario, 1975-2030, the demand is projected to increase by factors of 10.6 to 14.9 for the developing regions (IV, V, VI) but by factors of only 2.0 to 3.2 for the developed regions (I, II, III). The corresponding increases in the Low scenario are by factors of 6.6-7.9 and 1.4-2.3, respectively. Among the developing regions, the highest increase in final energy consumption in both the scenarios is projected to occur in Region VI, which had also been assigned higher economic growth (relative to the 1975 level) than Regions IV and V (see Table 3). Similarly, Region II among the developed regions -- which was assigned the highest relative increases in economic development in the basic scenario definitions of Table 3 -- is the region projected to have the largest increases in final energy consumption as is shown in Table 10.

The share of electricity in final energy is projected to grow in all the world regions in both scenarios, reaching, by 2030, levels of 20-23% in the developed regions (from 10-13%

own the body of knowledge essential for independent decision. An enlightened development planner would recognize the existence of these factors as a part of the actual framework in which objectives can be accomplished, and in doing so will be able to envisage an appropriate strategy.

But some of the constraints are endogenous, they belong to what can be called the capability of society to recognize internal shortages. We have mentioned above the scientific-technological infrastructure, a wide concept that involves complex interrelated systems: literacy and education; basic and applied, public and private R&D; public and private management ability; promotion of inventive and innovative activities. Besides, capacity of control of each system and coordination of all, which means existence of bodies of knowledge at the academic, private and official levels.

The constraint imposed by the lack or weakness of such an infrastructure grows in pace with economic growth and the resultant structural changes. If we could envisage that the process of national development occurs in stages [14] perhaps the last stage necessary is the one in which society becomes conscious of its true capability of realization and finally could use this knowledge to select the most convenient, self-reliant way for future action. This stage is characterized, in our view, by the formation and coordination of institutions of two types: one conforming to the scientific-technological infrastructure, the other relating the former to the objectives of its society, permitting understanding and assessment of what implementation is possible in the light of the existing capability.

Without such institutionalized bodies, it is hopeless to deal, for instance, with the subject of technology transfer. How could a primitive technical society make adequate decisions in this field, which in the long term must affect forthcoming--and more often than not irreversible--structural changes, if it is not able to understand its own limitations? There are examples of policy decisions taken to "modernize" through the indiscriminate acceptance of advanced technology, without a previous evaluation of society's capability of realization that have resulted in more dependence and less self-reliance. The problem has been conceptualized by referring to "appropriate technologies" for the development of LDCs: in our view, the level of appropriateness is a measure of society's capability of realization, so what is appropriate today could be harmful tomorrow.

In summary, the present framework for development is qualitatively and quantitatively different from the one within which the development of today's industrialized countries took place. Its concerted effect is one of cultural influence and guidance by example, a mermaid's song leading into a promising future. Yet without more attention being paid to the endogenous problems, self-reliant development becomes utopian. The consequence is that most developing countries are eager to industrialize according to schemes similar to those shown by current developed societies, compete with each other for foreign technology and markets and, simultaneously, continue with their own arms race.

5.4 Past-Present Development Performance

We must have some quantitative notion of development performance. In order to deal with the subject, we need a yardstick. We have previously shown that the concept of development is complex, a number of interrelated factors pertain to it. But they cannot be measured by a single, universal indicator. The secular behavior of world development has been only registered through macroeconomic parameters, in particular GNP/cap. It is true that literacy and health indicators have been collected, but little is known about their long-term behavior and their correlation with economic development. Through the concomitant effect of medical and communications progress in relatively recent times, some endemic diseases have been practically erradicated in developing countries: this fortunate result has not changed substantially their economic development patterns, though in some cases have worsened the situation due to previously unexpected population growth. On the other hand, the index of literacy only tells us how many can read, but very little about the repercussion on national product.

Different views have been reported by economists and social scientists on the advantages and limitations of the current monetary

This is due to a considerable increase in freight transportation, projected to grow with industrial output, as well as to an expected increase in personal travel and a reduction of average load factors. Among the developed regions the relative shares of transportation and industrial activities are markedly different in Regions I plus III (essentially OECD countries) and Region II, mirroring the differing emphasis on industrial activity and personal transportation in the two types of economies.

I Energy Demand of Industries

Industrial energy use is a major portion of the total consumption in every world region today; the scenario assumptions do not lead to major departures from that. Energy as a factor of production, as an "input" to productive output, is an indispensable commodity--qualitatively different from the energy used by households or that consumed in transportation activities. Yet, despite its firm footing in virtually all of the world's economies, industrial energy demand trends and possibilities span an impressively wide range. The scenario assumptions of Section 5.2.3 (see also Table 9.3.1) were based on considerations of such trends and appropriate possibilities in the techno-economic environment of the various world regions.

Manufacturing activities account for a lion's share of the industrial energy consumption (see Table 13). In 1975 the share of manufacturing activities, including coke use in the steel industry and feedstock inputs to petrochemical industries, out of total industrial energy consumption was 90 to 97% for Regions I to V in spite of considerable differences in the composition of their economic structure. In Region VI this share was relatively smaller--about 62%--due to the exceptionally low level of manufacturing activity and the dominance of oil and gas production activity in the industrial sector of this region. The scenario assumptions of changes in economic structure, composition of manufacturing activities and technological coefficients result in projections for the years 2000 and 2030 for which the share of manufacturing in the industrial energy consumption varies between 76 and 90% in all world regions.

Table 14 lists the present and projected final energy demand of the manufacturing sector in different world regions and also indicates the shares of electricity and coke plus feedstocks (essentially liquid fuel based, used in petrochemical industries) in this demand. It is seen that the share of electricity in manufacturing energy demand increases in all regions, reaching levels of 20-25% in 2030 as against 11-15% at the present time. The share of coke plus feedstocks also increases in all the regions (except in Region VI where petrochemical feedstock production for export purposes is an important activity at present) from about 13-28% in 1975 to 20-33% by 2030. Various factors are responsible for these changes. Some of the more important ones are assumed to be the following: i) a greater reduction in the energy intensity of manufacturing activities with respect to useful thermal energy than with respect to specific uses of electricity (e.g. motive power, electrolysis, lighting), ii) penetration of electricity in the useful thermal energy market of the manufacturing process, iii) a relatively small reduction in the demand of coke per ton of pig-iron production in the developed regions and iv) increasing importance of the basic materials industries in the manufacturing sectors of the developing countries.

We will now look into the changes in energy intensity of the manufacturing industries (excluding the use of coke in steel industry and that of liquid fuels for feedstock production) that result from our scenario assumptions of Table 9.3.1 and indicate as to what extent the shifts assumed to occur in the great variety of manufacturing activities in the world regions are responsible for these changes. The requirements of energy for a given mix of manufacturing activities can be reduced in various ways: by incorporating better machinery and processes (which reduces the energy intensity of these activities), by increasing the shares of electricity, district heat and soft wolar energy in meeting the demand for thermal processes (which reduces conversion losses), by making increased use of cogeneration and heat pumps (which reduces the requirements of final energy) and by improving the efficiency of fossil fuel conversion to process heat (which also reduces conversion losses). Tables 15 and 16 recapitulate some of our previoulsy described assumptions (see Tables 9.2 and 9.3.1) for the year 2030, according to the High scenario, in aggregated and/or more transparent form. The data for 1975 (column 1, Table 15) show considerable differences in the average useful energy intensity of manufacturing activities in the various world regions. These differences are partly due to different mixes of component activities and partly due to differences in processes, technologies and the extent of automation.

These projections (Table 15) in general indicate a greater potential for reduction of energy intensity in the developed regions than in the developing regions. These reductions -- which are in part due to structural changes in manufacturing -- are especially large in Regions II and I, but not so large in Region III where manufacturing activities have already undergone considerable modernization. The largest structural changes in the manufacturing sector are assumed for the developing regions (see Table 9.2), where both the most energy-intensive basic materials industries and the least energy-intensive machinery and equipment industries grow relatively faster than the nondurable goods industries; this has a balancing effect on the overall energy intensity of manufacturing.

As was mentioned in Section 5.2.3, Part I, the penetration of various more efficient energy forms as well as of cogeneration and heat pumps in the industrial heat market was projected in the light of regional differences in settlement patterns, past practices, current technological trends, geographical conditions, etc. All these technological changes essentially aim at reducing the demand of fossil fuels for industrial process heat. Yet, in spite of our rather optimistic assumptions of Table 16, more than 80% of the industrial process heat requirements in all the regions except in Region II would still have to be met by fossil fuels in 2030 in the High scenario (see Table 17). Note again that improvements in the average efficiency of fossil fuel use of the order of 20% are also assumed to be possible over the next 50 years (see Table 9.3.1, Group 3.1f). Table 17 lists the shares of various energy sources (fossil fuels, electricity, district heat, soft solar) in the heat demand of manufacturing industries resulting from the assumptions of the High scenario.

The overall effect of these technological developments, better practices and structural changes is a reduction in the average final energy intensity of manufacturing activities (excluding feedstocks and the use of coke in the steel industry) by about 35 to 55% in the various world regions for the High scenario, as is shown in Table 18. The effects of structural changes are not very large, as in Table 15, due to the high sectoral aggregation. A larger reduction in final energy intensity, as compared to that in useful energy intensity, is due to higher final-to-useful energy conversion efficiency, assumed to improve by 20-30%.

At present, use of coke in the steel industry amounts to 2-11% of the final energy requirements of manufacturing activities in the various world regions. The consumption of coke per ton of pig-iron produced varies considerably from country to country. Estimated regional averages for 1975 are between 500kg in Region III (WE/JANZ) and 1000kg in Region VI (ME/NAf). The scenario assumptions of Table 9.3.1, Group 3.1h, imply reduction in coke consumption of 20-60% in the various world regions. The share of coke for the steel industry in the industrial final energy demand of the regions changes only slightly except for Region II) over a period of 50 years and stays within a range of 2-10% in both the High and the Low scenarios. In Region II, this share would change from 11% in 1975 to about 4.5% in 2030.

A few words are here in order about the share of agriculture in the industrial energy demand. Agriculture in developing regions, based largely on traditional farming practices, is currently far less energy intensive than that in developed regions. According to the economic projections of the scenarios (see Table 9.2), the agricultural GDP in Regions IV, V and VI is expected to increase by a factor of 3.7 to 4.5 over the next 50 years; the expected increase would be 2.2 to 2.5 times in Regions I, II and III. The implications of these projections in energy terms can be seen in the parameters of Table 19.

Consider arable land in developing regions. There is not much potential for expanding arable land area in Regions IV, V and VI where the present per-capita availability of arable land is about 0.34 ha compared to 0.62 ha in the developed Regions I, II and III. If no significant new area is brought under cultivation, the per capita arable land availability will decrease over the next 50 years to 0.14 ha in the developing regions and to 0.46 ha in the developed regions.

The limits on arable land expansion imply that essential agricultural productivity improvements must come from increases in the use of fertilizers, irrigation and farm mechanization. But surface water is in short supply and precipitation is not adequate in most areas; increasing use will therefore have to be made of underground water.

Taking these factors into account, the energy intensity of agriculture (including mechanization and irrigation, but not including energy used to produce fertilizers) in Regions IV, V and VI was assumed to increase by a factor of 10 over the next 50 years (see Table 9.3.1, Group 3.1c). Thus by 2030 the average energy intensity in these regions would be about the same (2.8 kWh/$VA) as the present average value for the developed regions. The final energy used in agriculture would increase for the High and Low scenarios by about 45 and 37 times the 1975 level in the developing regions and by just 2.4 and 2.0 times in the developed regions. The share of agricultural activities in industrial energy consumption in 2030 is thus found to lie in the range of 3 to 5% in all regions except V where it amounts to 10% for the High scenario and 15% for the Low scenario. (The shares in all the regions in 1975 were in the range of 1 to 4%.)

Energy needed for fertilizer production is counted in this analysis in the basic materials manufacturing sector. For Regions IV and V those sectors are projected to increase in output by 2030 to about 10-20 times their 1975 levels. These increases should easily encompass the energy demand for chemical fertilizer, which may increase by a factor of 5-10 in the same period.

II <u>Energy Demand of Transportation</u>

Transportation activities take an appreciable share of the total final energy (see Table 12). In 1975 this share was about 20% in Regions II and III, 30% in Regions I and V, and 40% in Regions IV and VI; for the world as a whole, the share was about 24%. Of course, the ways in which this energy is used (the mix of transport modes--cars, buses, trains, trucks, planes--and the fuels used) vary considerably from country to country. But the end result is usually a large share of energy use in transport; and it has been growing.

The analysis reported here foresees some changes in this picture--relatively slower growth in personal travel in developed regions (except for air travel)--moderately increased use of public transportation for urban travel (a consequence of growing urban traffic congestion), and greater economies of gasoline consumption (see Table 9.3.2). These assumed changes are due to relative price increases, changes in public perceptions about energy availability (which may or may not be accompanied quickly by price changes), and government mandates.

The results are strikingly different in different parts of the world, as is shown in Table 20. Region I (NA) evidences the smallest relative increase in transportation energy use, although the high mobility, great distances, and large (but slowly shrinking) cars of the U.S. and Canada, keep the absolute level of energy use high. Howevever, the share of passenger travel in transportation activity declines considerably--from about75% in 1975, to 40-50% by 2030. In Regions II and III, demand of energy for both passenger travel and freight transportation continues to increase steadily with only minor changes in the relative shares of these two activities in total transportation energy. It may be pointed out here that in Region II (SU/EE), transportation energy use is currently low compared to both NA and WE/JANZ, despite large distances. The main factors for this contrast are the high share of rail in both freight and passenger transportation, and the emphasis on urban mass transit. Although a certain increase in car ownerwhip and attendant increase in energy use for personal transportation is envisaged in SU/EE, the total increase is not so marked because in freight transportation no significant shift towards trucks is expected.

In the developing Regions IV, V and VI, growth in transport energy demand is significantly higher, owing to greater freight transport accompanying growth in industrial and agricultural output,and to the fact that personal travel is far from the saturation mark. Further, the share of passenger travel in transportation energy demand increases in all developing regions, although the change is not as large in Region IV (LA) as in the other two regions.

Table 20 also shows the share of electricity in transportation energy demand resulting from the scenario assumptions of Table 9.3.2. In Regions I, IV, V and VI, this share increases from a very low level of 0.1-0.5% in 1975 to a modest level of 1.0-1.5% by 2030. The same share in Region III would increase from about 2% in 1975 to 3-4% in 2030, whereas for Region II, the projected increase over the same period, is from an already high level of 4% to a still higher level of 9%.

Passenger Travel

Consider the relative levels of passenger transport activity around the world in 1975. Total passenger travel (intercity plus urban) in North America in 1975 was some 4,100 billion passenger-kilometers (population 237 million); in Region II it was 1,700 (population 363 million); in Region III over 5,000 (population 560 million). The total activity for developing Regions IV, V and VI together was only 3,000 billion passenger kilometers, for 1,874 million people. But this seems sure to change. Passenger travel in the developed regions is expected to be nearing saturation levels--further increases will probably be relatively modest. (There are limits--of income and time--to how much one can travel.) This effect is especially pronounced in Region I. Regions I and III together show only a 1.2 to 1.6%/year growth in total passenger travel according to the MEDEE-2 runs for the two scenarios to 2030, while the developing Regions IV, V and VI together increase their personal travel amount by 3.9 to 4.4%/year. The Region II growth rate is projected at 1.9 to 2.4%/year.

But the types or modes of travel matter also--as do relative load factors. Table 21 summarizes, for the High scenario, the results of an array of assumptions for urban and intercity mobility, relative growth of different transport modes, and expected changes in load factors around the world (see Table 9.3.2). It is apparent in Table 21 that passenger travel in NA is assumed to shift away from automobiles and towards planes in the scenarios. Still, by 2030 the car would account for 73% of total passenger kilometers, compared to 50% or less in other regions. In general, developed regions are projected to continue observed tendencies toward relatively more air and (except NA) car travel, while developing regions reflect expected shifts towards cars (noticeably) and trains (less noticeably) and away from today's large fraction of bus travel (roughly 60% in developing regions compared to less than 20% in developed regions.

Automobiles

Cars consume prodigious amounts of energy. More precisely, they consume prodigious amounts of petroleum--a particularly important distinction.

In North America, total automobile travel (intercity and urban) is assumed to grow from 3,800 billion passenger-kilometers in 1975 (that is equivalent to four automobile trips coast to coast across the United States per person per year) to about 6000 by 2030. This average growth rate of just 0.8%/yr indicates a leveling-off in the so-far continuously increasing automobile use in this region. The Region III growth in total car travel, by contrast, is assumed to be 1.6-2.4%/year; while in Region II it is assumed to be 2.1 to 2.7%/year. In the developing Regions IV, V and VI the corresponding rates are between 4 and 6%/year--even though the assumptions restrict urban car travel, because of city traffic congestion, to 35-50% of all urban passenger travel.

Assumptions for car ownership and usage vary widely among regions, as recorded in Table 9.3.2, Group 3.2e. Car ownership is thought to be nearing limits in North America , as is the distance travelled per car. Region IV, Latin America, is assumed to approach the present statistics of Region III by 2030, whereas the figure for Region V in 2030 may be comparable to Region IV today. The relatively high growth in Regions IV,V and VI car ownership in the scenarios results from assumed higher growth in GDP/cap and anticipated increases in urbanization.

Region II (SU/EE), has now low car ownership and high distance travelled per car--figures more common to developing regions. The scenario projections for this region, maintain that automobile ownership will continue to be low, reaching only half of the present WE/JANZ level by 2030. This reflects the explicit desire in this region to develop public transport facilities, to minimize the need for private automobile use, and thus to minimize liquid fuels requirements.

Energy use in vehicles can be reduced significantly by increasing load factors (average number of passengers per trip, or passenger-kilometers divided by vehicle-kilometers) and by improving the vehicle's energy-using efficiency (see Table 9.3.2, Groups 3.2f and 3.2g). Load factors for automobiles are assumed to hold about constant in the scenario cases in the developed regions, but are reduced somewhat in the developing regions as cars become more common and family sizes shrink. However, the largest factor by far in reducing potential per-kilometer energy use in cars is efficiency improvement. The lion's share of this potential is found, not surprisingly, in North America.

Electric cars offer a potential for reduction of motor fuel use in automobiles. Electric cars, assumed to be three times as efficient as internal combustion engine automobiles, nevertheless would consume about the same total primary energy as conventional cars -- if, of course, the electricity would come from central station sources. It is assumed here (see Table 9.3.2, Group 3.2e) that by 2030 about 20% of urban car travel in the developed regions (I, II and III) and perhaps 5% of urban car travel in the developing regions (IV and VI) might be accounted for by electric cars.

As a result of these and other assumptions, automobile energy use declines sharply in Region I, and shows a modest decline (as a share of total transportation energy use) in Regions II and III. Regions IV, V and VI contrast sharply with these results, increasing in total automobile energy use markedly, largely because of the low level of use today.

Table 22 shows these projections for automobile energy use in the scenarios. The quantities are large, as can be seen. The gasoline consumption in cars in 2030 in Regions I through VI would amount to about 0.9 to 1.1 TWyr/yr of oil. One must ask the extent to which alternative transport modes could replace the car, and with what energy consequences.

Mass Transit

For intercity trips, North Americans travel relatively less by car, in these projections over fifty years, than they do today. One reason is an assumed modest shift away from cars and toward mass transit for intercity travel. In other regions, the shift assumed is actually toward cars for intercity travel, but trains continue to play a very significant role in Regions II, III, V and VI--by 2030, 35 to 40% in Region II, 20 to 35% in Region III, 16% in Region V, and 20% in Region VI, from 53%, 42%, 26% and 10% in 1975. In Region I (and IV), train intercity travel is assumed to remain low -- 1% (6%) of all intercity travel in 1975 to about 2% (3%) in 2030 (see Table 21).

Travelers take to the air in greatly increasing numbers in these scenario projections for the developed market economies, both High and Low cases. The rate of growth is also high for developing regions, but from a much smaller starting amount. In Region IV intercity air travel would grow from 2.6% in 1975 to 6-8% by 2030; in Regions V and VI the increase would be from 1.5% in 1975 to 3-7% by 2030 in the scenarios. In North America, airplane flights would account for as much as 30% of all intercity travel in 2030 (from 7% today), while Region III would increase plane travel from 3.5% today to as much as 18% of all intercity travel by 2030 in the scenarios. In Region II, air travel may account for as much as 27% of all intercity movements by 2030,from 20% today.

Load factors for trains and planes (and buses) are assumed in most cases to be approximately constant or increase only marginally in Regions I and III. This is hardly the case for the developing regions. There, overcrowding on buses and trains is the norm, not the exception. High population growth, coupled with the high mobility preferences accompanying income increases, keep the Regions IV and V load factors high--although a gradual relaxation of the present overcrowding is assumed to occur in parallel with increasing per capita income and a slowing down of population growth. Load factors of 20 and 25 passenger-kilometers per vehicle-kilometer for buses and about 140 for trains are common for Regions I and III. In Regions IV, V and VI the bus load factors of typically 40 to 50 today drop to 20 to 40 by 2030 in the scenarios, while train load factors fall from 500 to 200-400*. The bus and train load factors in Region II are also assumed to drop by a factor of 2 over the next 50 years and become comparable to those in Regions I and III (see Table 9.3.2, Group 3.2f).

Freight Transportation

Freight transport is assumed to grow significantly in all world regions roughly in parallel with the activity levels in the agriculture, mining and manufacturing and energy sectors. It is a big business: some 5 trillion (10^{12}) ton-kilometers of freight in 1975 reaches 11 trillion in the Low scenario and 19 trillion in the High scenario for the developed Regions I and III by 2030; energy use increases by a factor of 2.4 to 3.9 over the 50-year period. (see Tables 20 and 23). Freight transportation activity is much lower in Regions IV, V and VI. These regions together had only about 2 trillion ton-kilometers of freight movement in 1975; an increase of 6 to 10 times that level is projected by 2030. Gradual shifts toward increasing freight transportation on trains in Regions IV and VI and with trucks in Region V are assumed. No significant change is assumed in the present distribution of freight transportation modes in the developed Regions

*Of course, varying "vehicle" size among and even within regions increases the difficulties of drawing comparisons.

I, II and III. As a result of these assumptions, together with those concerning passenger travel, the share of freight movement in transportation energy would increase in Regions I and III and decrease, to varying extents, in other regions (see Table 20).

III. Energy Demand of the Household/Service Sector

Table 24 lists the final energy (commercial) demand projections of the household/service sector in various regions. The evolution of energy demand in this sector markedly differs between the regions. According to these projections, the demand would increase by a factor of 7 to 12 in the developing regions (IV, V, VI), by a factor of about 2 in Regions II (SU/EE) and III (WE/JANZ), and by less than 30% in Region I (NA) over the next 50 years. The share of services, in the final energy demand of the household/service sector as a whole, seems to increase in all the regions with the largest increase occurring in Region VI and the smallest one in Region I. The use of electricity grows quite rapidly in both households and services so that an increasingly larger fraction of the demand of this sector will, in the future, have to be met by electricity in all the world regions; the share of electricity, in 2030, for various world regions, is projected to be in the range of 30-50% for the High scenario as against 7-28% in 1975. These projections are the net outcome of our assumptions concerning likely changes in the values of a large number of parameters (see Table 9.3.3) that were considered necessary to describe the evolution of energy demand of this sector. In order to put these projections in proper perspective we will give here a brief overview of the above mentioned scenario assumptions in a relatively more aggregated form.

In 1975 there were 266 million homes in Regions I and III, 45% of which centrally-heated houses and apartments. There were 3.0 persons per household, on average. Housing construction in the scenarios is assumed to be tied to population growth (which is low), while allowing for further reductions in the assumed average number of persons per household by 2030: to 2.24 in Region I, and to 2.56 in Region III. Almost all new residential dwellings are assumed to be centrally heated; many of them are also air-conditioned. In these two regions by 2030 about 90% of dwellings would be centrally heated in the scenarios, compared to 45% as of today. Air-conditioning would be available for 30 to 40% of dwellings, as against 12% in 1975.

In Regions IV, V and VI taken together, the number of residential dwellings reaches about 1130 million by 2030, from 360 million in 1975, with persons per household dropping from 5.22 to 4.16. Space heating requirements being relatively small in these mostly warm regions, only about 25% of dwellings require space heat. By 2030, some 17 to 19% are assumed to use space heat, compared to 11% in 1975.

Service sector floor area increases fairly briskly in Regions I and III, reflecting the high growth of the total service sector in these regions. By 2030, from 1.7 to 2.1 times as much building area is in use, and to be energy-serviced, as in 1975 in these two regions; in Region II the increase is even larger, from 3.2 to 4.4-fold. Two main factors--higher population growth, and improvement in the working conditions of service sector employees--cause the growth in service sector activity in developing regions to be even greater than in developed regions. Service sector floor area in these regions is about 6.0 to 7.5 times (by 2030) that in 1975.

Tables 25, 26 and 27 report some of the energy consumption figures associated with the household/service sector activity levels just cited. Readily apparent in all of these tables is that by far the largest energy-gorging device in buildings in developed regions is the space itself. Space heating (and to a lesser extent, air-conditioning) overwhelm other needs in residences; in service sector buildings, energy consumption due to electrical appliances is also very high. In Regions I and III, about 60% of useful energy in buildings goes to heating the inside air; in the scenario projections here this number decreases to 40 to 50%, as various energy-reducing measures are introduced.

Improved insulation in homes, old and new, can reap substantial reductions in energy use. The assumptions in the scenarios of insulation improvements in new buildings plus retrofit of pre-1975 dwellings reduce the heat losses in dwellings in Regions I, II and III quite significantly. Retrofitting of the pre-1975 housing stock is assumed to reduce their heat losses by 20-30% over the next 50 years. Post-75 dwellings are already designed to have 10-15% lower heat losses today; according to the assumptions used here, by 2030 the average heat losses of all post-75 dwellings would be only 50% of those in 1975. Further gains are difficult beyond certain initial savings. Rising prices and an assumed increasing public awareness of energy uncertainties (plus a fair measure of government-instituted standards) are assumed to lead to these results.

Electricity used for appliances has grown by great leaps and bounds in recent years, usually much faster than rises in real income. Increased disposable income has to date seemed to go in rather large shares to "extras" such as dishwashers, color televisions, clothes dryers. In Region I, and to some extent in Regions II and III, some flattening of this growth curve is postulated--appliance ownership saturates, and their energy efficiencies, in response to rising prices, improve.

Relative increases in electricity consumption for household appliances (see Table 25) are much higher by 2030 in developing regions--being 3 to 5 times 1975 levels in Region IV, 5 to 10 times in Region V and 6 to 17 times in Region VI -- mainly because the present levels are so low. Most houses which use electricity at all in these regions today use it only for lighting and a bare minimum of other activities.

Another factor which is expected to play an important rôle in the future energy requirements of buildings in both the developed and developing regions is air-conditioning. Until now the extensive use of air-conditioning has been limited to Region I; scenario assumptions here project by 2030 considerable use of air-conditioning in several other world regions as well (see Tables 25 and 27).

At present the useful thermal energy requirements in the household/service sector are met essentially by fossil fuels and electricity in the developed regions and by fossil fuels and noncommercial energy in the developing regions. The scenario assumptions of Table 9.3.3 (Groups 3.3d, 3.3e) concerning the future use of noncommercial fuels, efficiency improvements in the use of all fuels, and penetration of electricity, soft solar, district heat and heat pumps lead to the final energy demand patterns shown in Table 28. There, the large reliance on district heat in Region II is simply a logical extension of the present situation. Also, the higher fossil, and lower electric, shares in developing regions than in developed reflect the end-use patterns typical in buildings in these two kinds of regions.

The extent of conservation implied in these projections may be judged from the fact that use of heat pumps in electrical heating to the extent of 40-50% in Regions I, II and III and 12% in Regions IV and VI as well as efficiency improvements of 10 to 25% in the use of fossil fuels in different world regions, have been assumed possible by 2030.

In spite of the unfavourable cost economics of present soft solar devices, we have introduced fairly aggressive build-up rate assumptions for soft solar systems in the household/service sector in both the developed and the developing regions (see Table 9.3.3, Group 3.3d). For example, it has been assumed that 50% of all new (post-1975) single-family centrally heated homes and low-rise service sector buildings will install solar heating systems (the assumptions are 30% for Region II and 20% for Region VI). These systems will be 50 to 80% solar -- that is, requiring backup (oil, electric, gas) for 20% to 50% of the time. Further, it is assumed that by 2030 some 30 to 40% of all the households in Regions I, III, IV and V, and 15-20% in

Regions II and VI, would be using solar water heating systems. With these assumptions one finds that, by 2030, soft solar devices would support 10-11% of the household/service sector's space and water heating demand in the developed regions (I, II and III) and about 14% of the corresponding demand in the developing regions (IV, V and VI) in both the High and the Low scenarios. The shares of soft solar in the total useful thermal energy demand (including cooking and air-conditioning requirements) will be even lower, as may be seen in Table 28 for the High scenario.

The rather optimistic buildup rate assumptions for soft solar used in this assessment serve to explore a reasonable upper bound to what they could contribute in the energy mix. However, the ultimate soft solar contribution seems to be constrained by the size of the market -- the demands for space and water heat in detached houses or low-rise service sector buildings are not excessive. Moreover, in the developing regions, a large fraction of the useful heat demand of the household/service sector originates from cooking requirements. This fraction was about 82% in 1975 and remains as high as 59-64% by 2030. Further, in these regions most of the dwellings that need space heating are heated with only detached room heaters and this practice is expected to continue -- although at a lower level -- in spite of increased income levels, as the heating seasons and requirements are generally small.

6. Concluding Remarks

The projections of final energy demand till 2030 for six out of the seven comprehensive world regions considered in IIASA's energy study (Energy Systems Program Group, 1981) and the various underlying assumptions have been discussed at some length. In evaluating them one has to appreciate that projecting energy demand in a medium- to long-term time frame is a fundamentally complex issue, full of uncertainties and pitfalls.

One gets a bare feeling of the difficulties and uncertainties involved in such an undertaking by looking at the various medium- to long-term energy demand projections available for one country, i.e., the U.S., whose present pattern of energy consumption is best understood and the relevant historical data of which are best documented. A number of recent primary energy projections for the U.S. are plotted in Figure 7. The wide variation in these projections speaks for itself aptly illustrating the difficulties involved. Obviously, the game becomes more difficult and the uncertainties increase as the projections extend to larger world regions covering several countries, given an availability of data that is much less satisfactory than for the United States. Nonetheless, estimates of future energy requirements of the various world regions are essential for us to sense the kind and size of problems the world may have to face in the wake of dwindling global conventional fuel resources and in order to be prepared to meet the challenge.

The assessments of final energy demand reported here represent such an effort. Of course, they are not predictions or forecasts; they simply describe a range of, in our judgment, realistic evolutions of future energy demand in various world regions that are consistent with a plausible range of world economic development and population growth.

The world's energy demand increased more or less exponentially between 1950 and 1975 at an average growth rate of 5% per year (see e.g. Doblin, 1979). Obviously, this trend cannot continue in view of the limited resources of conventional fuels. Although there are sources of energy -- solar and nuclear (through breeding and fusion) -- that promise virtually unlimited supply, the present status and cost economics of these sources is such that they may, at best, be expected to play only a minor role in the next 15-50 year period. Therefore, energy conservation leading to a shift away from the exponential energy growth trend of the last 30 years is indispensible, if one does not completely close ones eyes to the future. However, significant energy conservation is possible only in the most highly developed countries; most of the population in the developing world still lives at levels of energy consumption close to subsistence and will need increasing amounts of energy to improve its lot. The assessment of energy demand reported here is based on what we would consider optimistic, though not unrealistic, assumptions about measures of energy conservation and possible technological improvements.

The extent of energy savings embodied in the two scenarios can be seen in Figure 8a, b, where final energy per unit of GDP is plotted against GDP per capita for Regions I through VI. There the ratio of final energy demand to GDP is seen to continue to decrease for the developed regions (I, II and III) in line with the historical trends. On the other hand, the ratio continues to increase, at least initially, for all the developing regions, again in line with the historical trends, but flattens off later and even starts to go down in Regions IV and VI. These different trends in the developed and the developing regions are characteristic of economies that have already reached a high level of industrialization, but are still in the process of building up their industrial infrastructure.

Globally speaking, the curves of Figure 8a, b imply a reduction of final energy per dollar of GDP from 0.91 in 1975 to values of 0.53 and 0.62 in 2030 for the High and the Low scenarios, respectively. If only the developed Regions I, II and III are considered, the improvement is even more impressive: final energy per dollar of GDP decreases from 0.95 in 1975 to 0.45 and 0.55 over a period of 55 years. By far the largest improvement is seen in Region II (SU/EE), where the overall conservation resulting from various scenario assumptions amounts to 61 and 54%. The corresponding figures for Region I are 59 and 44% and for Region III (WE/JANZ) 45 and 33%. These improvements, seen in the light of real price increases of 3.0 and 2.4 times the prices in the recent past (see Energy Systems Program Group 1981, Chant 1980) appear quite pronounced but not unrealistic. Some measures behind this trend have been reported here in detail. Indicators such as automobile efficiency, average transport load factors, home insulation, structural changes in industry and others have been cited to illustrate the extent of the energy-using improvements assumed.

Another measure of the efficiency improvements assumed in the scenarios can be derived by calculating the final energy that would result by 2030 if the historical 1950-1975 final energy-to-GDP elasticity were to be applied for 1975 to 2030. Table 29 shows the differences between final energy calculated in this way and the final energy projections of the High and the Low scenarios.

Savings of roughly 20 to 50% occur in each region. The demand reductions in Regions I to VI through conservation measures embodied in the two IIASA scenarios thus represent a net final energy saving of 5.3 to 12.6 TWyr/yr by 2030.

These amounts are certainly substantial. They underscore the aggressive conservation measures assumed in the sceanrios. They reflect the belief that vigorous action to increase energy efficiency and to improve energy productivity is a necessity in any energy strategy -- short, medium- or long-term. Without such improvements, the adequate supply of energy necessary to meet the demand at the levels of world economic and population growth assumed would probably run into serious difficulties, and the two IIASA energy supply scenarios (Energy Systems Program Group, 1981) might have proved to be infeasible.

7. References

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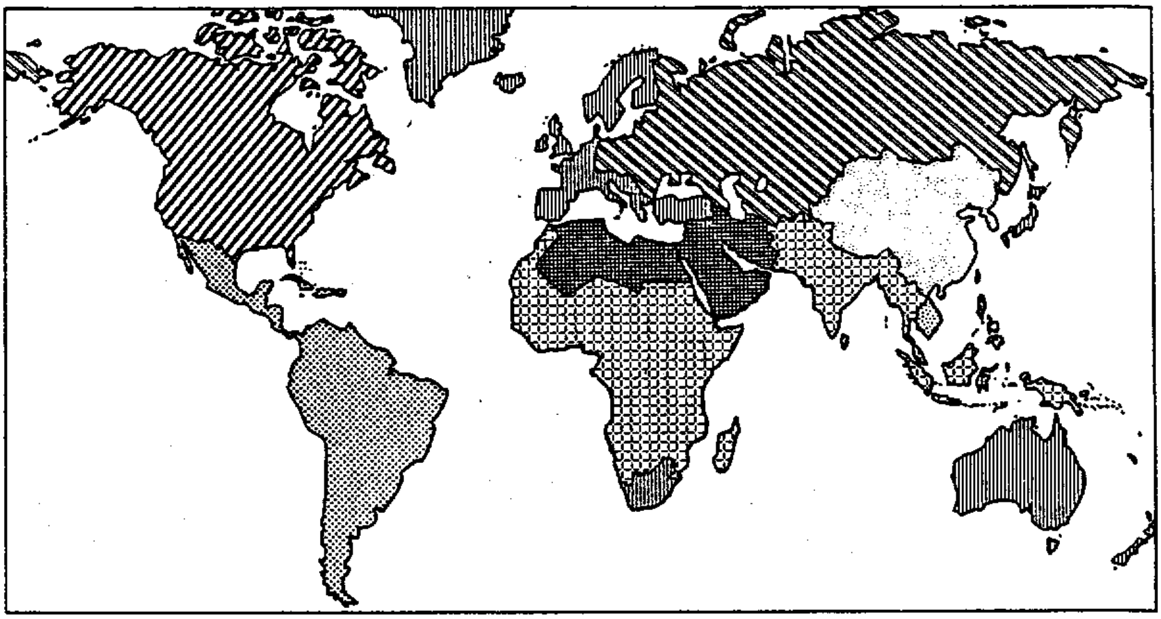
FIGURES



Region I	(NA) North America
Region II	(SU/EE) Soviet Union and Eastern Europe
Region III	(WE/JANZ) Western Europe, Japan, Australia, New Zealand, S. Africa, and Israel
Region IV	(LA) Latin America
Region V	(Af/SEA) Africa (except Northern Africa and S. Africa), South and Southeast Asia
Region VI	(ME/NAf) Middle East and Northern Africa
Region VII	(C/CPA) China and Centrally Planned Asian Economies

Figure I. The IIASA World Regions

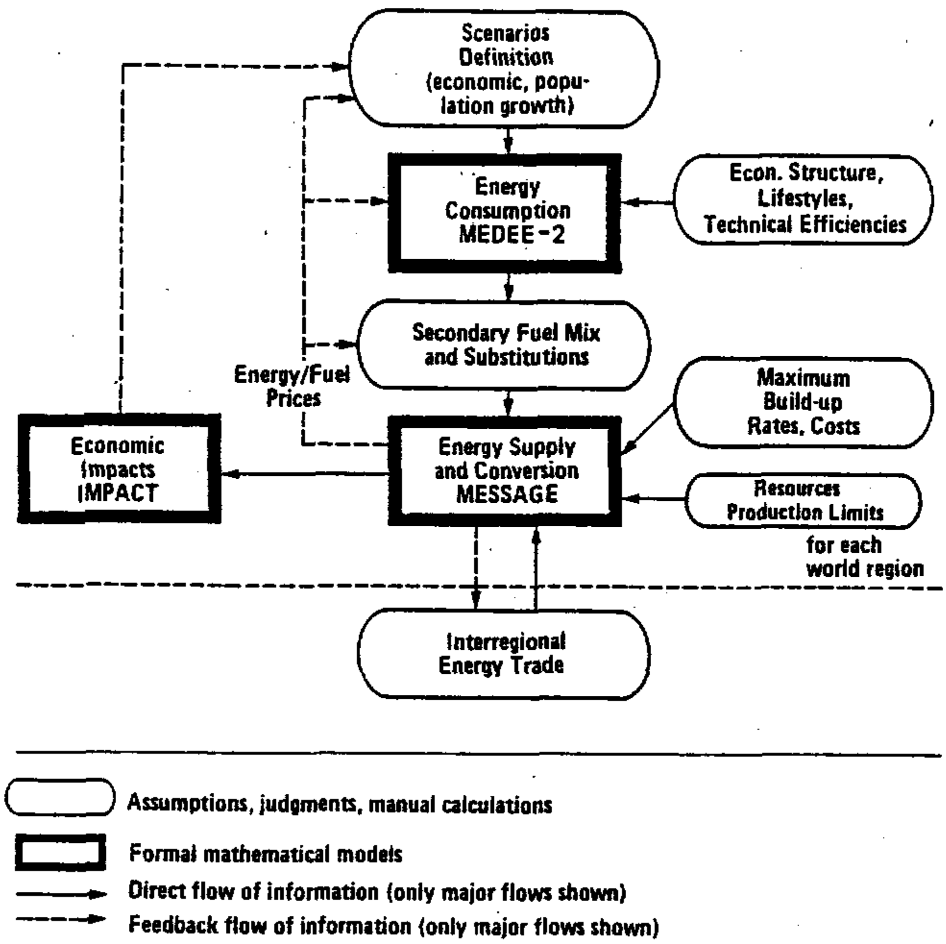


Figure 2. IIASA's Set of Energy Models: A Simplified Representation.

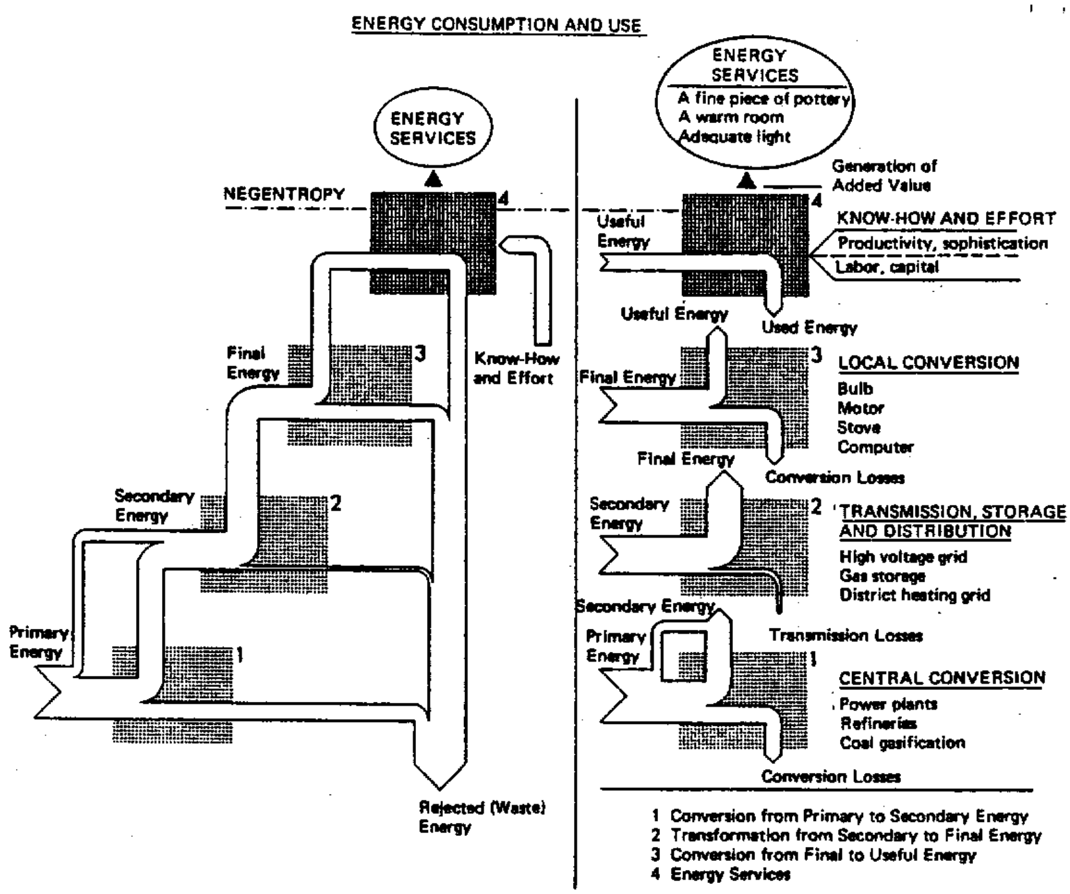


Figure 3. Energy Conversion and Use

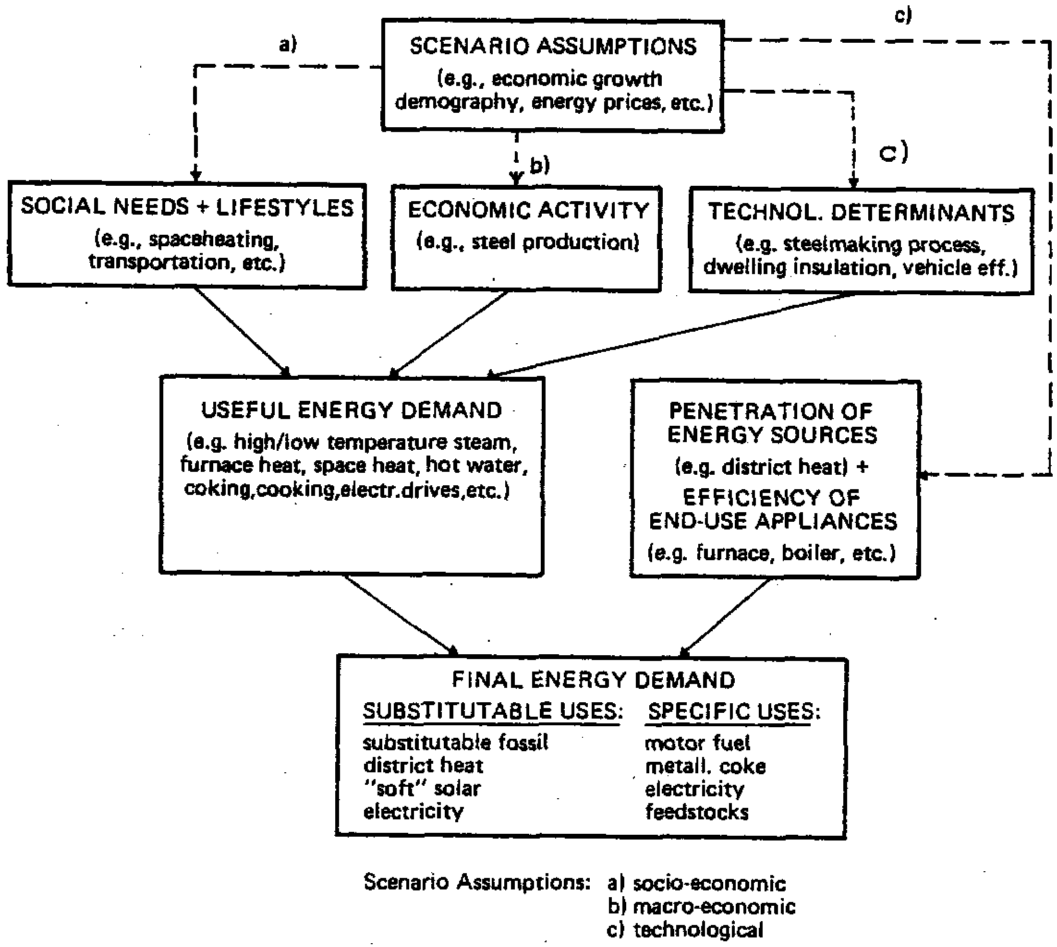
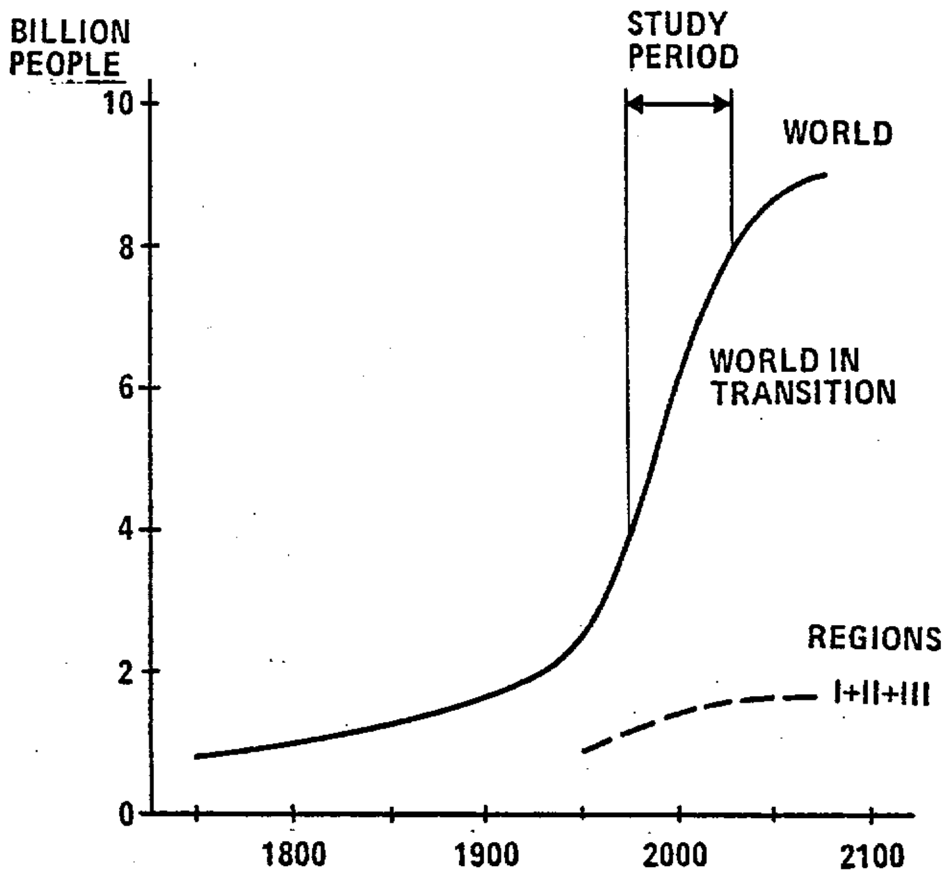
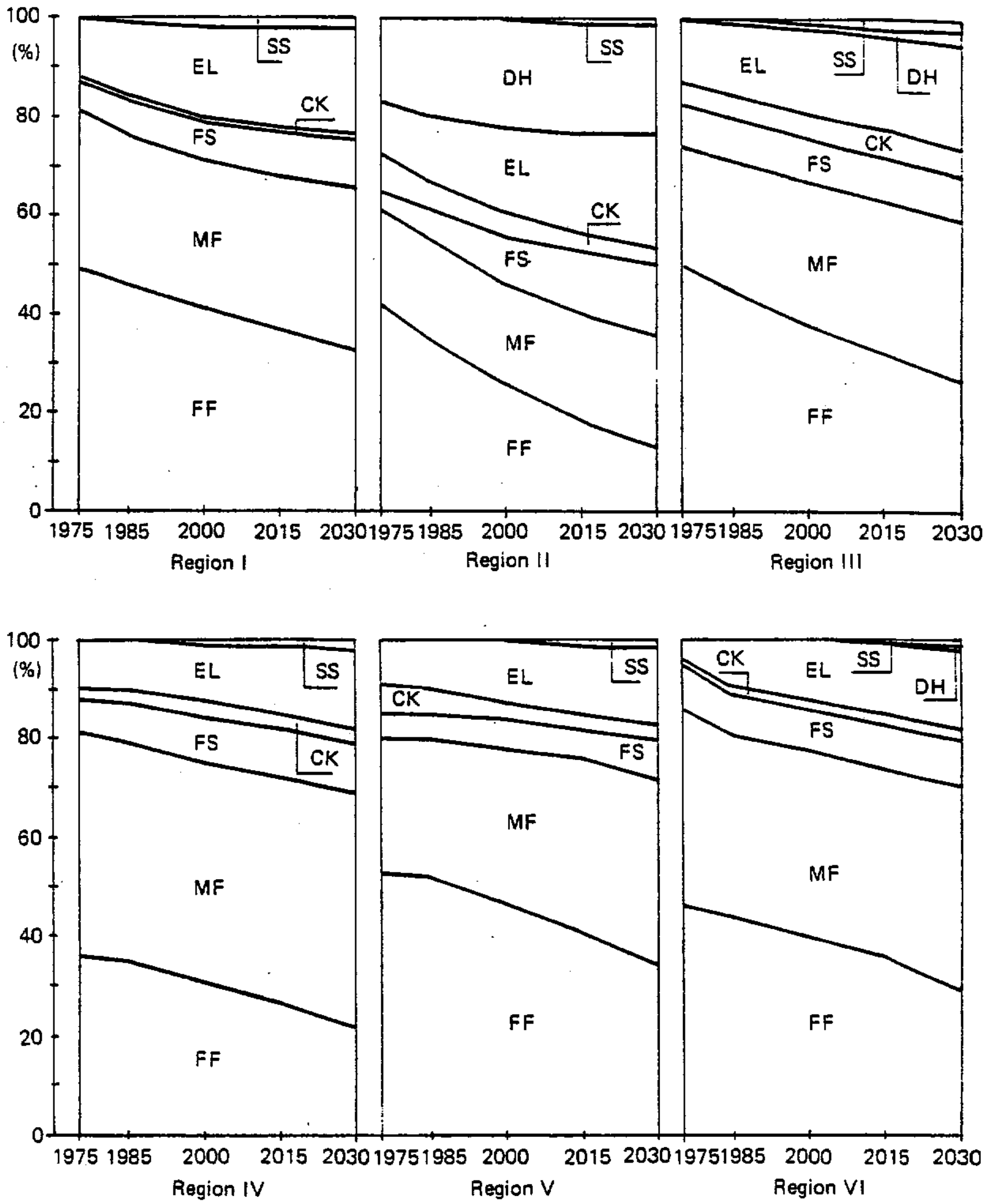


Figure 4. Schematic Description of MEDEE-2

Fig. 5 WORLD POPULATION HISTORICAL AND PROJECTED





FF = Substitutable Fossil Fuels
CK = Specific Uses of Coal (Ess.Coke)
MF = Motorfuel
EL = Electricity
SS = Soft Solar
FS = Feedstocks
DH = District Heat

Figure : Shares of Energy Forms in Final Energy Demand, 1975-2030 (High scenario).

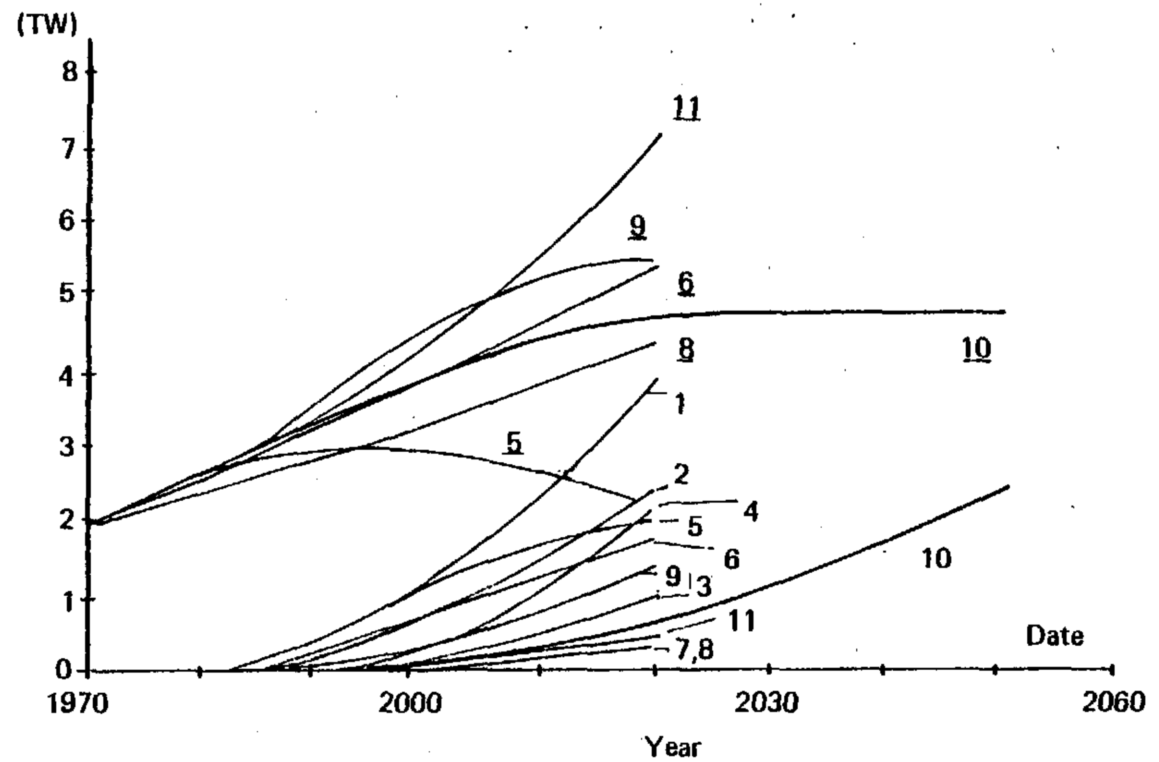


Figure 7: Some recent Projections of Primary Energy Demand and Potential Solar Shares for the U.S. Underlined numbers describe projections of total energy demand; numbers not underlined indicate total energy demand potentially available from solar energy sources: (1) MITRE (1973), (2) Morrow (1973) "maximum solar", (3) Morrow (1973) "minimum solar", (4) Wolf (1974), (5) Lovins (1976), (6,7,8) Renyl et al. (1976), (9) ERDA 49 (1975), CONAES (1977), (10) Weingart and Nakicenovic (1979), (11) Beller ed. (1975) "future ref. energy system".

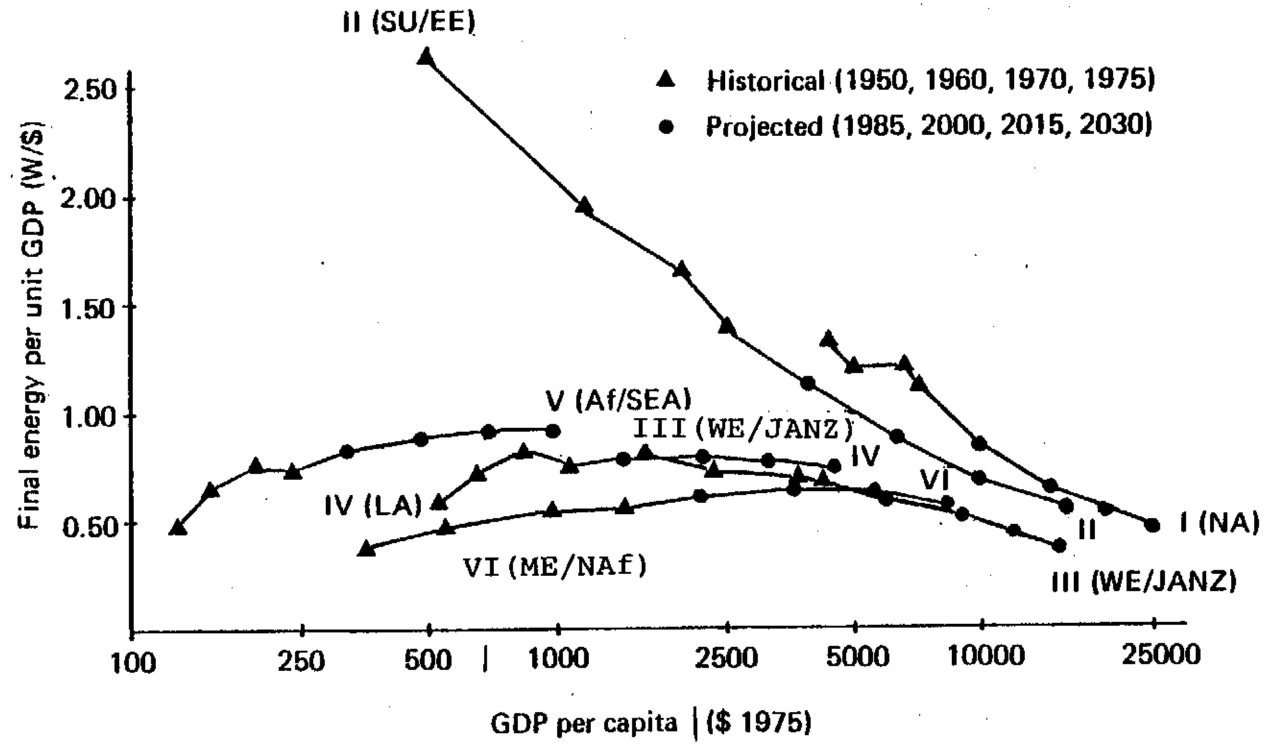


Figure 8a: Energy Intensity in Different World Regions (High scenario)

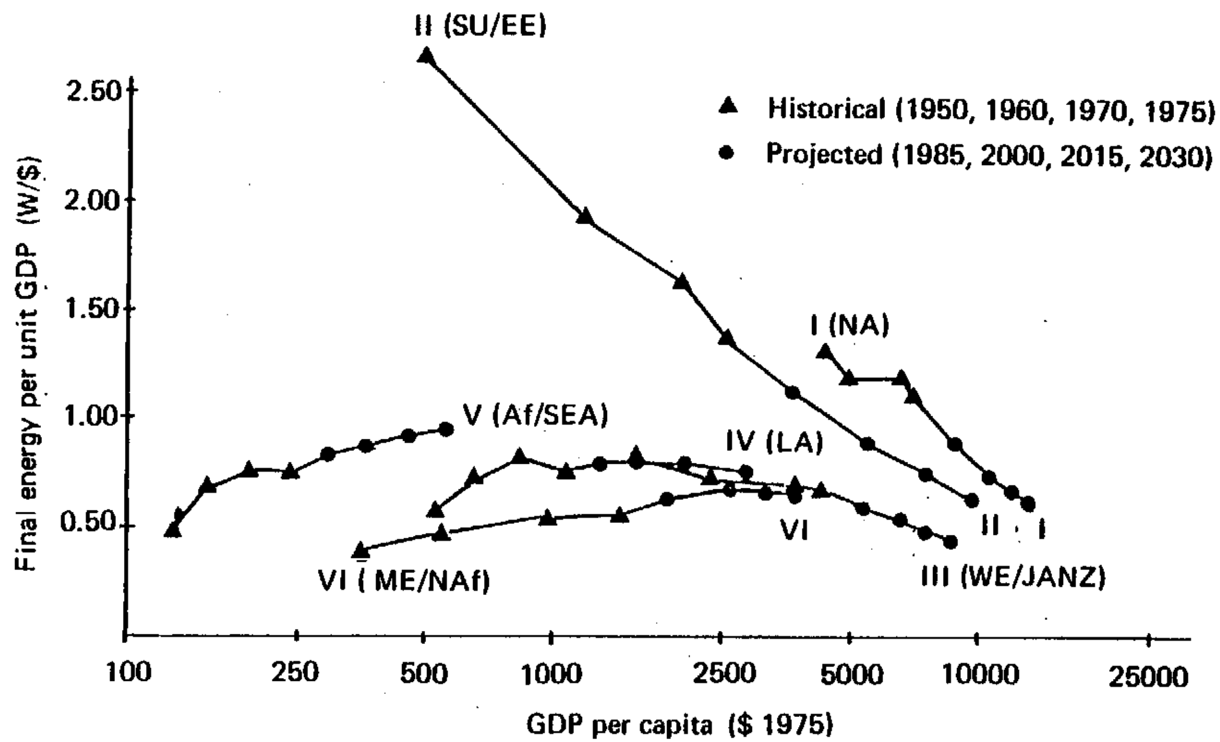


Figure 8b: Energy Intensity in Different World Regions (Low scenario)

TABLES

TABLE 1 Categories of Energy End Use Considered in MEDEE-2. Energy Sources are Coal (CL); Motor Fuel--Gasoline, Diesel, Jet Fuel (MF); Electricity (EL). F is Basic Energy Demand Calculated in Final Energy Forms; U is Basic Energy Demand Calculated in Useful Energy Forms

Transportation Module (F)	Industry Module: Sectors	Industry Module: Processes	Household/Service Module
Personal Transportation			Household
urban: car (MF, EL); mass transit (MF, EL)	Agriculture	Motor fuel use (F)	Space heating (U): pre-/post-75 dwellings; multifamily/single family; central heating/other
	Construction	Specific[a] electricity uses (F)	
intercity: car (MF); plane (MF); bus (MF); train (CL, MF, EL)	Mining	Thermal uses (U)	
	Manufacturing		
	Basic materials	Steam generation	Water heating (U)
	Machinery and equipment	Furnace operation	Cooking (U)
		Space and water heating	Cooling (U)
	Food textiles, and other	Coke for iron-ore reduction (F)	Electrical appliances (F)
Freight Transportation			
long distance: truck (MF); train (CL, MF, EL); barge (MF); pipeline (MF)	Energy[b]	Use of energy products as food stocks (F)	Service
			Thermal uses (U): pre-/post-75 buildings
			Cooling (U)
			Electrical appliances (F)
local truck (MF)			
Miscellaneous (MF)			
international freight and passenger (air and maritime) transport			

[a]By definition in the model, all present uses of electricity are included here.

[b]The energy sector should be considered separately if statistics permit. Its energy consumption should be determined for conversion from primary to secondary energy.

NOTES: Of course, the restriction of certain categories here to just one or two fuel types misses other possibilities. For instance, pipelines may use electricity rather than motor fuel; this is seriously considered and planned in the Soviet Union. But the simplifications of the kinds noted here should not materially affect the results.

Table 2 Population Projections by Region

	Population (10^6)		
	Base Year	Projection	
Region	1975	2000	2030
I (NA)	237	284	315
II (SU/EE)	363	436	480
III (WE/JANZ)	560	680	767
IV (LA)	319	575	797
V (Af/SEA)	1,422	2,528	3,550
VI (ME/NAf)	133	247	353
VII (C/CPA)	912	1,330	1,714
World	3,946	6,080	7,976

NOTES: 1975 data are mid-year estimates from United Nations *Monthly Bulletin of Statistics*, January 1978.
The same population projection is chosen for both High and Low scenarios.
SOURCE: Keyfitz (1977).

Table 3: GDP Projections by Region (10^9 $75)

Region	Base Year 1975	Projections High Scenario 2000		Low Scenario 2000	
		2000	2030	2000	2030
I (NA)	1670	4126	7926	3049	4170
II (SU/EE)	930	2729	7658	2420	4713
III (WE/JANZ)	2385	5999	11693	4452	6656
IV (LA)	340	1272	3569	918	2229
V (Af/SEA)	340	1207	3488	924	1995
VI (ME/NAf)	190	900	2918	643	1310
VII (C/CPA)	320	939	2450	690	1345
World	6175	17172	39702	13096	22418

Notes: GDP in constant 1975 U.S. dollars.

Base year data are estimates from UN (1977c), World Bank (1977) and OECD (1979a).

Table 4: GDP/cap Projections by Region (10^3 $75)

Regions	Base Year 1975	Projections High Scenario 2000		Projections Low Scenario 2000	
		2000	2030	2000	2030
I (NA)	7.05	14.53	25.16	10.74	13.24
II (SU/EE)	2.56	6.26	15.95	5.55	9.82
III (WE/JANZ)	4.26	8.82	15.25	6.55	8.68
IV (LA)	1.07	2.21	4.48	1.60	2.80
V (Af/SEA)	0.24	0.48	0.98	0.37	0.56
VI (ME/NAf)	1.43	3.64	8.27	2.60	3.71
VII (C/CPA)	0.35	0.71	1.43	0.52	0.78
World	1.56	2.82	4.98	2.15	2.81

Note: based on Tables 2 and 3.

Table 5: Primary Energy Consumption, Electricity Generation and Noncommercial Energy Use in the Base Year (1975) by Region

Primary Energy Consumption (GWyr):	Region					
	I	II	III	IV	V	VI
Solid	484	770	541	16	119	3
Liquid	1167	635	1252	228	159	77
Natural gas	763	374	238	48	20	43
Hydro (primary equiv.)	174	50	180	45	29	5
Nuclear (primary equiv.)	66	6	45	1	1	0
Total	2654	1835	2256	338	328	128
Electricity Generation (GWyr):						
Hydro	58	17	59	15.1	9.9	1.5
Conventional Thermal (from fossil fuels)	181	139	167	12.6	16.0	3.9
Nuclear	21	2	15	0.3	0.4	0
Total	260	158	241	28	26	5
Noncommercial Fuels (GWyr):						
Wood	-	44	-	84	229	2
Agricultural and Animal Wastes	-	-	-	25	115	8
Total	-	44	-	109	344	10

Table 6: Estimate of Final Energy Use by Energy Form and by Region in the Base Year (1975) (GWyr)

Energy Form	Region I	II	III	IV	V	VI
Coal[a]	108	353	232	12	81	2
Oil[b]	951	428	979	189	138	70
Gas[c]	584	148	177	29	12	29
Electricity	228	130	201	24	22	5
District Heat	-	218	-	-	-	-
Total	1871	1277	1589	254	253	106

a includes coke consumption of the iron and steel industry.

b includes feedstocks derived from crude oil.

c includes manufactured gas.

Table 7:Estimate of Sectoral Distribution of Final Energy Use in the Base Year (1975)

	Regions					
	I	II	III	IV	V	VI
Total Final Energy (GWyr):	1871	1277	1589	254	253	106
% electricity	12.2	10.2	12.7	9.6	8.7	4.4
% district heat	-	17.1	-	-	-	-
Industry (GWyr)	757	759	805	119	149	49
% electricity	12.5	13.3	14.0	14.5	11.9	7.5
% district heat	-	22.4	-	-	-	-
Transport (GWyr)	541	224	313	105	76	42
%electricity	0.1	4.0	1.9	0.2	0.5	0.1
Household/Service (GWyr):	573	293	471	31	28	15
%electricity	23.3	6.9	17.6	22.7	13.6	6.6
% district heat	-	16.4	-	-	-	-
Noncommercial energy (households only) (GWyr):	-	44	-	109	344	10

Table 8 : Base Year Data / Inputs

Group 1 : Demography

Variable	Region					
	I	II	III	IV	V	VI
PO	237.	363.	560.	319.	1422.	133.
PLF	0.64	0.64	0.63	0.542	0.538	0.523
PARTLF	0.69	0.61	0.72	0.59	0.708	0.512
POLC	0.64	0.42	0.51	0.63	0.87	0.71
PRUR*	0.24	0.41	0.29	0.40	0.78	0.55
CAPH	2.98	3.7	3.	5.1	5.24	5.25

Group 2 : Macroeconomics

Variable	Region					
	I	II	III	IV	V	VI
Y	1670.	930.	2385.	340.	340.	190.
PYAG	0.028	0.107	0.058	0.122	0.361	0.07
PYB	0.041	0.079	0.075	0.057	0.058	0.065
PYMIN†	0.	0.	0.	0.025	0.015	0.51
PYMAN	0.245	0.382	0.336	0.248	0.166	0.078
PYEN	0.038	0.042	0.046	0.025	0.016	0.007
PYSER	0.648	0.39	0.485	0.523	0.384	0.27
PVAIG	0.248	0.233	0.33	0.308	0.264	0.2
PVAM	0.432	0.476	0.42	0.264	0.176	0.1
PVAC	0.32	0.291	0.25	0.429	0.56	0.7
I*	0.18	0.3	0.25	0.23	0.2	0.215
P*	0.65	0.45	0.58	0.7	0.71	0.325
PCDG*	0.19	0.1	0.1	0.1	0.07	0.1
PCNDG*	0.42	0.6	0.56	0.6	0.73	0.6
PCSER*	0.39	0.3	0.34	0.3	0.2	0.3

* The values for these variables do not directly affect the calculations of the version of the MEDEE-2 model used for the present assessment, but they are used for projecting the evolution of other variables, outside the model calculations.

† For Regions I, II and III, mining of coal, oil and gas is included in the energy sector and that of other materials is included under manufacturing of basic materials. (see definition of sectors in Appendix III).

Table 8 : Base Year Data / Inputs (cont'd)

Group 3 : Energy Consumption

Group 3.1 : Industry (Agriculture, Construction, Mining, Manufacturing)

Group 3.1a : Energy Intensity of Agriculture, Construction, Mining

Variable	Region I	II	III	IV	V	VI
EI.AGR.MF	5.07	1.36	1.49	0.132	0.165	0.252
EI.AGR.EL	0.56	0.88	a	0.062	0.1	0.065
EI.AGR.TH	a	a	a	a	a	a
EI.CON.MF	2.53	2.56	1.97	1.44	0.05	0.25
EI.CON.EL	a	0.95	a	0.065	a	a
EI.CON.TH	a	a	a	a	a	a
EI.MIN.MF	b	b	b	5.1	1.47	a
EI.MIN.EL	b	b	b	1.82	a	a
EI.MIN.TH	b	b	b	a	a	1.366

Group 3.1b : Energy Intensity of Manufacturing Industries

Variable	Region I	II	III	IV	V	VI
EI.BM.MF	0.14	a	a	a	a	a
EI.BM.EL	4.62	5.	1.27	2.35	5.5	4.4
EI.BM.US	18.05	17.286	5.81	7.38	12.5	11.74
EI.ME.MF	a	a	a	a	a	a
EI.ME.EL	0.9	1.5	1.87	0.68	1.85	0.66
EI.ME.US	1.14	4.4	0.81	0.576	1.025	1.89
EI.ND.MF	a	a	a	a	a	a
EI.ND.EL	1.32	0.58	0.23	1.54	1.38	1.69
EI.ND.US	2.48	5.	1.06	2.868	6.85	3.19

Group 3.1c : Change of Energy Intensity of Agr., Constr., Min.

Variable	Region I	II	III	IV	V	VI
CH.AGR.MF	1.	1.	1.	1.	1.	1.
CH.AGR.EL	1.	1.	1.	1.	1.	1.
CH.AGR.TH	1.	1.	1.	1.	1.	1.
CH.CON.MF	1.	1.	1.	1.	1.	1.
CH.CON.EL	1.	1.	1.	1.	1.	1.
CH.CON.TH	1.	1.	1.	1.	1.	1.
CH.MIN.MF	1.	1.	1.	1.	1.	1.
CH.MIN.EL	1.	1.	1.	1.	1.	1.
CH.MIN.TH	1.	1.	1.	1.	1.	1.

Group 3.1d : Change of Energy Intensity of Manufacturing Industries

Variable	Region I	II	III	IV	V	VI
CH.MAN.MF	1.	1.	1.	1.	1.	1.
CH.MAN.EL	1.	1.	1.	1.	1.	1.
CH.MAN.US	1.	1.	1.	1.	1.	1.

a: separate data were not available to us; the corresponding requirements are accounted for elsewhere.

b: the mining sector is not considered separately for Regions I, II and III (see definition of PYMIN, PYEN, PYMAN and PVAIG in Appendix III.)

Table 8 : Base Year Data / Inputs (cont'd)

Group 3.1e : Breakdown of Useful Thermal Energy in Manufacturing Industries

Variable	Region					
	I	II	III	IV	V	VI
STSHI	0.5	0.69	0.5	0.42	0.4	0.4
STI	0.4	0.6	0.4	0.4	0.4	0.4
LTH	0.2	0.3	0.2	0.15	0.15	0.15

Group 3.1f : Penetration of Alternative Energy Sources and Efficiencies †

Variable	Region					
	I	II	III	IV	V	VI
ELPIND*	0.	0.	0.	0.	0.	0.
(HPI)	(0)	(0)	(0)	(0)	(0)	(0)
EFFHPI	2.	2.	2.	2.	2.	2.
IDH	0.	0.69	0.	0.	0.	0.
SPLT	0.	0.	0.	0.	0.	0.
SPHT	0.	0.	0.	0.	0.	0.
FIDS	0.7	0.3	0.7	0.8	0.8	0.8
ICOGEN	0.	0.	0.3	0.	0.	0.
EFFCOG	0.65	0.65	0.65	0.65	0.65	0.65
HELRAT	5.	5.	5.	5.	5.	5.
EFFIND**	0.65	0.605	0.65	0.6	0.5	0.55

*zero by definition, i.e. only penetration above levels reached today is considered

**efficiency of fossil fuel use relative to electricity.

†Values in parentheses are to be interpreted as fractions of the preceding category.

Group 3.1g : Constants for Projection of Feedstock Use and Steel Production

Variable	Region					
	I	II	III	IV	V	VI
CFEED(1)	0.	-44.3	0.	0.	0.	5.6
CFEED(2)	0.77	1.	0.36	0.488	0.553	0.4
CPST(1)	0.	71.4	0.	0.	0.	0.
CPST(2)	0.49	1.33	0.83	0.732	0.606	0.304

Group 3.1h : Coke Use in Iron&Steel Industry

Variable	Region					
	I	II	III	IV	V	VI
BOF	0.8	0.8	0.8	1.	1.	1.
IRONST	0.97	0.9	0.97	0.6	0.95	1.2
EICOK	600.	700.	500.	600.	900.	1000.

Table 8 : Base Year Data / Inputs (cont'd)

Group 3.2 : Transportation

Group 3.2a : Constants for Projecting Freight and Misc. Transportation

Variable	Region I	II	III	IV	V	VI
CTKFRT(1)	-118.45	1120.	0.	0.	0.	0.
CTKFRT(2)	6.125	7.12	1.45	6.19	2.83	4.353
CMISMF(1)	0.	560.	0.	0.	0.	0.
CMISMF(2)	0.225	0.3	0.07	0.16	0.16	0.2

Group 3.2b : Distribution of Freight Transportation by Mode*

Variable	Region I	II	III	IV	V	VI
TRU	0.234	0.025	0.55	0.615	0.45	0.426
(TRUL)	(0.15)	(0.)	(0.)	(0.)	(0.)	(0.)
FTRA	0.39	0.775	0.3	0.175	0.35	0.024
(TRAEF)	(0.)	(0.35)	(0.3)	(0.01)	(0.15)	(0.05)
(TRASTF)	(0.)	(0.055)	(0.)	(0.)	(0.55)	(0.)
BA	0.164	0.05	0.1	0.15	0.08	0.03
PIP	0.212	0.15	0.05	0.06	0.12	0.52

* values in parentheses are to be interpreted as fractions of the preceding category.

Group 3.2c : Energy Intensity of Freight Transportation Modes

Variable	Region I	II	III	IV	V	VI
DTRU	400.	800.	800.	800.	800.	800.
DTRUL	1100.	0.	0.	0.	0.	0.
DTRAF	110.	100.	200.	200.	200.	200.
DBA	80.	100.	200.	200.	200.	200.
DPIP	0.	0.	0.	0.	0.	70.

Table 8 : Base Year Data / Inputs (cont'd)

Group 3.2d : Total Distance Travelled per Person (Intercity/Urban)

Variable	Region					
	I	II	III	IV	V	VI
DI	10000.	2650.	7500.	1850.	500.	1050.
DU	56.	10.	9.7	16.5	11.	11.

Group 3.2e : Car Travel *

Variable	Region					
	I	II	III	IV	V	VI
CO	2.	40.	5.21	25.64	268.	59.5
DIC	7000.	5000.	5000.	6300.	6700.	6000.
LFIC	2.6	3.	2.3	3.5	3.5	3.
UC	0.966	0.4	0.7	0.3	0.33	0.3
(UCE)	(0.)	(0.)	(0.)	(0.)	(0.)	(0.)
LFUC	1.6	2.5	1.5	2.5	2.5	2.

*Values in parentheses are to be interpreted as fractions of the preceding category.

Group 3.2f : Public Transportation *

Variable	Region					
	I	II	III	IV	V	VI
PBU	0.153	0.15	0.35	0.845	0.67	0.844
PTRA	0.051	0.62	0.6	0.107	0.314	0.132
(TRAEP)	(0.01)	(0.5)	(0.3)	(0.01)	(0.15)	(0.05)
(TRASTP)	(0.)	(0.02)	(0.)	(0.)	(0.55)	(0.)
PLA	0.796	0.23	0.05	0.048	0.016	0.024
LFBU	22.	45.	25.	40.	40.	40.
LFTRA	140.	400.	140.	500.	500.	500.
LFP	0.5	0.9	0.6	0.6	0.8	0.75
UMT	0.034	0.6	0.3	0.7	0.67	0.7
(UMTE)	(0.4)	(0.8)	(0.4)	(0.05)	(0.03)	(0.02)
LFMTB	17.6	40.	20.	50.	50.	50.
LFMTE	20.5	50.	30.	60.	60.	60.

* values in parentheses are to be interpreted as fractions of the preceding category.

Group 3.2g : Specific Energy Consumption of Passenger Transportation Modes

Variable	Region					
	I	II	III	IV	V	VI
GIC	14.	12.	9.	9.	9.	11.5
GUC	19.6	14.	11.	12.	12.	14.5
ELUC	0.25	0.25	0.25	0.25	0.25	0.25
DBU	39.	35.	40.	40.	40.	40.
DTRAP	42790.	22750.	20000.	20000.	20000.	20000.
DPLA	691.	800.	700.	700.	700.	700.
DMT	50.	40.	60.	60.	60.	60.
ELMT	3.4	3.4	3.4	3.4	3.4	3.4

Table 8 : Base Year Data / Inputs (cont'd)

Group 3.3 : Household and Service Sector

Group 3.3a : Important Constants / Initial Values

Variable	Region I	II	III	IV	V	VI
DD	2600.	4000.	2200.	1200.	300.	500.
DWSH,ARSH	1.	1.	1.	0.25	0.15	1.
DW-75	79.4	98.	187.	62.6	271.4	25.3
SHDWO(1)	23500.	17750.	17000.	5000.	0.	2700.
SHDWO(2)	12800.	11500.	11000.	3500.	0.	1800.
SHDWO(3)	9600.	6300.	4000.	1250.	450.	900.
TAREA-75	2720.	1500.	3000.	600.	1250.	180.
CPLSER	1.2	1.028	1.2	1.534	1.536	0.824
HAREAO	290.	220.	135.	50.	15.	25.
BYRNCF	a	47.5	a	117.	370.	10.5

a. noncommercial fuels are not considered in Regions I and III.

Group 3.3b : Other Factors Determining Present Useful Energy Consumption

Variable	Region I	II	III	IV	V	VI
COOKDW	1000.	1000.	1100.	1600.	1000.	1600.
DWHW	1.	0.6	0.7	0.2	0.1	0.6
HWCAP	1500.	700.	700.	400.	40.	60.
DWAC	0.39	0.	0.	0.	0.	0.01
ACDW	4472.	2000.	3000.	1500.	1500.	2000.
ELAPDW	3850.	880.	1950.	700.	50.	200.
PREDW(1)	0.48	0.05	0.1	0.08	0.	0.01
PREDW(2)	0.32	0.35	0.2	0.16	0.	0.05
PREDW(3)	0.2	0.6	0.7	0.56	0.35	0.4
AREAH	0.8	1.	0.7	0.8	0.35	0.7
ELARO	120.	40.	40.	25.	15.	15.
AREAAC	0.55	0.	0.05	0.05	0.	0.04
ACAREA	70.	70.	70.	70.	70.	70.
EFFAC	2.	2.	2.	2.	2.	2.

Table 8 : Base Year Data / Inputs (cont'd)

Group 3.3c : Factors Relevant for Projection of Useful Energy Consumption

Variable	Region I	II	III	IV	V	VI
DEMDW	not applicable for base year					
NEWDW(1)						
NEWDW(2)						
NEWDW(3)						
DWS(1)						
DWS(2)						
DWS(3)						
K(1)						
K(2)						
K(3)						
ISC(1)	0	0.	0.	0.	0.	0.
ISC(2)	0	0.	0.	0.	0.	0.
ISC(3)	0	0.	0.	0.	0.	0.
AREAL	not applicable for base year					
DEMAR						
HAREAN						
ELARN						
ISCSV	0.	0.	0.	0.	0.	0.

Group 3.3d : Penetration of Alternative Energy Sources*

Variable	Region I	II	III	IV	V	VI
ELP.H.SH	0.12	0.	0.04	0.01	0.01	0.01
ELP.H.HW	0.3	0.07	0.24	0.01	0.01	0.01
ELP.H.CK	0.47	0.15	0.36	0.005	0.	0.
ELP.S.TH	0.05	0.	0.04	0.01	0.3	0.01
(HPHS)	(0.)	(0.)	(0.)	(0.)	(0.)	(0.)
EFFHPR	2.	2.	2.	2.	2.	2.
DHPH	0.	0.467	0.	0.	0.	0.
SPSH †	0.	0.	0.	0.	0.	0.
FDSHS	0.7	0.4	0.5	0.8	0.8	0.8
SPHW	0.	0.	0.	0.	0.	0.
FDHWS	0.7	0.6	0.7	0.8	0.8	0.8
PLB	0.3	0.3	0.3	0.3	0.7	0.7
SPSV †	0.	0.	0.	0.	0.	0.
FDHS	0.7	0.4	0.55	0.8	0.8	0.8
CHGNCF	a	1.	a	1.	1.	1.

[a] noncommercial fuels are not considered in Regions I and III.

† only relevant for post-75 buildings.

* values in parentheses are to be interpreted as fractions of the preceding category.

Table 8: Base Year Data / Inputs (cont'd)

Group 3.3e : Fossil Fuel Efficiencies (relative to electricity)

Variable	Region					
	I	II	III	IV	V	VI
EFF.H.SH	0.63	0.59	0.63	0.6	0.5	0.6
EFF.H.HW	0.57	0.49	0.57	0.55	0.5	0.55
EFF.H.CK	0.41	0.4	0.51	0.5	0.5	0.5
EFF.S.TH	0.7	0.59	0.7	0.65	0.55	0.6
EFFNCF	a	0.3	a	0.075	0.075	0.075

a. noncommercial fuels are not considered in Regions I and III.

Table 9.1 : Detailed Scenario Assumptions - Demography (Group I).

Variable	Region I 1975	Region I 2000 L, H	Region I 2030 L, H	Region II 1975	Region II 2000 L, H	Region II 2030 L, H	Region III 1975	Region III 2000 L, H	Region III 2030 L, H
PO	237.	284.	315.	363.	436.	480.	560.	680.	767.
PLF	0.64	0.64	0.64	0.64	0.64	0.64	0.63	0.65	0.65
PARTLF	0.69	0.69, 0.75	0.69, 0.8	0.61	0.66, 0.7	0.7, 0.8	0.72	0.75, 0.77	0.77, 0.8
POLC	0.64	0.635	0.625	0.42	0.3	0.2	0.51	0.48	0.45
PRUR*	0.24	0.14	0.07	0.41	0.25	0.12	0.29	0.18	0.08
CAPH	2.98	2.48	2.24	3.7	3.	2.7	3.	2.72	2.56

Variable	Region IV 1975	Region IV 2000	Region IV 2030	Region V 1975	Region V 2000	Region V 2030	Region VI 1975	Region VI 2000	Region VI 2030
PO	319.	575.	797.	1422.	2528.	3550.	133.	247.	353.
PLF	0.542	0.623	0.69	0.538	0.616	0.694	0.523	0.608	0.698
PARTLF	0.59	0.59	0.59	0.708	0.708	0.708	0.512	0.512	0.512
POLC	0.63	0.47	0.31	0.87	0.77	0.56	0.71	0.55	0.35
PRUR*	0.40	0.25	0.15	0.78	0.66	0.45	0.55	0.38	0.18
CAPH	5.1	4.8	4.15	5.24	4.8	4.15	5.25	4.9	4.35

* The values for this variable do not directly affect the calculations of the version of the MEDEE-2 model used for the present assessment, but they are used for projecting the evolution of other variables, outside the model calculations.

Table 9.2 : Detailed Scenario Assumptions - Macroeconomics (Group 2)

Variable	Region I			Region II			Region III		
	1975	2000 L , H	2030 L , H	1975	2000 L , H	2030 L , H	1975	2000 L , H	2030 L , H
Y	1670.	3049. , 4126.	4170. , 7926.	930.	2420. , 2729.	4713. , 7658.	2385.	4452. , 5999.	6656. , 11693.
PYAG	0.028	0.023 , 0.021	0.02 , 0.015	0.107	0.086 , 0.074	0.07 , 0.04	0.058	0.044 , 0.045	0.03 , 0.025
PYB	0.041	0.044 , 0.043	0.046 , 0.045	0.079	0.08 , 0.075	0.08 , 0.07	0.075	0.073 , 0.071	0.07 , 0.065
PYMIN †	0.			0.			0.		
PYMAN	0.245	0.24 , 0.223	0.238 , 0.207	0.382	0.335 , 0.337	0.3 , 0.29	0.336	0.317 , 0.313	0.297 , 0.281
PYEN	0.038			0.042	0.046	0.05	0.046	0.05 , 0.049	0.053 , 0.05
PYSER	0.648	0.655 , 0.675	0.658 , 0.695	0.39	0.453 , 0.468	0.5 , 0.55	0.485	0.516 , 0.522	0.55 , 0.58
PVAIG	0.248	0.237 , 0.232	0.232 , 0.212	0.233	0.222 , 0.23	0.217 , 0.227	0.33	0.312 , 0.311	0.294 , 0.282
PVAM	0.432	0.458 , 0.47	0.47 , 0.517	0.476	0.514 , 0.521	0.53 , 0.568	0.42	0.445 , 0.46	0.471 , 0.512
PVAC	0.32	0.305 , 0.298	0.298 , 0.271	0.291	0.264 , 0.249	0.253 , 0.205	0.25	0.243 , 0.23	0.235 , 0.206
I*	0.18	0.195	0.21	0.3	0.265 , 0.29	0.25 , 0.28	0.25		
P*	0.65	0.625	0.59	0.45	0.52 , 0.499	0.55	0.58		
PCDG*	0.19	0.21 , 0.22	0.23 , 0.25	0.1	0.135 , 0.139	0.15 , 0.18	0.1	0.131 , 0.15	0.16 , 0.2
PCNDG*	0.42	0.38 , 0.36	0.35 , 0.3	0.6	0.53 , 0.502	0.5 , 0.4	0.56	0.503 , 0.47	0.45 , 0.38
PCSER*	0.39	0.41 , 0.42	0.42 , 0.45	0.3	0.335 , 0.359	0.35 , 0.42	0.34	0.366 , 0.38	0.39 , 0.42

† For Regions I, II and III, minings of coal, oil and gas is included in the energy sector and that of other materials is included under manufacturing of basic materials (see definition of sectors in Appendix III).

* The values for these variables do not directly affect the calculations of the version of the MEDEE-2 model used for the present assessment, but they are used for projecting the evolution of other variables, outside the model calculations.

(cont'd) Table 9.2: Detailed Scenario Assumptions - Macroeconomics (Group 2).

Variable	Region IV 1975	Region IV 2000 L, H	Region IV 2030 L, H	Region V 1975	Region V 2000 L, H	Region V 2030 L, H	Region VI 1975	Region VI 2000 L, H	Region VI 2030 L, H
Y	340.	918. , 1272.	2229. , 3569.	340.	924. , 1207.	1995. , 3488.	190.	643. , 900.	1310. , 2918.
PYAG	0.122	0.095 , 0.076	0.065 , 0.046	0.361	0.296 , 0.255	0.232 , 0.162	0.07	0.05 , 0.041	0.04 , 0.023
PYB	0.057	0.06	0.07	0.058	0.06	0.06	0.065	0.106	0.091 , 0.076
PYMIN †	0.025	0.02	0.02	0.015	0.018	0.022	0.51	0.155 , 0.2	0.175 , 0.09
PYMAN	0.248	0.285 , 0.304	0.291 , 0.33	0.166	0.2 , 0.223	0.228 , 0.258	0.078	0.258 , 0.242	0.25 , 0.273
PYEN	0.025	0.035 , 0.036	0.049 , 0.05	0.016	0.026 , 0.028	0.038 , 0.042	0.007	0.024 , 0.023	0.028
PYSER	0.523	0.505 , 0.504	0.505 , 0.484	0.384	0.4 , 0.417	0.42 , 0.456	0.27	0.407 , 0.388	0.416 , 0.51
PVAIG	0.308	0.344 , 0.356	0.364 , 0.352	0.264	0.297 , 0.319	0.311 , 0.367	0.2	0.35	0.4 , 0.35
PVAM	0.264	0.333 , 0.356	0.386 , 0.42	0.176	0.22 , 0.242	0.256 , 0.3	0.1	0.12 , 0.15	0.2 , 0.4
PVAC	0.429	0.322 , 0.289	0.25 , 0.227	0.56	0.484 , 0.44	0.433 , 0.333	0.7	0.53 , 0.5	0.4 , 0.25
I*	0.23			0.2	0.22	0.23	0.215	0.35	0.3 , 0.25
P*	0.7	0.65 , 0.64	0.63 , 0.61	0.71	0.67	0.65	0.325	0.445	0.47 , 0.55
PCDG*	0.1	0.11 , 0.12	0.12 , 0.14	0.07	0.08 , 0.09	0.1 , 0.13	0.1	0.12 , 0.13	0.13 , 0.15
PCNDG*	0.6	0.57 , 0.55	0.54 , 0.51	0.73	0.7 , 0.68	0.67 , 0.61	0.6	0.55 , 0.555	0.55 , 0.515
PCSER*	0.3	0.32 , 0.33	0.34 , 0.35	0.2	0.22 , 0.23	0.24 , 0.26	0.3	0.33 , 0.315	0.32 . 0.335

† For Regions I, II and III, mining of coal, oil and gas is included in the energy sector and that of other materials is included under manufacturing of basic materials (see definition of sectors in Appendix III).

* The values for these variables do not directly affect the calculations of the version of the MEDEE-2 model used for the present assessment, but they are used for projecting the evolution of other variables, outside the model calculations.

Table 9.3.1 : Detailed Scenario Assumptions - Industry
Change of Energy Intensity of Agr./Constr./Mining (Group 3.1c).

Variable	Region I 1975	Region I 2000	Region I 2030	Region II 1975	Region II 2000 L, H	Region II 2030 L, H	Region III 1975	Region III 2000	Region III 2030
CH.AGR.MF	1.	1.	1.	1.	0.92, 0.9	0.85, 0.8	1.	1.	1.
CH.AGR.EL	1.	1.	1.	1.	0.97, 0.95	0.95, 0.9	a.		
CH.AGR.TH	a.			a.			a.		
CH.CON.MF	1.	1.	1.	1.	0.92, 0.9	0.85, 0.8	1.	1.	1.
CH.CON.EL	a.			1.	0.97, 0.95	0.95, 0.9	a.		
CH.CON.TH	a.			a.			a.		
CH.MIN.MF	b.			b.			b.		
CH.MIN.EL	b.			b.			b.		
CH.MIN.TH	b.			b.			b.		

Variable	Region IV 1975	Region IV 2000	Region IV 2030	Region V 1975	Region V 2000	Region V 2030	Region VI 1975	Region VI 2000	Region VI 2030
CH.AGR.MF	1.	5.5	10.	1.	5.5	10.	1.	4.5	7.
CH.AGR.EL	1.	5.5	10.	1.	5.5	10.	1.	8.	20.
CH.AGR.TH	a.			a.			a.		
CH.CON.MF	1.	0.85	0.75	1.	5.5	10.	1.	4.5	6.
CH.CON.EL	1.	1.	1.	a.			a.		
CH.CON.TH	a.			a.			a.		
CH.MIN.MF	1.	0.85	0.75	1.	5.5	10.	a.		
CH.MIN.EL	1.	1.	1.	a.			a.		
CH.MIN.TH	a.			a.			1.	1.	1.

a) separate data were not available to us.

b) the corresponding requirements are accounted for elsewhere.

Table 9.3.1 : Detailed Scenario Assumptions - Industry (cont'd)
Change of Energy Intensity of Manufacturing Industries (Group 3.1d).

Variable	Region I			Region II			Region III		
	1975	2000 L, H	2030 L, H	1975	2000 L, H	2030 L, H	1975	2000 L, H	2030 L, H
CH.MAN.MF	1.			a.			a.		
CH.MAN.EL	1.	0.93	0.9	1.	0.94, 0.93	0.9, 0.85	1.	0.93	0.9
CH.MAN.US	1.	0.87, 0.86	0.8, 0.75	1.	0.8, 0.75	0.6, 0.5	1.	0.87, 0.85	0.8, 0.75

Variable	Region IV			Region V			Region VI		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
CH.MAN.MF	a.			a.			a.		
CH.MAN.EL	1.	1.	1.	1.	1.	1.	1.	0.81	0.75
CH.MAN.US	1.	0.85	0.75	1.	0.85	0.75	1.	0.6	0.5

a) separate data were not available to us.

Table 9.3.1 : Detailed Scenario Assumptions - Industry (cont'd)
Penetration of Alternative Energy Sources and Efficiencies (Group 3.1f).

Variable	Region I 1975	Region I 2000 L, H	Region I 2030 L, H	Region II 1975	Region II 2000 L, H	Region II 2030 L, H	Region III 1975	Region III 2000 L, H	Region III 2030 L, H
ELPIND*	0.	0.07	0.1	0.	0.03, 0.05	0.05, 0.1	0.	0.03	0.05
(HPI)	(0.)	(0.33)	(0.5)	(0)	(0.)	(0.)	(0.)	(0.33)	(0.5)
EFFHPI	2.	2.	2.	2.	2.	2.	2.	2.	2.
IDH	0.	0.	0.	0.69	0.8	0.85	0.	0.07	0.15
SPLT	0.	0.07	0.15	0.	0.04	0.1	0.	0.07	0.15
SPHT	0.	0.02	0.05	0.	0.01	0.03	0.	0.02	0.05
FIDS	0.7	0.7	0.7	0.3	0.3	0.3	0.7	0.7	0.7
ICOGEN	0.	0.33	0.5	0.	0.	0.	0.3	0.45	0.6
EFFCOG	a.	0.72	0.75	a.			0.65	0.72	0.75
HELRAT	a.	5.	5.	a.			5.	5.	5.
EFFIND**	0.65	0.72, 0.74	0.75, 0.8	0.605	0.7	0.8	0.65	0.72	0.75, 0.8

Variable	Region IV 1975	Region IV 2000	Region IV 2030	Region V 1975	Region V 2000	Region V 2030	Region VI 1975	Region VI 2000	Region VI 2030
ELPIND*	0.	0.03	0.1	0.	0.01	0.04	0.	0.03	0.1
(HPI)	(0.)	(0.04)	(0.2)	(0.)	(0.01)	(0.1)	(0.)	(0.04)	(0.2)
EFFHPI	2.	2.	2.	2.	2.	2.	2.	2.	2.
IDH	0.	0.03	0.12	0.	0.	0.	0.	0.03	0.12
SPLT	0.	0.05	0.3	0.	0.05	0.3	0.	0.05	0.3
SPHT	0.	0.01	0.1	0.	0.01	0.1	0.	0.01	0.1
FIDS	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
ICOGEN	0.	0.05	0.2	0.	0.04	0.15	0.	0.15	0.25
EFFCOG	a.	0.68	0.75	a.	0.68	0.75	a.	0.68	0.75
HELRAT	a.	5.	5.	a.	5.	5.	a.	5.	5.
EFFIND**	0.6	0.63	0.7	0.5	0.54	0.63	0.55	0.66	0.7

* electricity penetration into the thermal energy market above levels reached today

** efficiency of fossil fuel use relative to electricity

a. not applicable if ICOGEN is zero

Note: Values in parenthesis are to be interpreted as fractions of the preceding category.

Table 9.3.1 : Detailed Scenario Assumptions - Industry (cont'd)
Coke Use in Iron&Steel Industry (Group 3.1h).

Variable	Region I			Region II			Region III		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
BOF	0.8	0.8	0.8	0.8	0.7	0.5	0.8	0.8	0.8
IRONST	0.97	0.97	0.97	0.9	0.9	0.9	0.97	0.97	0.97
EICOK	600.	440.	350.	700.	590.	400.	500.	450.	400.

Variable	Region IV			Region V			Region VI		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
BOF	1.	1.	1.	1.	1.	1.	1.	1.	1.
IRONST	0.6	0.7	0.8	0.95	0.85	0.8	1.2	0.9	0.8
EICOK	600.	500.	400.	900.	750.	550.	1000.	500.	400.

Table 9.3.2 : Detailed Scenario Assumptions - Transportation Distribution of Freight Transportation by Mode (Group 3.2b).

Variable	Region I			Region II			Region III		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
TRU	0.234	0.239	0.242	0.025	0.043	0.05	0.55	0.55	0.55
(TRUL)	(0.15)	(0.12)	(0.1)	(0.)	(0.)	(0.)	(0.)	(0.)	(0.)
FTRA	0.39	0.379	0.373	0.775	0.757	0.75	0.3	0.3	0.3
(TRAEF)	(0.)	(0.)	(0.)	(0.35)	(0.55)	(0.8)	(0.3)	(0.4)	(0.5)
(TRASTF)	(0.)	(0.)	(0.)	(0.055)	(0.02)	(0.)	(0.)	(0.)	(0.)
BA	0.164	0.165	0.165	0.05	0.05	0.05	0.1	0.1	0.1
PIP	0.212	0.217	0.22	0.15	0.15	0.15	0.05	0.05	0.05

Variable	Region IV			Region V			Region VI		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
TRU	0.615	0.6	0.56	0.45	0.56	0.6	0.426	0.56	0.51
(TRUL)	(0.)	(0.)	(0.)	(0.)	(0.)	(0.)	(0.)	(0.)	(0.)
FTRA	0.175	0.21	0.28	0.35	0.28	0.27	0.024	0.07	0.18
(TRAEF)	(0.01)	(0.05)	(0.2)	(0.15)	(0.3)	(0.5)	(0.05)	(0.12)	(0.3)
(TRASTF)	(0.)	(0.)	(0.)	(0.55)	(0.15)	(0.)	(0.)	(0.)	(0.)
BA	0.15	0.13	0.1	0.08	0.08	0.08	0.03	0.04	0.06
PIP	0.06	0.06	0.06	0.12	0.08	0.06	0.52	0.33	0.25

Note: Values in parenthesis are to be interpreted as fractions of the preceding category.

Table 9.3.2 : Detailed Scenario Assumptions - Transportation (cont'd)
Energy Intensity of Freight Transportation Modes (Group 3.2c).

Variable	Region I			Region II			Region III		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
DTRU	400.			800.	750.	700.	800.		
DTRUL	1100.			a			a	no	
DTRAF	110.	no		100.	90.	80.	200.		
DBA	80.	change		100.	90.	80.	200.	change	
DPIP	b			b			b		

Variable	Region IV			Region V			Region VI		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
DTRU	800.	no		800.	no		800.	no	
DTRUL	a			a			a		
DTRAF	200.	change		200.	change		200.	change	
DBA	200.			200.			200.		
DPIP	b			b			70.		

a separate data were not available to us

b corresponding energy consumption accounted for elsewhere

Table 9.3.2 : Detailed Scenario Assumptions - Transportation (cont'd)
Distance Travelled per Person (Group 3.2d).

Variable	Region I			Region II			Region III		
	1975	2000 L , H	2030 L , H	1975	2000 L , H	2030 L , H	1975	2000 L , H	2030 L , H
DI[a]	10000.	13340. , 13600.	15000. , 17000.	2650.	4350. , 5000.	5600. , 7500.	7500.	8800. , 10000.	10000. , 12000.
DU[b]	56.	60. , 61.	62. , 65.	10.	13. , 16.	15. , 20.	9.7	15. , 18.5	20. , 30.

Variable	Region IV			Region V			Region VI		
	1975	2000 L , H	2030 L , H	1975	2000 L , H	2030 L , H	1975	2000 L , H	2030 L , H
DI[a]	1850.	2600. , 3500.	4400. , 6800.	500.	750. , 950.	1100. , 1900.	1050.	2600. , 3650.	4000. , 10000.
DU[b]	16.5	19.5 , 20.5	24. , 26.5	11.	12.5 , 13.	16. , 17.	11.	15. , 16.	22. , 25.

a distance travelled per person per year, intercity (applies to the total population)

b distance travelled per person per day, intracity (applies only to the population of large cities)

Table 9.3.2 : Detailed Scenario Assumptions - Transportation (cont'd)
Car Travel (Group 3.2e).

Variable	Region I 1975	Region I 2000 L, H	Region I 2030 L, H	Region II 1975	Region II 2000 L, H	Region II 2030 L, H	Region III 1975	Region III 2000 L, H	Region III 2030 L, H
CO	2.	1.9	1.9	40.	20. , 16.	15. , 10.	5.21	4.17 , 3.28	3.2 , 2.22
DIC	7000.	7530. , 7570.	7800. , 8000.	5000.	5580. , 5750.	6000. , 6500.	5000.	5310. , 5500.	5600. , 5800.
LFIC	2.6	2.6	2.6	3.	3. , 2.8	3. , 2.6	2.3	2.3	2.3
UC	0.966	0.926	0.9	0.4	0.4	0.4	0.7	0.61	0.5
(UCE)	(0.)	(0.06)	(0.2)	(0.)	(0.05)	(0.2)	(0.)	(0.06)	(0.2)
LFUC	1.6	1.68	1.8	2.5	2.5 , 2.3	2.5 , 2.1	1.5	1.5	1.5

Variable	Region IV 1975	Region IV 2000 L, H	Region IV 2030 L, H	Region V 1975	Region V 2000 L, H	Region V 2030 L, H	Region VI 1975	Region VI 2000 L, H	Region VI 2030 L, H
CO	25.64	13.83 , 9.98	6.94 , 4.34	268.	113. , 87.	46. , 26.	59.5	23.7 , 16.9	12.6 , 5.64
DIC	6300.	7500.	8000.	6700.	7500.	8000.	6000.	7000.	8000.
LFIC	3.5	2.8 , 2.6	2.4 , 2.3	3.5	3.3 , 3.2	3. , 2.8	3.	2.8 , 2.6	2.4 , 2.2
UC	0.3	0.35	0.35	0.33	0.35	0.35	0.3	0.4	0.45 , 0.5
(UCE)	(0.)	(0.01)	(0.05)	(0.)	(0.)	(0.)	(0.)	(0.01)	(0.05)
LFUC	2.5	2.3 , 2.2	2.	2.5	2.45 , 2.4	2.3 , 2.2	2.	1.9 , 1.85	1.8 , 1.65

Note: Values in parenthesis are to be interpreted as fractions of the preceding category.

Table 9.3.2 : Detailed Scenario Assumptions - Transportation (cont'd)
Public Transportation (Group 3.2f).

Variable	Region I 1975	Region I 2000 L, H	Region I 2030 L, H	Region II 1975	Region II 2000 L, H	Region II 2030 L, H	Region III 1975	Region III 2000 L, H	Region III 2030 L, H
PBU	0.153	0.135, 0.123	0.123, 0.075	0.15	0.18	0.2	0.35	0.319, 0.3	0.29, 0.25
PTRA	0.051	0.051	0.051, 0.05	0.62	0.56, 0.52	0.5, 0.45	0.6	0.58, 0.51	0.56, 0.4
(TRAEP)	(0.01)	(0.14)	(0.2)	(0.5)	(0.65)	(0.8)	(0.3)	(0.4)	(0.5)
(TRASTP)	(0.)	(0.)	(0.)	(0.02)	(0.)	(0.)	(0.)	(0.)	(0.)
PLA	0.796	0.814, 0.826	0.826, 0.875	0.23	0.26, 0.3	0.3, 0.35	0.05	0.101, 0.19	0.15, 0.35
LFBU	22.	22.	22.	45.	35.	25.	25.	25.	25.
LFTRA	140.	140.	140.	400.	300.	200.	140.	140.	140.
LFP	0.5	0.57	0.6	0.9	0.8	0.7	0.6	0.6	0.6
UMT	0.034	0.074	0.1	0.6	0.6	0.6	0.3	0.39	0.5
(UMTE)	(0.4)	(0.47)	(0.5)	(0.8)	(0.8)	(0.8)	(0.4)	(0.4)	(0.4)
LFMTB	17.6	17.6	17.6	40.	30.	20.	20.	20.	20.
LFMTE	20.5	20.5	20.5	50.	40.	30.	30.	30.	30.

Variable	Region IV 1975	Region IV 2000 L, H	Region IV 2030 L, H	Region V 1975	Region V 2000 L, H	Region V 2030 L, H	Region VI 1975	Region VI 2000 L, H	Region VI 2030 L, H
PBU	0.845	0.81, 0.79	0.77, 0.73	0.67	0.66, 0.65	0.64, 0.6	0.844	0.755, 0.745	0.64, 0.6
PTRA	0.107	0.085, 0.09	0.07	0.314	0.3	0.3	0.132	0.2	0.3
(TRAEP)	(0.01)	(0.05)	(0.2)	(0.15)	(0.3)	(0.5)	(0.05)	(0.12)	(0.3)
(TRASTP)	(0.)	(0.)	(0.)	(0.55)	(0.15)	(0.)	(0.)	(0.)	(0.)
PLA	0.048	0.105, 0.12	0.16, 0.2	0.016	0.04, 0.05	0.06, 0.1	0.024	0.045, 0.055	0.06, 0.1
LFBU	40.	38., 35.	30., 26.	40.	39., 38.	35., 30.	40.	35., 34.	30., 25.
LFTRA	500.	350.	250., 200.	500.	480., 450.	400., 350.	500.	375., 350.	250., 200.
LFP	0.6	0.6	0.6	0.8	0.7	0.6	0.75	0.6	0.6
UMT	0.7	0.65	0.65	0.67	0.65	0.65	0.7	0.6	0.55, 0.5
(UMTE)	(0.05)	(0.1)	(0.25)	(0.03)	(0.04)	(0.08)	(0.02)	(0.035)	(0.1)
LFMTB	50.	45., 40.	40., 30.	50.	48., 45.	40., 35.	50.	42., 38.	35., 25.
LFMTE	60.	55., 48.	45., 35.	60.	55., 52.	45., 40.	60.	52., 48.	40., 35.

Note: Values in parenthesis are to be interpreted as fractions of the preceding category.

Table 9.3.2 : Detailed Scenario Assumptions - Transportation (cont'd)
Specific Energy Consumption of Passenger Transportation Modes (Group 3.2g).

Variable	Region I 1975	Region I 2000	Region I 2030 L, H	Region II 1975	Region II 2000 L, H	Region II 2030 L, H	Region III 1975	Region III 2000	Region III 2030 L, H
GIC	14.	6.5	6.2 , 6.	12.	9.6 , 7.5	8. , 6.	9.	8.5	6.2 , 6.
GUC	19.6	8.9	8.5 , 7.6	14.	11.6 , 9.5	10. , 8.	11.	10.	8.5 , 7.5
ELUC	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DBU	39.	39.	39.	35.	33.	30.	40.	40.	40.
DTRAP	42790.	42790.	42790.	22750.	20000.	18000.	20000.	20000.	20000.
DPLA	691.	565.	500.	800.	700.	600.	700.	700	700
DMT	50.	50.	50.	40.	37.	35.	60.	60.	60.
ELMT	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4

Variable	Region IV 1975	Region IV 2000	Region IV 2030	Region V 1975	Region V 2000	Region V 2030	Region VI 1975	Region VI 2000	Region VI 2030
GIC	9.	8.	8.	9.	8.	8.	11.5	8.5	7.5
GUC	12.	10.5	10.5	12.	10.5	10.5	14.5	10.7	9.5
ELUC	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DBU	40.	40.	40.	40.	40.	40.	40.	40.	40.
DTRAP	20000.	20000.	20000.	20000.	20000.	20000.	20000.	20000.	20000.
DPLA	700.	700.	700.	700.	700.	700.	700.	700.	700.
DMT	60.	60.	60.	60.	60.	60.	60.	60.	60.
ELMT	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4

Table 9.3.3 : Detailed Scenario Assumptions - Household/Service Sector Factors Affecting Useful Energy Consumption (i) (Group 3.3b)

Variable	Region I 1975	Region I 2000 L, H	Region I 2030 L, H	Region II 1975	Region II 2000 L, H	Region II 2030 L, H	Region III 1975	Region III 2000 L, H	Region III 2030 L, H
COOKDW	1000.	1000.	1000.	1000.	1000.	1000.	1100.	1100.	1100.
DWHW	1.	1.	1.	0.6	0.75, 0.8	0.9, 1.	0.7	0.9, 1.	1.
HWCAP	1500.	1500.	1500.	700.	860.	1000.	700.	900., 1060.	1100., 1400.
DWAC	0.39	0.46, 0.51	0.5, 0.6	0.	0.05, 0.1	0.15, 0.2	0.	0.1, 0.14	0.2, 0.3
ACDW	4472.	5360.	5800.	2000.	2000.	2000.	3000.	3000.	3000.
ELAPDW	3850.	5300., 6210.	6250., 8000.	880.	2100., 2900.	3000., 5000.	1950.	3270., 3680.	4500., 6000.
PREDW(1)	0.48	0.56	0.6	0.05	0.06	0.12	0.1	0.2, 0.26	0.3, 0.4
PREDW(2)	0.32	0.37	0.4	0.35	0.42	0.8	0.2	0.36, 0.38	0.5, 0.55
PREDW(3)	0.2	0.07	0.	0.6	0.52	0.08	0.7	0.44	0.2, 0.05
AREAH	0.8	0.8	0.8	1.	1.	1.	0.7	0.7	0.7
ELARO	120.	126., 131.	130., 150.	40.	50., 60.	60., 80.	40.	50., 60.	60., 80.
AREAAC	0.55	0.65, 0.69	0.7, 0.8	0.	0.07, 0.15	0.2, 0.3	0.05	0.1, 0.15	0.15, 0.2
ACAREA	70.	70.	70.	70.	70.	70.	70.	70.	70.
EFFAC	2.	2.	2.	2.	2.	2.	2.	2.	2.

Table 9.3.3: Detailed Scenario Assumptions - Household/Service Sector

Factors Affecting Useful Energy Consumption (i) (Group 3.3b)cont'd.

Variable	Region IV 1975	Region IV 2000 L, H	Region IV 2030 L, H	Region V 1975	Region V 2000 L, H	Region V 2030 L, H	Region VI 1975	Region VI 2000 L, H	Region VI 2030 L, H
COOKDW	1600.	1700.	1800.	1000.	1050.	1200.	1600.	1700.	1800.
DWHW	0.2	0.3	0.35	0.1	0.12, 0.13	0.14, 0.16	0.6	0.9, 0.95	1.
HWCAP	400.	600., 650.	750., 1000.	40.	60., 70.	100., 140.	60.	175., 200.	300., 400.
DWAC	0.	0.04, 0.05	0.12, 0.2	0.	0.002, 0.004	0.006, 0.012	0.01	0.06, 0.1	0.2, 0.3
ACDW	1500.	2000., 2500.	2600., 3500.	1500.	2000.	2600.	2000.	2600., 3000.	3000., 4000.
ELAPDW	700.	1200., 1700.	2150., 3400.	50.	115., 150.	255., 485.	200.	705., 942.	1200., 3300.
PREDW(1)	0.08	0.08	0.08	n.a.			0.01	0.014, 0.018	0.02, 0.03
PREDW(2)	0.16	0.16	0.16	n.a.			0.05	0.09, 0.1	0.15, 0.2
PREDW(3)	0.56	0.56	0.56	0.35	0.4, 0.45	0.55, 0.65	0.4	0.6, 0.75	0.82, 0.77
AREAH	0.8	0.85, 0.87	0.95, 1.	0.35	0.45, 0.6	0.65, 0.95	0.7	0.9, 0.95	1.
ELARO	25.	35., 40.	40., 50.	15.	20., 21.	25., 30.	15.	30., 35.	40., 50.
AREAAC	0.05	0.12, 0.15	0.35, 0.4	0.	0.005, 0.01	0.02, 0.05	0.04	0.15, 0.2	0.3, 0.5
ACAREA	70.	70.	70.	70.	70.	70.	70.	70.	70.
EFFAC	2.	2.	2.	2.	2.	2.	2.	2.	2.

n.a.=not applicable.

Table 9.3.3 : Detailed Scenario Assumptions - Household/Service Sector (cont'd)
Factors Affecting Useful Energy Consumption (ii) (Group 3.3c)

Variable	Region I			Region II			Region III		
	1975	2000 L, H	2030 L, H	1975	2000 L, H	2030 L, H	1975	2000 L, H	2030 L, H
DEMDW	↑	0.02	0.02	↑	0.045	0.045	↑	0.03	0.03
NEWDW(1)		0.6	0.6		0.2, 0.25	0.2, 0.3		0.35	0.35
NEWDW(2)		0.4	0.4		0.6, 0.63	0.6, 0.65		0.5	0.5
NEWDW(3)		a	a		0.2, 0.12	0.2, 0.05		0.15	0.15
DWS(1)		148.	150.		80.	100.		98.	110.
DWS(2)	n.a.	88.	90.	n.a.	62.	80.	n.a	74.	80.
DWS(3)		a	a		67.	85.		85.	95.
K(1)		1.9	1.5		1.8	1.3		1.9	1.5
K(2)		1.7	1.2		1.7	1.2		1.7	1.2
K(3)	↓	a	a	↓	0.8	0.7	↓	0.7	0.6
ISO(1)	0.	0.22	0.3	0.	0.12	0.2	0.	0.22	0.3
ISO(2)	0.	0.15	0.2	0.	0.12	0.2	0.	0.15	0.2
ISO(3)	0.	0.	0.	0.	0.05	0.1	0.	0.15	0.2
AREAL	↑	44., 46.1	45., 48.	↑	37., 38.	45., 50.	↑	30., 31.	32., 35.
DEMAR	n.a.	0.03	0.03		0.05	0.05		0.03	0.03
HAREAN		250.	250.	n.a.	176.	160.	n.a.	120.	120.
ELARN	↓	140., 150.	140., 150.	↓	70., 80.	80., 100.	↓	90., 94.	100., 110.
ISOSV	0.	0.15	0.2	0.	0.12	0.2	0.	0.15	0.2

n.a.=not applicable.

a=category not considered for this region.

Table 9.3.3: Detailed Scenario Assumptions - Household/Service Sector (cont'd)

Factors Affecting Useful Energy Consumption (ii) (Group 3.3c)

Variable	Region IV			Region V			Region VI		
	1975	2000 L, H	2030 L, H	1975	2000 L, H	2030 L, H	1975	2000 L, H	2030 L, H
DEMDW	↑	0.01, 0.015	0.015, 0.025	↑	0.007, 0.01	0.012, 0.02	↑	0.015, 0.02	0.025, 0.03
NEWDW(1)		0.16	0.2		a	a		0.025, 0.03	0.035, 0.05
NEWDW(2)		0.28, 0.36	0.4, 0.52		a	a		0.15, 0.2	0.25, 0.4
NEWDW(3)		0.36, 0.32	0.28		0.5, 0.6	0.8, 1.		0.65, 0.75	0.715, 0.55
DWS(1)		120.	150.		a	a		100.	120.
DWS(2)	n.a.	80.	90.	n.a.	a	a	n.a.	70.	90.
DWS(3)		40.	40.		26.	35.		35.	40.
K(1)		2.5	2.5		a	a		2.75	2.5
K(2)		2.	2.		a	a		2.25	2.
K(3)	↓	2.	2.	↓	3.	3.	↓	3.	3.
ISO(1)	0.	0.1	0.15	a			0.	0.	0.
ISO(2)	0.	0.1	0.15	a			0.	0.	0.
ISO(3)	0.	0.1	0.15	0.	0.	0.	0.	0.	0.
AREAL	↑	20.	30.	↑	12., 13.	15., 18.	↑	20., 22.	30., 35.
DEMAR		0.015, 0.02	0.02, 0.03		0.007, 0.01	0.012, 0.02		0.02, 0.025	0.025, 0.03
HAREAN	n.a.	75.	100.	n.a.	16.	20.	n.a.	35.	45.
ELARN	↓	60., 70.	85., 100.	↓	35., 40.	45., 60.	↓	60., 70.	85., 100.
ISOSV	0.	0.02	0.02	0.	0.	0.	0.	0.	0.

n.a.=not applicable.

a=category not considered for this region.

Table 9.3.3 : Detailed Scenario Assumptions - Household/Service (cont'd)
Penetration of Alternative Energy Sources (Group 3.3d).

Variable	Region I 1975	Region I 2000	Region I 2030	Region II 1975	Region II 2000 L, H	Region II 2030 L, H	Region III 1975	Region III 2000	Region III 2030
ELP.H.SH	0.12	0.21	0.25	0.	0.03	0.05	0.04	0.08	0.1
ELP.H.HW	0.3	0.42	0.5	0.07	0.12	0.15	0.24	0.32	0.4
ELP.H.CK	0.47	0.6	0.7	0.15	0.22, 0.27	0.3, 0.4	0.36	0.43	0.5
ELP.S.TH	0.05	0.17	0.25	0.	0.05	0.1	0.04	0.08	0.1
(HPHS)	(0.)	(0.33)	(0.5)	(0.)	(0.1)	(0.4)	(0.)	(0.33)	(0.5)
EFFHPR	2.	2.	2.	2.	2.	2.	2.	2.	2.
DHPH	0.	0.	0.	0.467	0.65	0.8	0.	0.12	0.25
SPSH	0.	0.5	0.5	0.	0.3	0.3	0.	0.5	0.5
FDSHS	0.7	0.7	0.7	0.4	0.4	0.4	0.5	0.5	0.5
SPHW	0.	0.18	0.4	0.	0.08	0.2	0.	0.18	0.4
FDHWS	0.7	0.7	0.7	0.6	0.6	0.6	0.7	0.7	0.7
PLB	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
SPSV	0.	0.5	0.5	0.	0.3	0.3	0.	0.5	0.5
FDHS	0.7	0.7	0.7	0.4	0.4	0.4	0.55	0.55	0.55
CHGNCF	a			1.	1.	1.	a		

a=noncommercial fuels not considered in Regions I and III.

Note: Values in parentheses are to be interpreted as fractions of the preceding category.

Table 9.3.3 : Detailed Scenario Assumptions - Household/Service (cont'd)
Penetration of Alternative Energy Sources (Group 3.3d).

Variable	Region IV			Region V			Region VI		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
ELP.H.SH	0.01	0.04	0.08	0.01	0.03	0.08	0.01	0.03	0.05
ELP.H.HW	0.01	0.04	0.08	0.01	0.015	0.03	0.01	0.03	0.05
ELP.H.CK	0.005	0.03	0.1	0.			0.	0.01	0.05
ELP.S.TH	0.01	0.025	0.06	0.3	0.25	0.15	0.01	0.03	0.05
(HPHS)	(0.)	(0.03)	(0.12)	(0.)	(0.)	(0.)	(0.)	(0.02)	(0.12)
EFFHPR	2.	2.	2.	2.	2.	2.	2.	2.	2.
DHPH	0.	0.03	0.2	0.	0.	0.	0.	0.	0.
SPSH	0.	0.3	0.5				0.	0.03	0.2
FDSHS	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
SPHW	0.	0.2	0.3	0.	0.1	0.3	0.	0.02	0.15
FDHWS	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
PLB	0.3	0.3	0.3	0.7	0.6	0.5	0.7	0.6	0.5
SPSV	0.	0.3	0.5	0.	0.2	0.5	0.	0.03	0.2
FDHS	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
CHGNCF	1.	1.	1.	1.	1.	1.	1.	1.	1.

a=noncommercial fuels not considered in Regions I and III.

Note: Values in parentheses are to be interpreted as fractions of the preceding category.

Table 9.3.3 : Detailed Scenario Assumptions - Household/Service (cont'd)
Fossil Fuel Efficiencies (relative to electricity) (Group 3.3e).

Variable	Region I			Region II			Region III		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
EFF.H.SH	0.63	0.73	0.8	0.59	0.63	0.65	0.63	0.665	0.7
EFF.H.HW	0.57	0.65	0.7	0.49	0.53	0.55	0.57	0.585	0.6
EFF.H.CK	0.41	0.46	0.5	0.4	0.45	0.5	0.51	0.529	0.55
EFF.S.TH	0.7	0.76	0.8	0.59	0.63	0.65	0.7	0.725	0.75
EFFNCF	a			0.3			a		

Variable	Region IV			Region V			Region VI		
	1975	2000	2030	1975	2000	2030	1975	2000	2030
EFF.H.SH	0.6	0.63	0.7	0.5	0.53	0.6	0.6	0.63	0.7
EFF.H.HW	0.55	0.58	0.65	0.5	0.53	0.6	0.55	0.58	0.65
EFF.H.CK	0.5	0.51	0.55	0.5	0.51	0.55	0.5	0.51	0.55
EFF.S.TH	0.65	0.68	0.75	0.55	0.58	0.65	0.6	0.63	0.7
EFFNCF	0.075	0.09	0.15	0.075	0.085	0.12	0.075	0.085	0.12

a=noncommercial fuels not considered in Regions I and III.

Table 10: Final Energy in the Two Scenarios (TWyr/yr)

Region	1975	High 2000	High 2030	Low 2000	Low 2030
I (NA)	1.87	2.63	3.67	2.26	2.64
(% elec.)	(12)	(18)	(20)	(18)	(21)
II (SU/EE)	1.28	2.39	4.11	2.17	2.95
(% elec.)	(10)	(17)	(23)	(16)	(20)
III (WE/JANZ)	1.59	3.04	4.38	2.39	2.99
(% elec.)	(13)	(17)	(21)	(17)	(21)
IV (LA)	0.25	1.00	2.64	0.73	1.66
(% elec.)	(10)	(12)	(15)	(12)	(16)
V (Af/SEA)	0.25	1.06	3.17	0.80	1.88
(% elec.)	(9)	(13)	(16)	(12)	(15)
VI (ME/NAf)	0.11	0.58	1.64	0.43	0.87
(% elec.)	(4)	(12)	(17)	(12)	(15)
I + III	3.46	5.66	8.04	4.65	5.62
(% elec.)	(12)	(17)	(21)	(17)	(21)
IV+V+VI	0.61	2.65	7.45	1.97	4.40
(% elec.)	(8)	(12)	(16)	(12)	(15)
Total	5.35	10.69	19.61	8.79	12.98
(% elec.)	(11)	(16)	(19)	(16)	(19)

Table 11: Per Capita Final (Commercial) Energy Consumption,

Two Scenarios 1975 to 2030 (kW/cap)

Region	Base Year 1975	High Scenario 2000	High Scenario 2030	Low Scenario 2000	Low Scenario 2030
I (NA)	7.89	9.25	11.63	7.95	8.37
II (SU/EE)	3.52	5.47	8.57	4.98	6.15
III (WE/JANZ)	2.84	4.46	5.70	3.52	3.90
IV (LA)	0.80	1.75	3.31	1.28	2.08
V (Af/SEA)	0.18	0.42	0.89	0.32	0.53
VI (ME/NAf)	0.80	2.34	4.64	1.76	2.46
I + III	4.34	5.87	7.43	4.82	5.20
IV+V+VI	0.33	0.79	1.59	0.59	0.94
I through VI	1.76	2.25	3.13	1.85	2.07

NOTE: The figures are average rates of final energy use, averaged over the population and the year.

TABLE 12 Shares of Sectors in Final Energy Demand (% of final energy)

Region	1975			High Scenario 2030			Low Scenario 2030		
	Transport.	Industry[a]	Buildings[b]	Transport.	Industry[a]	Buildings[b]	Transport.	Industry[a]	Buildings[b]
I (NA)	29	40	31	28	52	20	26	50	24
II (SU/EE)	18	59	23	19	64	17	19	63	18
III (WE/JANZ)	20	51	29	25	52	23	23	49	28
IV (LA)	41	47	12	44	46	10	44	43	13
V (Af/SEA)	30	59	11	29	62	9	32	55	13
VI (ME/NAf)	39	47	14	37	52	11	36	50	14

[a] Industry includes agriculture, manufacturing, mining, and construction.

[b] Buildings in the household and service sectors.

NOTE: The boxed figures highlight the most visible of regional differences.

Table 13: Final Energy Projections for Industry (including coke and feedstocks, TWyr/yr)

(TWyr/yr)

Region	1975	High 2000	High 2030	Low 2000	Low 2030
I (NA)	0.76	1.31	1.91	1.08	1.31
(% manuf.)	(92)	(91)	(89)	(91)	(90)
II (SU/EE)	0.76	1.49	2.64	1.35	1.85
(% manuf.)	(92)	(91)	(90)	(90)	(88)
III (WE/JANZ)	0.81	1.55	2.27	1.18	1.46
(% manuf.)	(91)	(89)	(89)	(90)	(89)
IV (LA)	0.12	0.48	1.23	0.33	0.72
(% manuf.)	(90)	(91)	(90)	(89)	(87)
V (Af/SEA)	0.15	0.67	1.97	0.47	1.02
(% manuf.)	(97)	(88)	(82)	(85)	(76)
VI (ME/NAf)	0.05	0.32	0.85	0.24	0.43
(% manuf.)	(62)	(83)	(86)	(85)	(80)

Table 14: Final Energy Projections for Manufacturing (including coke and feedstocks, TWyr/yr)

		High		Low	
Region	1975	2000	2030	2000	2030
I (NA)	0.70	1.19	1.70	0.98	1.19
(% elec.)	(13)	(18)	(21)	(18)	(20)
(% coke+feedst.)	(18)	(21)	(23)	(21)	(22)
II (SU/EE)	0.70	1.35	2.37	1.22	1.62
(% elec.)	(12)	(18)	(24)	(16)	(21)
(% coke+feedst.)	(20)	(26)	(31)	(24)	(26)
III (WE/JANZ)	0.73	1.39	2.01	1.05	1.30
(% elec.)	(15)	(19)	(24)	(19)	(21)
(% coke+feedst.)	(28)	(32)	(33)	(31)	(32)
IV (LA)	0.11	0.44	1.10	0.29	0.63
(% elec.)	(14)	(16)	(21)	(17)	(21)
(% coke+feedst.)	(22)	(28)	(33)	(27)	(33)
V (Af/SEA)	0.14	0.59	1.62	0.40	0.77
(% elec.)	(11)	(15)	(21)	(15)	(20)
(% coke+feedst.)	(13)	(16)	(20)	(15)	(18)
VI (ME/NAf)	0.03	0.26	0.73	0.20	0.35
(% elec.)	(12)	(20)	(25)	(20)	(25)
(% coke+feedst.)	(33)	(22)	(25)	(23)	(26)

TABLE 15 Projected Reduction in Average Useful Energy Intensity of Manufacturing Industries, High Scenario

Region	Useful Energy Intensity (kWh/$VA) 1975	2030	% Reduction In 2030 Relative To 1975	Of Which (%) Due To Structural Change[a]
I (NA)	8.66	6.06	30	8
II (SU/EE)	10.86	6.12	44	1
III (WE/JANZ)	4.20	3.21	24	4
IV (LA)	5.81	4.51	22	4
V (Af/SEA)	11.06	9.29	16	-3
VI (ME/NAf)	7.68	4.96	35	-8

[a] Structural changes are the result of modernization in the manufacturing activities.

NOTES: Useful energy is expressed as equivalent electricity requirement. Data are for manufacturing industries, excluding coke and petrochemical feedstock use.

TABLE 16 Assumed Penetration of Electricity, District Heat, Cogeneration, Heat Pump and Soft Solar in Their Potential Industrial Heat Markets in 2030, High Scenario (% of potential industrial heat markets)[a]

Region	Elec-tricity	District Heat	Cogen-eration	Heat Pump	Soft Solar Low Temp.	Soft Solar High Temp.
I (NA)	0.10	0	0.50	0.50	0.15	0.05
II (SU/EE)	0.10	0.85[b]	0	0	0.10	0.03
III (WE/JANZ)	0.05	0.15	0.60[b]	0.50	0.15	0.05
IV (LA)	0.10	0.12	0.20	0.20	0.30	0.10
V (Af/SEA)	0.04	0.05	0.15	0.10	0.30	0.10
VI (ME/NAf)	0.10	0.12	0.25	0.20	0.30	0.10

[a] Potential industrial heat markets: electricity, all process heat; district heat, steam and hot water; cogeneration, low temperature steam and hot water; heat pump, steam and hot water demand met by electricity; and soft solar, steam and hot water.

[b] In Region II district heat and in Region III on-site cogeneration were already supplying 69% and 30% of their respective potential markets in 1975.

Table 17: Shares of Energy Sources in the Heat Market of the Manufacturing Sector, High Scenario (% of total useful thermal energy)

	2000						2030					
Region	FF	(COG)	EL	(HP)	DH	SS	FF	(COG)	EL	(HP)	DH	SS
I (NA)	92	(5.9)	7	(1.2)	0	1	87	(9.0)	10	(2.5)	0	3
II (SU/EE)	39	(0.0)	5	(0.0)	55	1	30	(0.0)	10	(0.0)	59	1
III (WE/JANZ)	92	(8.1)	3	(0.5)	4	1	85	(10.8)	5	(1.3)	8	2
IV (LA)	95	(0.4)	3	(0.1)	1	1	80	(1.6)	10	(0.8)	5	5
V (Af/SEA)	99	(0.2)	1	(0.0)	0	0	90	(0.9)	4	(0.2)	2	4
VI (ME/NAf)	95	(0.9)	3	(0.0)	1	1	81	(1.5)	10	(0.8)	5	4

Notes: FF = fossil fuels; COG = with cogeneration of electricity (included in FF);
EL = electricity; HP = (electric) heat pumps (included in EL);
DH = district heat; SS = soft solar.

In 1975, the fossil fuel share is 100% in all regions except Regions II (48% district heat); in Region III, cogeneration was estimated to be 5%.

TABLE 18 Average Final Energy Intensity of Manufacturing Activities (excluding feedstocks and coke)

Region	Energy Intensity High Scenario (kWh/$VA) 1975	2030	Relative Decrease (%)	Reduction Due To Structural Change (%)
I (NA)	12.3	7.0	43	6
II (SU/EE)	13.9	6.4	54	1
III (WE/JANZ)	5.7	3.6	37	4
IV (LA)	8.6	5.5	36	3
V (Af/SEA)	19.6	12.6	36	-2
VI (ME/NAf)	12.2	6.1	50	-7

Table 19 . Agricultural Patterns in Different World Regions in 1975

Region	Arable land per capita (ha/cap)	Irrigation (% of arable land)	Mechanical appliances (per 1000 ha)	Fertilizer use (kg/ha)
I (NA)	1.07	7	22	80
II (SU/EE)	0.77	7	15	96
III (WE/JANZ)	0.34	9	45	117
IV (LA)	0.45	9	7	32
V (Af/SEA)	0.32	14	1	14
VI (ME/NAf)	0.33	25	4	27
VII (C/CPA)	0.15	61	2	50

All data refer to arable land including land under permanent crops.

Mechanical appliances included here are tractors and harvester--threshers.

Fertilizer use refers to consumption in terms of N_2, P_2O_5 and K_2O.

Sources of data: FAO Production Yearbook, Vol. 30, 1976 (FAO 1977).
U.N. Statistical Yearbook 1976 (U.N. 1977b).

Table 20: Projections of Transportation Final Energy Demand (TWyr/yr)

		High		Low	
Regions	1975	2000	2030	2000	2030
I (NA)	0.54	0.65	1.01	0.56	0.68
(% elec.)	(0.1)	(0.6)	(1.1)	(0.7)	(1.5)
(% passenger)	(74)	(48)	(39)	(54)	(49)
II (SU/EE)	0.22	0.42	0.79	0.38	0.55
(% elec.)	(4.0)	(6.4)	(8.9)	(6.3)	(9.2)
(% pas.)	(25)	(30)	(27)	(28)	(28)
III (WE JANZ)	0.31	0.71	1.11	0.53	0.69
(% elec.)	(1.9)	(2.2)	(3.1)	(2.6)	(3.9)
(% pas.)	(60)	(59)	(54)	(58)	(56)
IV (LA)	0.11	0.41	1.15	0.30	0.73
(% elec.)	(0.2)	(0.4)	(1.4)	(0.4)	(1.5)
(% pas.)	(31)	(33)	(35)	(35)	(38)
V (Af/SEA)	0.08	0.27	0.91	0.22	0.61
(% elec.)	(0.5)	(0.8)	(1.5)	(0.8)	(1.6)
(% pas.)	(40)	(45)	(55)	(47)	(59)
VI (ME/NAf)	0.04	0.20	0.61	0.14	0.31
(% elec.)	(0.1)	(0.2)	(0.9)	(0.2)	(1.0)
(% pas.)	(20)	(23)	(34)	(26)	(34)

TABLE 21 Assumptions on Passenger Travel (Intercity and Urban) and its Distribution by Mode of Transportation, High Scenario

Region	1975 Activity Level (10^3km/person/yr)	1975 Modal Split (%) Plane	Car	Train[a]	Bus	2000 Activity Level (10^3km/per/yr)	2000 Modal Split (%) Plane	Car	Train[a]	Bus	2030 Activity Level (10^3km/per/yr)	2030 Modal Split (%) Plane	Car	Train[a]	Bus
I (NA)	17.4	4	93	1	2	21.7	12	83	2	3	25.9	20	73	3	4
II (SU/EE)	4.8	11	26	51	12	9.1	13	29	45	13	13.3	15	30	41	14
III (WE/JANZ)	9.2	3	37	37	23	13.5	9	44	27	20	18.0	12	50	20	18
IV (LA)	4.1	1	37	5	57	7.5	3	45	5	47	13.5	4	49	9	38
V (Af/SEA)	1.0	1	25	14	60	2.0	2	32	11	55	4.6	2	39	10	49
VI (ME/NAf)	2.2	1	29	5	65	6.3	2	34	9	55	15.9	4	38	15	43

[a] Train includes urban electric mass transit.

SOURCES of data for 1975: United Nations (1977c); International Road Federation (1976); Europa (1976); CMEA (1976).

TABLE 22: Energy Use by Automobiles in Six World Regions

Region	Base Year 1975	High Scenario 2000	High Scenario 2030	Low Scenario 2000	Low Scenario 2030
I (NA)					
Energy used by cars (GWyr/yr)	364	205	194	203	201
As share of total transportation energy (%)	*(67)*	*(32)*	*(19)*	*(36)*	*(29)*
II (SU/EE)					
Energy used by cars (GWyr/yr)	26	45	63	42	50
As share of total transportation energy (%)	*(11)*	*(11)*	*(8)*	*(11)*	*(9)*
III (WE/JANZ)					
Energy used by cars (GWyr/yr)	111	214	249	168	179
As share of total transportation energy (%)	*(35)*	*(30)*	*(22)*	*(32)*	*(26)*
IV (LA)					
Energy used by cars (GWyr/yr)	20	82	238	67	179
As share of total transportation energy (%)	*(19)*	*(20)*	*(21)*	*(22)*	*(25)*
V (Af/SEA)					
Energy used by cars (GWyr/yr)	17	67	277	60	216
As share of total transportation energy (%)	*(22)*	*(25)*	*(30)*	*(27)*	*(36)*
VI (ME/NAf)					
Energy used by cars (GWyr/yr)	6	27	108	22	67
As share of total transportation energy (%)	*(13)*	*(13)*	*(18)*	*(16)*	*(21)*

Table 23: Projections of Freight Transportation Activity
(10^{12} ton-km)

		High		Low	
Region	1975	2000	2030	2000	2030
I (NA)	3.1	7.0	12.5	5.5	7.4
II (SU/EE)	4.6	10.0	21.8	9.2	15.2
III (WE/JANZ)	1.5	3.5	6.0	2.7	3.7
IV (LA)	0.9	3.4	9.9	2.5	5.9
V (Af/SEA)	0.5	1.8	4.8	1.4	2.9
VI (ME/NAf)	0.6	2.0	5.3	1.4	2.8

Table 24: Projections of Final Energy Demand* in the Household/ Service Sector

(TWyr/yr)

Region	1975	High 2000	High 2030	Low 2000	Low 2030
I (NA)	0.57	0.66	0.74	0.62	0.64
(% elec.)	(23)	(39)	(50)	(37)	(46)
(% serv.)	(28)	(30)	(33)	(27)	(28)
II (SU/EE)	0.29	0.48	0.69	0.44	0.55
(% elec.)	(7)	(21)	(33)	(17)	(26)
(% serv.)	(25)	(28)	(35)	(26)	(29)
III (WE/JANZ)	0.47	0.78	1.00	0.69	0.84
(% elec.)	(18)	(28)	(41)	(28)	(37)
(% serv.)	(14)	(15)	(19)	(15)	(17)
IV (LA)	0.031	0.11	0.26	0.10	0.21
(% elec.)	(23)	(33)	(48)	(28)	(43)
(% serv.)	(10)	(12)	(15)	(12)	(20)
V (Af/SEA)	0.028	0.12	0.30	0.11	0.25
(% elec.)	(14)	(19)	(32)	(16)	(22)
(% serv.)	(9)	(12)	(16)	(10)	(12)
VI (ME/NAf)	0.015	0.06	0.18	0.05	0.12
(% elec.)	(7)	(22)	(43)	(19)	(31)
(% serv.)	(7)	(19)	(32)	(18)	(29)

* The figures in this table refer only to the demand of commercial energy. These figures have been arrived at after taking into account the requirements of households that are/would be met by noncommercial fuels.

TABLE 25: Projected Useful Energy Requirements in Households (10^3 kWh per dwelling per year)

Region	1975				High Scenario 2030				Low Scenario 2030			
	Cooking	Space & Water Heating	Air Condi-tioning	Misc. Elec. Appl.	Cooking	Space & Water Heating	Air Condi-tioning	Misc. Elec. Appl.	Cooking	Space & Water Heating	Air Condi. tioning	Misc. Elec. Appl.
I (NA)	1.2	25.3	1.0	3.9	1.2	18.2	2.0	8.0	1.2	18.2	1.7	6.3
II (SU/EE)	1.2	11.9	0	0.9	1.2	14.4	0.2	5.0	1.2	13.6	0.2	3.0
III (WE/JANZ)	1.3	9.5	0	2.0	1.3	12.8	0.5	6.0	1.3	11.4	0.4	4.5
IV (LA)	1.9	1.0	0	0.7	2.1	2.9	0.4	3.4	2.1	2.3	0.2	2.2
V (Af/SEA)	1.2	0.05	0	0.05	1.4	0.2	0.02	0.5	1.4	0.1	0.01	0.3
VI (ME/NAf)	1.9	0.8	0.01	0.2	2.1	3.8	0.7	3.3	2.1	3.1	0.4	1.2

NOTES: *Useful energy* is expressed as electricity equivalent.
Figures here are averages for all dwellings within a region.

TABLE 26: Household Use of Electricity, 1975 and Scenario Assumptions (10^3 kW/household)

Region	Base Year 1975	High Scenario 2000	High Scenario 2030	Low Scenario 2000	Low Scenario 2030
I (NA) total electricity	9.4	13.0	15.0	11.9	12.9
(% thermal uses)[a]	*(59)*	*(52)*	*(47)*	*(56)*	*(52)*
II (SU/EE) total electricity	1.2	3.9	6.5	3.0	4.3
(% thermal uses)	*(25)*	*(26)*	*(23)*	*(29)*	*(30)*
III (WE/JANZ) total elec.	3.1	6.0	9.1	5.3	7.1
(% thermal uses)	*(38)*	*(39)*	*(34)*	*(38)*	*(36)*
IV (LA) total electricity	0.7	1.9	4.2	1.4	2.7
(% thermal uses)	*(3)*	*(11)*	*(20)*	*(13)*	*(21)*
V (Af/SEA) total electricity	0.05	0.2	0.5	0.1	0.3
(% thermal uses)	*(1)*	*(4)*	*(8)*	*(3)*	*(11)*
VI (ME/NAf) total electricity	0.2	1.2	4.3	0.9	1.8
(% thermal uses)	*(9)*	*(22)*	*(23)*	*(19)*	*(33)*

[a] Thermal uses include air-conditioning.

NOTES: Only for Region I (NA) were sufficient statistics available; for other regions estimates come from partial data and/or data for selected countries.

Consumption of electricity per household for specific uses (lighting, electrical appliances) is a direct assumption; consumption for thermal uses results from separate assumptions on useful energy consumption for space heating, water heating, cooking, and air conditioning and from assumed penetration of electricity into these markets.

Table 27: Useful Energy[1] Projections for Service Sector

Region	1975				2030 High				2030 Low			
	service sector working area $10^9 m^2$	kWh/m^2			service sector working area $10^9 m^2$	kWh/m^2			service sector working area $10^9 m^2$	kWh/m^2		
		space and water heating	Air condi- tioning	Misc. electrical appliances		space and water heating	Air condi- tioning	Misc. electrical appliances		space and water heating	Air condi- tioning	Misc. electrical appliances
I (NA)	2.72	270	22	120	5.00	227	33	150	3.79	225	28	136
II (SU/EE)	1.50	256	0	40	6.65	186	12	100	4.75	186	8	80
III (WE/JANZ)	3.00	110	2	40	7.26	96	8	104	5.99	95	6	89
IV (LA)	0.60	12	2	25	3.20	19	16	65	3.41	22	14	66
V (Af/SEA)	1.25	1	0	15	9.40	2	2	38	6.90	2	1	33
VI (ME/NAf)	0.18	20	2	15	2.54	52	20	100	1.84	52	12	85

[1] Useful energy is expressed as electricity equivalent.

Table 28: Shares of Energy Sources in the Household/Service Sector Heat Market

(% of total useful thermal energy)

Region	High Scenario 2000 NCE[1]	FF	EL	DH[2]	SS	2030 NCE	FF	EL	DH	SS
I (NA)	0	68	24	0	8	0	56	31	0	13
II (SU/EE)	4	44	6	43	3	3	22	10	60	5
III (WE/JANZ)	0	73	15	6	6	0	55	21	13	11
IV (LA)	18	72	3	1	6	14	57	9	8	12
V (Af/SEA)	37	63	0	0	0	26	70	2	0	2
VI (ME/NAf)	3	94	2	0	1	2	86	5	2	5

1 In 1975, noncommercial energy share is estimated to be 7, 39, 68 and 9% in Regions II, IV, V and VI, respectively. The Low scenario shares are quite similar to those in the High scenario.

2 The share of district heat in Region II was already 25% in 1975.

NCE = noncommercial energy sources

FF = fossil fuels (for Regions IV, V and VI, this column includes the fossil fuel equivalent of charcoal/wood and biogas to be supplied as commercial fuel)

EL = electricity

DH = district heat

SS = soft solar

TABLE 29: Final Energy in the Two Scenarios Compared to Final Energy Calculated with Historical Elasticities (2030)

Region	High Scenario (GWyr/yr)	With Historical ε_f[a] (GWyr/yr)	Difference[b] (%)	Low Scenario (GWyr/yr)	With Historical ε_f[a] (GWyr/yr)	Difference[b] (%)
I (NA)	3,665	6,921	47	2,636	4,036	35
II (SU/EE)	4,114	5,355	23	2,952	3,850	23
III (WE/JANZ)	4,375	6,037	28	2,987	3,761	21
IV (LA)	2,641	4,385	40	1,656	2,481	33
V (Af/SEA)	3,175	6,900	54	1,876	3,121	40
VI (ME/NAf)	1,620	2,590	37	850	1,015	16
Total of I to VI	19,590	32,188	39	12,957	18,264	29

[a] Calculated using historical (1950-1975) final energy-to-GDP elasticity (ε_f) for each region.

[b] Calculated as final energy using historical ε_f minus IIASA scenario projection divided by final energy using historical ε_f.

APPENDICES

Appendix I

The Seven World Regions of the IIASA Energy Systems Program

REGION I: NORTH AMERICA (NA)

Highly developed market economies with energy resources.

Canada
United States of America

REGION II: THE SOVIET UNION AND EASTERN EUROPE (SU/EE)

Highly developed centrally-planned economies with energy resources.

Albania
Bulgaria
Czechoslovakia
German Democratic Republic
Hungary
Poland
Romania
Union of Soviet Socialist Republics

REGION III: W. EUROPE, JAPAN, AUSTRALIA, NEW ZEALAND, S. AFRICA, AND ISRAEL (WE/JANZ)

Highly developed market economies with relatively low energy resources.

Member Countries of the European Community

Belgium
Denmark
France
Germany, Federal Republic of
Ireland
Italy
Luxemburg
Netherlands
United Kingdom

Other Western European Countries

Austria
Cyprus
Finland
Greece
Iceland
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
Yugoslavia

Others

Australia
Israel
Japan
New Zealand
South Africa

REGION IV: LATIN AMERICA (LA)

Developing economies with some energy resources and significant population growth.

Argentina	Honduras
Bahamas	Jamaica
Belize	Martinique
Bolivia	Mexico
Brazil	Netherlands Antilles
Chile	Nicaragua
Colombia	Panama
Costa Rica	Paraguay
Cuba	Peru
Dominican Republic	Puerto Rico
Ecuador	Surinam
El Salvador	Trinidad and Tobago
Guadeloupe	Uruguay
Guatemala	Venezuela
Guyana	Other Caribbean
Haiti	

REGION V: AFRICA (EXCEPT NORTHERN AFRICA AND SOUTH AFRICA), SOUTH AND SOUTHEAST ASIA (Af/SEA)

Slowly developing economies with some energy resources and significant population growth.

Africa

Angola	Mauritania
Benin	Mauritius
Botswana	Morocco
Burundi	Mozambique
Cameroon	Namibia
Cape Verde	Niger
Central African Republic	Nigeria
Chad	Reunion
Congo	Rhodesia
Ethiopia	Rwanda
Gabon	Senegal
Gambia	Sierra Leone
Ghana	Somalia
Guinea	Sudan
Guinea Bissau	Swaziland
Ivory Coast	Tanzania, United Republic of
Kenya	Togo
Lesotho	Tunisia
Liberia	Uganda
Madagascar	Upper Volta
Malawi	Western Sahara
Mali	Zaire
Malta	Zambia

Asia

Afghanistan
Bangladesh
Brunei
Burma
Comoros
Hong Kong
India
Indonesia
Korea, Republic of (South)
Macau
Malaysia
Nepal
Pakistan
Papua New Guinea
Philippines
Singapore
Sri Lanka
Taiwan
Thailand
East Timor
West South Asia n.e.s.

REGION VI: MIDDLE EAST AND NORTHERN AFRICA (ME/NAf)

Developing economies with large energy resources.

Member Countries of the Organization of Arab Petroleum Exporting Countries (OAPEC)

Algeria
Bahrain
Egypt
Iraq
Kuwait
Libyan Arab Republic
Qatar
Saudi Arabia
Syrian Arab Republic
United Arab Emirates

Others

Iran
Jordan
Lebanon
Oman
Yemen
Yemen, People's Democratic Republic of

REGION VII: CHINA AND CENTRALLY-PLANNED ASIAN ECONOMIES (C/CPA)

Developing centrally-planned economies with energy resources.

China, People's Republic of
Kampuchea, Democratic (formerly Cambodia)
Korea, Democratic Republic of
Laos, People's Democratic Republic of
Mongolia
Viet-Nam, Socialist Republic of

APPENDIX II

Definition of Parameter Variables*

Variable	Unit	Explanation
PO	10^6	Total population
PLF	fraction	Share of population of age 15-64 in the total population (potential labor force)
PARTLF	fraction	Share of potential labor force actually working
POLC	fraction	Share of population living outside large cities (the definition in terms of city size varies from region to region; the variable is used to determine the approximate potential market for district heating and mass transportation systems)
PRUR	fraction	Share of rural population (according to UN definition; the variable was not used in the present version of MEDEE-2, but was considered outside the model for estimating some other parameters.
CAPH	persons per household	Average household size (the number of dwellings is calculated as PO/CAPH, i.e. the term household is used in the sense "persons living together in one dwelling").

*Constants and initial values are marked by ^{c} and ^{i}, respectively; the values of all other variables have to be specified for each point in time considered. The names correspond in general to those used in the MEDEE-2 code; if not, the name used in the program is shown in parentheses.

Variable	Unit	Explanation
Y	10^9 \$75	Total GDP
Group (a):		
PYAG(YREL(1)) PYB(YREL(2)) PYMIN(YREL(3)) PYMAN(YREL(4)) PYEN(YREL(5)) PYSER(YREL(6))		Distribution of GDP formation by kind of economic acticity; sectors considered: agriculture, construction, mining, manufacturing, energy, services
PVAIG(VAREL(1)) PVAM(VAREL(2)) PVAC(VAREL(3)) PVAMIS(VAREL(4))		Distribution of manufacturing value added; sectors considered: basic materials, machinery and equipment, nondurables and miscellaneous industries
Group (b):		
I (IB) (IM)		Share of GDP spent on investments (I), and distribution of investments among construction (IB) and machinery and equipment ((IM)
P (PCDG) (PCNDG) (PCSER)		Share of private consumption expenditures in total GDP (P), and distribution of private consumption among durable goods (PCDG), nondurable goods (PCNDG), and services (PCSER)
Group (c):		
$CYAG^c$(1 to 2) CYB^c(1 to 2) $CYMIN^c$(1 to 2) $CYMAN^c$(1 to 3) $CYEN^c$(1 to 2) $CYSER^c$(1 to 2) $CVAMAN^c$(1 to 2) $CVAIG^c$(1 to 4) $CVAM^c$(1 to 3) $CVAC^c$(1 to 2) $CVAMIS^c$(1 to 2)		Coefficients of linear equations to determine the GDP formation of 6 major economic sectors and the value added contributions of 4 aggregated manufacturing sectors as a function of total GDP and the structure of GDP expenditure; the parameters in group (b) and (c) need only be specified if the parameters in group (a) are not specified.

Variable	Unit	Explanation
$EI.AGR.MF^{i}$ (EIBYR(1,1)) $EI.AGR.EL^{i}$ (EIBYR(1,2)) $EI.AGR.TH^{i}$ (EIBYR(1,3)) $EI.CON.MF^{i}$ (EIBYR(2,1)) $EI.CON.EL^{i}$ (EIBYR(2,2)) $EI.CON.TH^{i}$ (EIBYR(2,3)) $EI.MIN.MF^{i}$ (EIBYR(3,1)) $EI.MIN.EL^{i}$ (EIBYR(3,2)) $EI.MIN.TH^{i}$ (EIBYR(3,3))	10^3kcal/$VA (for MF, TH); kWh/$VA (for EL)	Specific energy consumption per dollar value added by sector and energy form in the base year. <u>Sectors</u>: AGR = agriculture, CON = construction, MIN = mining. <u>Energy forms</u>: MF = motor fuel, EL = electricity, TH = thermal uses (final energy).
$EI.BM.MF^{i}$ (EIBYR(4,1)) $EI.BM.EL.^{i}$ (EIBYR(4,2)) $EI.BM.US^{i}$ (EIBYR(4,3)) $EI.ME.MF^{i}$ (EIBYR(5,1)) $EI.ME.EL.^{i}$ (EIBYR(5,2)) $EI.ME.US^{i}$ (EIBYR(5,3)) $EI.ND.MF^{i}$ (EIBYR(6,1)) $EI.ND.EL^{i}$ (EIBYR(6,2)) $EI.ND.US^{i}$ (EIBYR(6,3))	10^3kcal/$VA (for MF, US); kWh/$VA (for EL)	Specific energy consumption per dollar value added by manufacturing subsector and energy form in the base year. <u>Sectors</u>: BM = basic materials, ME = machinery and equipment, ND = nondurables. <u>Energy forms</u>: MF = motor fuel, EL = electricity, US = thermal uses (useful energy).
CH.AGR.MF(EICHG(1,1)) CH.AGR.EL(EICHG(1,2)) CH.AGR.TH(EICHG(1,3)) CH.CON.MF(EICHG(2,1)) CH.CON.EL(EICHG(2,2)) CH.CON.TH(EICHG(2,3)) CH.MIN.MF(EICHG(3,1)) CH.MIN.EL(EICHG(3,2)) CH.MIN.TH(EICHG(3,3))		Ratio of energy intensity in the current year relative to the base year by sector and by energy form (same sectors and energy forms as above)
CH.MAN.MF(EICHG(4,1)) CH.MAN.EL(EICHG(4,2)) CH.MAN.US(EICHG(4,3))		Ratio of energy intensity in the current year relative to the base year in the manufacturing sector, by energy form (same energy forms as above; the same factor is applied to all manufacturing subsectors).

Variable	Unit	Explanation
$PUSIND^c(I,J)$	fractions	Share of useful thermal energy demand of manufacturing sector I for process category J
Sectors:		
I = 1		Basic materials
I = 2		Machinery and equipment
I = 3		Non-durables
I = 4		Miscellaneous manufacturing industries
Process Categories:		
J = 1		Steam generation
J = 2		Furnace/direct heat
J = 3		Space/water heating
STSHI, STI	fractions	Share of useful thermal energy demand in manufacturing for steam generation and space/water heating together (STSHI) and for steam generation only (STI). (Note: 1-STSHI represent the share of useful energy demand for furnace/direct heat, but excluding the use of coke for iron ore reduction and electrolysis). These two variables must be specified only if the array PUSIND is zero.
LTH	fraction (relative to STI)	Share of low-temperature steam in the total steam demand of the manufacturing sector.
ELPIND(J), J=1,2,3	fraction	Share of useful thermal energy demand in manufacturing for process category J that is supplied by electricity (must be specified if PUSIND $\neq$ 0)
ELPIND(4)	fraction	Average electricity penetration into thermal uses in manufacturing (must be specified only if PUSIND = 0)
(HPI)	fraction	Contribution of heat pumps to low-temperature use of electricity

Variable	Unit	Explanation
EFFHPI	$\left[\frac{\text{thermal energy extracted}}{\text{electric energy input}}\right]$	Coefficient of performance of (electric) heat pumps in industry
IDH	fraction	Share of the manufacturing demand for steam and hot water that is supplied by district heat
SPLT	fraction	Share of the manufacturing demand for low-temperature steam and for hot water which is supplied by solar systems
SPHT	fraction	Share of the manufacturing demand for high-temperature steam that is supplied by solar systems
FIDS	fraction	Approximate share of useful thermal energy demand that can be met by a solar installation (i.e., 1-FIDS determines the backup requirements)
ICOGEN	fraction	Share of the manufacturing demand for low-temperature steam and hot water which is supplied by fossil fuels, but with cogeneration of electricity
EFFCOG	fraction	System efficiency of cogeneration, i.e., (heat+electricity output)/(heat content of fuels used)

Variable	Unit	Explanation
HELRAT	$\left[\frac{\text{kWh steam}}{\text{kWh electricity}}\right]$	Ratio of heat to electricity in the output of cogeneration systems
EFFIND(J), J=1,2,3	fraction	Average efficiency of fossil fuel use for thermal process J in manufacturing relative to the efficiency of electricity (must be specified if PUSIND $\neq$ 0)
EFFIND(4)	fraction	Average efficiency of fossil fuel use in thermal processes relative to the efficiency of electricity (must be specified only if PUSIND = 0)
CFEED(1)[c] CFEED(2)[c]	10^6 tons tons/10^3\$VA	Constants used to project the feedstock requirements of the petrochemical industry
CPST(1)[c] CPST(2)[c]	10^6 tons tons/10^3\$VA	Constants used to project the amount of steel produced
BOF	fraction	Share of steel produced in non-electric furnaces (the electricity requirements for electric steelmaking must be reflected in EI.BM.EL for the base year, and in CH.MAN.EL for the projections).

Variable	Unit	Explanation
IRONST	[tons of pig iron / ton of steel]	Tons of pig iron input per ton of steel produced (the residual is assumed to be scrap)
EICOK	[kg coke / ton of pig iron]	Coke input in blast furnaces per unit output of pig iron
CTKFRT(1)	10^9 ton-km	Constants used to project the total demand for freight transportation
CTKFRT(2)	ton-km/$	
CMISMF(1)	10^{12} kcal	Constants used to project the total motor fuel demand for international, military and misc. transportation
CMISMF(2)	10^3 kcal/$	
TRU	fraction	Share of trucks in the total demand for freight transportation
(TRUL)	fraction (rel. to TRU)	Share of local truck transportation in the total freight transportation performed by trucks (the residual is assumed to be long-distance hauls)
FTRA	fraction	Share of rail in the total demand for freight transportation
(TRAEF)	fraction (rel. to FTRA)	Share of electric freight trains in the total freight transportation by rail
(TRASTF)	fraction (rel. to FRTRA)	Share of steam freight trains in the total freight transportation by rail
BA	fraction	Share of inland waterways or coastal shipping in the total demand for freight transportation
PIP	fraction	Share of pipelines in the total demand for freight transportation

Variable	Unit	Explanation
DTRU	kcal/ton-km	Energy intensity of trucks (average or, if TRUL $\neq$ 0, long-distance)
DTRUL	kcal/ton-km	Energy intensity of trucks for short hauls (only relevant if TRUL $\neq$ 0)
DTRAF	kcal/ton-km	Energy intensity of diesel freight trains (the energy intensity of electric and steam trains is assumed to be lower and higher, respectively, by a factor of 3)
DBA	kcal/ton-km	Energy intensity of inland waterways and coastal shipping (only motor fuel considered)
DPIP	kcal/ton-km	Energy intensity of pipelines (only motor fuel considered)
DI	km/yr/person	Average intercity distance travelled per year per person (applies to the total population)
DU	km/day/person	Average intracity distance travelled per day per person (applies only to the population living in large cities)
CO	$\left[\frac{\text{population}}{\text{number of cars}}\right]$	Inverse of car ownership
DIC	km/yr/car	Average intercity distance driven per year per car (one must be careful that the average distance driven in intracity travel as implied by the assumptions on PO, POLC, DU, UC, LFUC together with the assumption on DIC, matches the total average distance driven per year per car)

Variable	Unit	Explanation
LFIC	persons per car	Average load factor of cars in intercity travel
UC	fraction	Share of cars in the total demand for intracity passenger transportation
(UCE)	fraction (rel. to UC)	Share of electric cars in the total intracity car travel
LFUC	persons per car	Average load factor of cars in intracity travel
PBU	fraction	Share of buses in intercity passenger travel excluding travel by car
PTRA	fraction	Share of trains in intercity passenger travel excluding travel by car
(TRAEP)	fraction (rel. to PTRA)	Share of electric trains in the total intercity travel by train
(TRASTP)	fraction (rel. to PTRA)	Share of steam trains in the total intercity travel by train
PLA	fraction	Share of air planes in intercity passenger travel excluding travel by car
LFBU	persons per bus	Average load factor of buses (intercity)
LFTRA	persons per train	Average load factor of trains (intercity)
LFP	fraction	Average capacity utilization factor of air planes
UMT	fraction	Share of mass transportation systems in the total demand for intracity passenger transportation
(UMTE)	fraction (rel. to UMT)	Share of electric mass transit in the total intracity mass transportation (1-UMTE is the share of buses)

Variable	Unit	Explanation
LFMTB	persons per bus	Average load factor of nonelectric mass transit systems (intracity)
LFMTE	persons per vehicle	Average load factor of electric mass transit systems (intracity)
GIC	liter/100 veh-km	Specific gasoline consumption of cars in intercity travel
GUC	liter/100 veh-km	Specific gasoline consumption of cars in intracity travel
ELUC	kWh/veh-km	Specific electricity consumption of electric cars (intracity travel)
DBU	liter/100 veh-km	Specific diesel consumption of buses (intercity)
DTRAP	kcal/train-km	Specific fuel consumption of diesel passenger trains (intercity)
DPLA	kcal/seat-km	Specific energy consumption of air planes
DMT	liter/100 veh-km	Specific diesel consumption of buses (intracity)
ELMT	kWh/veh-km	Specific electricity consumption of intracity mass transportation systems

Variable	Unit	Explanation
DD^c	degree-day	The definition in the U.S. Statistical Abstract (see U.S. (1976a), p. 178) is as follows: "A unit, based upon temperature difference and time, used in estimating fuel consumption and specifying nominal heating load in winter. For any one day, when the mean temperature is less than 65°F there exist as many degree days as there are Fahrenheit degrees difference in the temperature between the average temperature for the day and 65°F." The definition used here differs in that it is (i) based on Celsius degrees, with the threshold being 18°C; (ii) based on monthly average temperature; (iii) averaged over a region (weighted by population) by selection of a few representative cities. Our values are therefore rough approximations.
$DWSH^c$, $ARSH^c$	fractions	Share of dwellings (service sector floor area) which is in climatic conditions where heating is required
$DW\text{-}75^i$ (DW)	10^6 dwellings	Total stock of dwellings in the base year (1975)
$SHDWO(1)^i$, $SHDWO(2)^i$, $SHDWO(3)^i$	10^3kcal/yr/dwelling	Specific space heat requirements of pre-75 dwellings (useful energy); 1 = single family house with central heating; 2 = apartment with central heating; 3 = dwelling with room heating only

Variable	Unit	Explanation
TAREA-75[i] (TAREA)	$10^6 m^2$	Total floor area of service sector buildings in the base year 1975
CPLSER[c]		Constant used to project the service sector share in the total labor force
HAREAO[i]	10^3kcal/ yr/m^2	Specific heat requirements of pre-75 service sector buildings (useful energy)
BYRNCF[i]	10^6tce	Amount of noncommercial fuels used in the base year (1975); noncommercial fuel use is considered only in the household sector in the model
COOKDW	10^3kcal/ yr/dw	Specific energy consumption for cooking in dwellings (useful energy)
DWHW	fraction	Share of dwellings with hot water facilities
HWCAP	10^3kcal/ yr/person	Specific energy consumption for water heating per person (useful energy)
DWAC	fraction	Share of dwellings with air-conditioning
ACDW	10^3kcal/ yr/dw	Specific cooling requirements per dwelling
ELAPDW	kWh/yr/dw	Specific electricity consumption per dwelling (for uses other than space heating, water heating, cooking and air-conditioning)

Variable	Unit	Explanation
PREDW(1) PREDW(2) PREDW(3)	fractions	Distribution of pre-75 dwellings per type (definition of dwelling types as for SHDWO above)
AREAH	fraction	Share of service sector floor area (in cold climates) actually heated
ELARO	$kWh/yr/m^2$	Specific electricity consumption in pre-75 service sector buildings
AREAAC	fraction	Share of air-conditioned service sector floor area
ACAREA	$10^3 kcal/yr/m^2$	Specific cooling requirements in the service sector
EFFAC	$\left[\frac{\text{thermal energy extracted}}{\text{electric energy input}}\right]$	Coefficient of performance of (electric) air-conditioners
DEMDW	fraction	Average demolition rate of dwellings over a 5-year period between the previous and the current model years
NEWDW(1) NEWDW(2) NEWDW(3)	fractions	Distribution of dwellings, constructed between the previous and the current model years by type (definition of dwelling types as for SHDWO above)

Variable	Unit	Explanation
DWS(1) DWS(2) DWS(3)	m^2/dw	Average floor area heated in post-75 dwellings (definition of dwelling types as for SHDWO above)
K(1) K(2) K(3)	kcal/h/ $m^2/^oC$	Specific heat loss rate in dwellings built after 1975 (definition of dwelling types as for SHDWO above)
ISO(1) ISO(2) ISO(3)	fractions	Reduction of the average space heat demand of pre-75 dwellings in the current year relative to that in the base year due to better insulation (definition of dwelling types as for SHDWO above)
AREAL	m^2/worker	Average floor area per worker in the service sector
DEMAR	fraction	Average demolition rate of the floor area of service sector buildings over a 5-year period between the previous and the current model year
HAREAN	10^3kcal/ yr/m^2	Specific heat requirements of post-75 service sector buildings
ELARN	kWh/yr/m^2	Specific electricity consumption in post-75 service sector buildings
ISOSV	fraction	Reduction of the average heat demand in pre-75 service sector buildings in the current year relative to that in the base year due to better insulation

Variable	Unit	Explanation
ELP.H.SH(ELPHS(1)) ELP.H.HW(ELPHS(2)) ELP.H.CK(ELPHS(3)) ELP.S.TH(ELPHS(4))	fractions	Electricity penetration into thermal uses in the household/ service sector. The categories are: H.SH = space heating (households); H.HW = water heating (households); H.CK = cooking (households); S.TH = thermal uses (service sector)
(HPHS)	fraction	Contribution of heat pump to electric space and water heating in the household/service sector
EFFHPR	[thermal energy extracted / electric energy input]	Coefficient of performance of (electric) heat pumps in the household/service sector
DHPH	fraction	District heat penetration into space and water heating of dwellings and thermal uses in the service sector (large cities only)

Variable	Unit	Explanation
SPSH	fraction	Solar penetration into space heating in post-75 single family houses with central heating
FDSHS	fraction	Approximate share of space heat demand in households that can be met by a solar installation (the residual must be covered by a backup system)
SPHW	fraction	Solar penetration into water heating in dwellings (total demand)
FDHWS	fraction	Approximate share of the hot water demand that can be met by a solar installation (the residual must be covered by a backup system)
PLB	fraction	Share of low-rise buildings (e.g., up to 3 floors) in the total service sector floor area
SPSV	fraction	Solar penetration into thermal uses in post-75 low-rise buildings of the service sector
FDHS	fraction	Approximate share of thermal energy demand in the service sector that can be met by a solar installation (the residual must be covered by a back-up system)
CHGNCF		Ratio of the amount of noncommercial fuels used in the current year relative to that in the base year

Variable	Unit	Explanation
EFF.H.SH(EFFHS(1)) EFF.H.HW(EFFHS(2)) EFF.H.CK(EFFHS(3)) EFF.S.TH(EFFHS(4))	fractions	Efficiency of fossil fuel use relative to that of electricity use for thermal uses in the household/service sector (definition of categories as for ELP.X.YY above)
EFFNCF	fraction	Efficiency of noncommercial fuel use relative to that of thermal electricity uses

Appendix III: Definitions of Macro-Economic Sectors in Terms of ISIC* Categories

	Regions I, II, III	Regions IV, V, VI
Agriculture	ISIC 1	ISIC 1
Construction	ISIC 5	ISIC 5
Mining	---	ISIC 2
Manufacturing	ISIC 3	ISIC 3
	-ISIC 353,354	
	+ISIC 2	
	-ISIC 21,22	
Energy	ISIC 4	ISIC 4
	+ISIC 21,22	
	+ISIC 353,354	
Services**	ISIC 6,7,8,9,	ISIC 6,7,8,9

Manufacturing subsectors:

Basic materials	ISIC 341,351,352,36,37	ISIC 341,351,352,
	+ISIC 2	+ISIC 353,354
	-ISIC 21,22	+ISIC 36, 37
Machinery & equip.	ISIC 38	ISIC 38
Nondurables	ISIC 31,32,33,342,355,356,39	ISIC 31,32,33
		+ISIC 342,355,356
		+ISIC 39

* International Standard Industrial Classification of all Economic Activities, Statistical Paper Series No. 4 Rev. 2, UN New York (1968)

** For Region II, a rough estimate of services belonging to the nonmaterial sphere has been included.