RM-77-60

ASSESSMENT OF ALTERNATIVE ENERGY/ENVIRONMENT FUTURES FOR AUSTRIA 1977-2015

AN EXECUTIVE SUMMARY

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December 1977

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PREFACE

This report is one of a series describing a multi-disciplinary, multinational IIASA research study on Management of Energy/Environment Systems. The primary objective of the research is the development of quantitative tools for energy and environment policy design and analysis--or in a broader sense, the development of a coherent, realistic approach to energy/environment management. Particular attention is being devoted to the design and use of these tools at the regional level. The outputs of this research program include concepts, applied methodologies, and case studies. During 1975 and 1976, the case studies focused on three greatly differing regions, namely the German Democratic Republic, the Rhone-Alpes region in southern France, and the state of Wisconsin in the U.S.A. In 1977, a case study of Austria was carried out.

This memorandum consists of the Executive Summary for the Austrian Case Study, a preliminary document summarizing the main findings of the study. A more detailed final Research Report describing the Austrian study will be published in 1978.

Other publications on the management of energy/environment systems are listed in Appendix C at the end of this report.

ABSTRACT

This report was prepared to complement a presentation made Oct. 25, 1977 at IIASA. The presentation, titled "An Executive Briefing Session", was designed to present the final results of a thirteen-month study of the Austrian Energy/Environment System to leaders in Austrian government, industry, and science. This written documentation of the results (of which a German translation is also available) presents in a brief form the final conclusions of this study. The study results provide a comprehensive spatial and sectoral description of Austrian energy consumption, and examine alternative energy and environmental policy strategies. This report, however, is only a summary and a more complete description will appear in research report form in 1978.

ACKNOWLEDGMENTS

The work summarized here was made possible through a generous grant from the Austrian National Bank. Equally important, it has benefited from the cooperation of a large number of individuals and institutions. Individuals who made substantial research contributions include W.A. Buehring (of the University of Wisconsin), A. Kydes (of Brookhaven National Laboratory), J.L. Pappas (of the University of Wisconsin), J.R. Peerenboom (of the University of Wisconsin), J. Richter (of the Bundeskammer der gewerblichen Wirtschaft), and A. Toifelhardt (of IIASA). A complete list of individuals and institutes and their specific contributions are too numerous to describe in this summary; a few of the institutions should, however, be recognized here, namely:

Bundeskammer der gewerblichen Wirtschaft
Bundesministerium für Gesundheit und Umweltschutz
Bundesministerium für Handel, Gewerbe und Industrie, Energiesektion
Brookhaven National Laboratories, U.S.A.
Energy Research Center (University of Wisconsin)
Institute for Environmental Studies (University of Wisconsin)
Kernkraftwerk Planungsgesellschaft
Magistrat Linz, Hygieneinstitut
Österreichische Elektrizitätswirtschafts AG (Verbundgesellschaft)
Österreichisches Institut für Bauforschung
Österreichisches Institut für Raumplanung (ÖIR)
Österreichische Mineralölverwaltung (ÖMV)
Österreichisches Statistisches Zentralamt (ÖStZ)
Österreichisches Wirtschaftsforschungsinstitut (WIFO)
Wiener Stadtwerke, Energiereferat.

The 28 members of the Austrian energy and environmental communities who participated in the first two workshops at IIASA played a crucial role in structuring the research program.

A special note of thanks is given to Elizabeth Ampt, Helen Maidment, Judy Ray and Nora Steidl for their competent, dedicated and cheerful assistance throughout the research.

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I. INTRODUCTION

This study has two primary objectives:

(1) To examine alternative energy futures and strategies for Austria and to consider some of their environmental implications.

(2) To investigate and implement appropriate concepts and methodologies for energy/environment management and policy design in Austria.

The establishment of these objectives was based upon the conviction that in Austria, as in most regions and nations of the world, there is an urgent need for the development and application of methods for studying regional energy systems and for testing the impact of alternative policies. In view of the major role which energy plays in the determination of environmental quality, this study was designed to aid in the integration of energy and environmental management from a systems perspective.

"Regional", in the context of our previous studies, is not strictly defined as subnational or as a specific class of geographic units; rather, it refers to a region, appropriately bounded so that it is possible to speak of energy and environmental systems, either from a physical, socio-economic, or administrative perspective, or from all three. At the beginning of this study, we intended to limit its scope to a selected few Austrian Länder (states); we quickly realized that Austria's size and vigorous interregional links precluded anything less than a national study.

A. INSTITUTIONAL FORMAT OF THE STUDY

The study has been conducted in an institutional format which has promoted frequent interaction with the indidivuals and institutions for whom the results are intended. After the initial organizational phase of the study within IIASA, a major three-day workshop was held in January,1977, with a broadly-based representation of energy/environment specialists and decision makers from the Austrian private and public sectors, both at the regional and national levels. This workshop played a crucial role in determining the critical issues which the study would address. It also served to establish links to various institutions through which information could flow during the remainder of the research program. Several of these institutions played important roles in the research by providing data or conducting analysis. A second workshop (July, 1977) served to evaluate the study to that point, and to establish priorities for the final phase. The Austrian participants in that workshop also suggested the format within which the conclusions and methods resulting from this study should be communicated and transferred to the energy/environment community.

B. CRITICAL ISSUES STUDIED

The issues studied were chosen through an iterative procedure, beginning with suggestions at the first workshop, followed with exploration by the IIASA team to see whether they could be analyzed within the time and resource limitations. One major decision was that this study, as with previous ones, would address broad mid- to long-term strategies and policies, rather than issues related to day-to-day operational problems. Consequently, the time horizon of the study is 2015, with, however, greater attention devoted to the earlier part of the time period. Although there was a broad spectrum of issues raised, the major issues fell into the following categories:

Energy Demand. A central issue in Austria is the probable and possible levels of future energy demand. Important aspects of the demand issue are its relationship to the rate and structure of economic growth, to demographic factors, to human settlement and land use patterns and technologies, to transportation systems design, to industrial structure and technology, and to energy-use technologies in general. As in many other countries, the relationships between energy use and social well-being are hotly debated.

Energy Conservation. The potential energy conservation measures and their impact are major issues. Although some conservation measures have already been implemented, there is extensive ongoing debate on this topic.

Energy Supply Options and Strategies. The choice of fuels and energy supply technologies is a third high priority issue, closely linked to the first two above. Decisions on the continued implementation of nuclear technology in Austria will in all likelihood be based in part on estimates of future growth of electricity demand; low growth in electricity demand, in part due to major implementation of conservation measures, could weaken some of the arguments for expanding the nuclear system. In a similar manner, the seriousness for Austria of greatly increased scarcity or even shortfalls of petroleum will in part depend on the level and the structure of petroleum demand. The feasibility of alternative fuels, e.g., coal and solar, playing a major role over the next several decades is under active discussion. Austria's reliance on other countries or specific regions of the world for fuels is an important economic and political issue.

Environment Impacts and Protection Strategies. Concern about the environment, especially public health and safety, is currently very high and is strongly linked to alternative energy supply strategies. Nuclear power is central to this concern. Air pollution is of increasing interest, as Austria is just now defining air pollution standards and examining alternative strategies and the tradeoffs associated with them.

The above four categories certainly do not subsume all of the important energy-related issues, nor can all of them be answered or even addressed in this limited study. However, we have attempted to provide a better perspective from which public discussions on these and other issues can proceed.

II. SUMMARY OF MAJOR FINDINGS

This study assesses alternative energy/environment futures for Austria through the year 2015. Four scenarios of energy demand and supply were developed (see Table 1, Section III) within a range of economic growth patterns. Energy demand implications of population and economic factors, of selected lifestyle patterns, and of some energy-use technologies are inferred from the scenarios. Associated sensitivity studies were used as a basis for complementary analysis. Implications for environmental quality and the choice of energy supply strategies are assessed. The findings are not the result of any single scenario but rather were deduced from the analysis of the entire set of scenarios and sensitivity studies. Although the findings, in general, are applicable to the long run (2015), more attention has been devoted to the initial two decades of the study.

The major findings of the study are as follows:

A. ENERGY DEMAND (Section V)

(1) Total energy demand will probably increase at a rate considerably lower than in the past two decades. If these lower demand estimates are valid, they imply major rethinking of energy supply policies that are based on higher overall projections.

(2) An overall "societal energy intensiveness," defined roughly as primary energy use per unit of GNP, will probably decrease over the coming few decades.

(3) Electricity will supply an increasing fraction of total end-use energy. Nevertheless, growth of electricity generation will be much lower than historical rates. Needs for future facilities should be examined in light of their dependence on the structure and rate of Austria's economic development.

(4) The continued dominance of the industrial sector in energy use suggests that policy measures for altering energy-use patterns must focus largely on this sector. However, energy demand growth in the next few decades appears to be greatest in the service sector of the economy, with the lowest growth likely in the transportation sector.

(5) There is considerable potential for energy conservation by means of improved insulation practices in the residential sector. Because of the institutional barriers related to initial costs,

the realization of the economic benefits of this potential may require vigorous government support of conservation measures.

(6) By the end of the time period under study, the center of gravity of energy use in Austria will have shifted westward; this shift and the associated environmental impacts should be taken into consideration in long-term regional planning.

B. ENERGY SUPPLY (Section VI)

(7) Nuclear power could play a major role in electricity generation over the next several decades. However, during the time period considered, the continued slowing of electricity demand growth, coupled with further vigorous conservation measures, could make future nuclear plants unnecessary if hydropower were exploited fully.

(8) Coal is generally considered to be an unattractive long-term supply option for Austria. However, our economic analysis of the Austrian energy supply system, based on a resource allocation model for the year 1990, indicates that a shift toward increased reliance on lignite, coupled with decreased reliance on gas and petroleum, would be cost effective.

(9) Extrapolation of most previous Austrian energy forecasts yields a continuation of the trend toward greater reliance on petroleum and natural gas. However, assessment of world petroleum resources and future demands demonstrates a serious gap between potential petroleum demand and supply in Austria in the 1990's, even under the assumption of low growth (Conservation Scenario S4).

C. ENVIRONMENT (Section VII)

(10) Potential system-wide environmental impacts due to energy use and supply in Austria are appreciable. Because of continuing energy demand growth, the system-wide impacts would not significantly decrease over the time period studied, despite introduction of improved pollution control technology.

(11) Air pollution will be the largest contributor to energy-related impacts on public health. These air pollution impacts will be concentrated in the five major urban areas of Austria, namely Vienna, Salzburg, Graz, Linz, and Innsbruck.

(12) Desulfurization of fuel oil for use in urban residential and commercial buildings would be an effective and important measure for protecting the public from health effects of sulfur emissions.

(13) Regional and local environmental effects due to Austria's energy systems are significant. However, there is also a family of effects whose significance is better assessed from a global perspective. Examples of these are long term climate modifications due to CO_2 emissions from combustion of fossil fuels, and potential dangerous flows of fissile material within the nuclear fuel cycle. Such global concerns can and must be addressed from an international perspective to avoid the "tragedy of the commons" on a global scale.

III. DESCRIPTION OF METHODOLOGY AND OVERVIEW OF ENERGY SCENARIOS

A. METHODOLOGY

Views about the future—scenarios, forecasts, predictions—constitute the language of energy policy debate, the frames of reference for decision and policy analysis, and the bases of assumptions about what is or what is not inevitable. Our study uses scenario building as a formal quantitative approach to policy analysis and the examination of energy/environment strategies.

Broadly described, scenario building is a detailed examination of the possible futures and the consequences of alternative assumptions about them. This set of futures may provide a better view of what is to be avoided or facilitated, the types of decisions that are important, and the points in time after which various decision branches will have been passed. Important policy issues and related tradeoffs can be examined by so-called "sensitivity studies" in which only one or a few parameters are varied and the resulting scenarios are compared.

In order to specify a "policy set" or framework within which a scenario was built, we developed a means for expressing a scenario in terms of a limited number of characteristics. As shown in the first column of Table 1, we relate those characteristics to four overall scenario properties, namely, Socio-Economic Structure, Lifestyle, Technology, and Environment. Within these four general categories, a larger number of assumptions about future events and/or policies and strategies are built into the scenarios.

The general framework summarized in column 1 of Table 1 is used only to provide the exogenous functions, boundary conditions and constraints for the family of models and data bases used to calculate the details of the alternative energy environment futures. Figure 1 gives a more detailed representation of the flow of information which occurs in the calculation of energy demand and pollutant emission for the residential sector of the economy.

Table 1
OVERVIEW OF SCENARIOS

SUMMARY CHARACTERISTICS		SCENARIO S1 (Base Case)	SCENARIO S2 (High Case)	SCENARIO S3 (Low Case)	SCENARIO S4 (Conservation Case)
STRUCTURE	Population	Average Austrian Growth Rate of 0.22%/yr.			
	Human Settlements	Migration Important: Rural to Urban, Vienna Declining, Western Cities Grow More Rapidly			
	Economy	Medium Growth Rate 1970-1985: 3.30%/yr 1985-2015: 1.76%/yr	High Growth Rate 1970-1985: 3.43%/yr 1985-2015: 2.73%/yr	Low Growth Rate 1970-1985: 3.23%/yr 1985-2015: 1.21%/yr	Low Growth Rate 1970-1985: 3.25%/yr 1985-2015: 1.21%/yr
LIFESTYLE	Personal Consumption	Current trends in Personal Consumption	Higher Consumption than S1	Lower Consumption than S1	Lower Consumption than S1
	Transportation	Car ownership 300 vehicles/ 1000 population	Car ownership 400 vehicles/1000 population	Car ownership 250 vehicles/1000 population	Car ownership 300 vehicles/1000 population
	Housing	Bigger new homes ($0.8\ m^2/yr$) Emphasis on electrical appliances and convenience fuels	New home size increases faster than S1 High emphasis on electrical appliances and convenient fuels	New home size increases more slowly than S1 Less emphasis on electrical appliances and convenient fuels	Bigger new homes ($0.8\ m^2/yr$) as S3 Emphasis on conservation
TECHNOLOGY	Industry	Overall decrease in energy intensiveness through significant penetration of energy conserving technology	General increase in intensiveness	Overall decrease in energy intensiveness through significant penetration of energy conserving technology	Significant decrease in energy intensiveness through vigorous development & implementation of energy conserving technology
	Transportation	Car efficiency 8.9 ℓ/100 km	Car efficiency 12.3 ℓ/100 km	Car efficiency 8.9ℓ /100 km	Car efficiency 7.0 ℓ/100 km
	Housing	1971 insulation standards	1971 insulation standards	New homes 40% better than 1971 insulation standard by 2000	New homes 55% better than than 1971 insulation standard by 2000
	Energy Supply	Decreased emphasis on coal Electricity demand grows more rapidly than total end-use energy demand			
		Medium nuclear growth Adequate oil and gas supply	High Nuclear growth Adequate oil and gas supply	Low nuclear growth Adequate oil and gas supply	No nuclear growth Constrained oil supply
ENVIRONMENT	Environmental Regulations	Proposed SO_2 oil desulfurization regulations by 1981 plus U.S. emission limits of SO_2, all sources, by 2000.			
		.50 of U.S. emission limits on SO_2, point sources, by 2015	.42 of U.S. emission limits on SO_2, point sources, by 2015	.71 of U.S. emission limits on SO_2, point sources, by 2015	Same as S3
		U.S. transportation emissions controls on automobiles			
		1.18 of U.S. emission limits on particulates, industry point sources, by 2015	1.0 of U.S. emission limits on particulates, industry point sources, by 2015	1.60 of U.S. emission limits on particulates, industry point sources, by 2015	Same as S3
		1.0 of U.S. emission limits of particulates, electric power plant, by 2015			

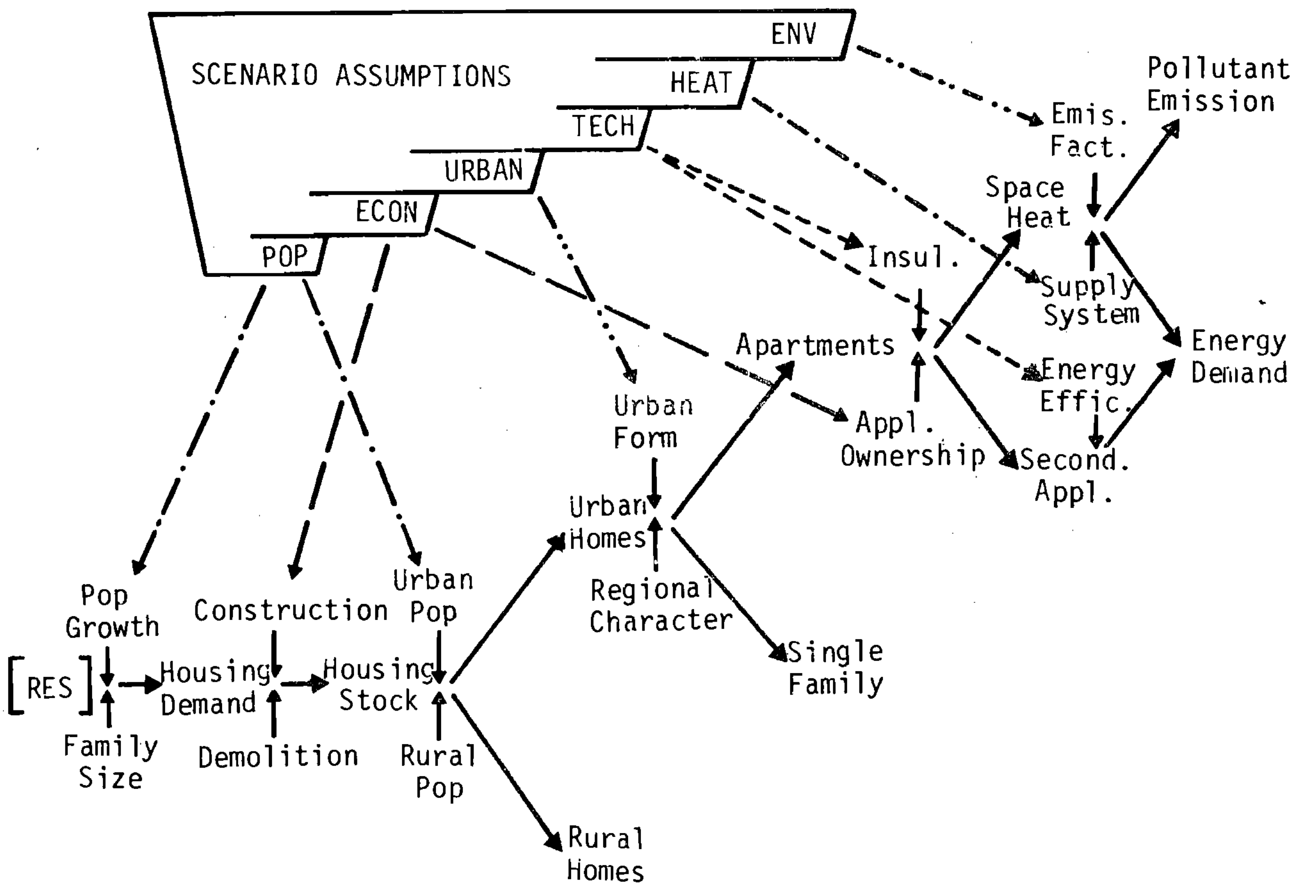

FIGURE 1

FLOW OF INFORMATION IN THE RESIDENTIAL ENERGY DEMAND MODEL

As indicated in Table 1, four scenarios were examined in detail. The main assumptions underlying these scenarios were chosen primarily on the basis of the first IIASA Workshop on Austrian Energy/Environment Systems which had the participation of many members of the Austrian private and public sectors. As described in the following sections, many of the exogenous inputs, particularly in the socio-economic area, were provided by collaborating individuals or institutions in Austria.

B. SCENARIO OVERVIEW

The four energy scenarios summarized in Table 1 were chosen to allow examination of the issues enumerated in Section I of this report. To aid in the study of energy demands, the scenarios were based upon alternative world and regional economic assumptions that resulted in three different growth rates (medium, high, low) for the Austrian economy. These were coupled with various other policies and assumptions as shown in the table to develop the scenarios S1 (Base Case), S2 (High Case) and S3 (Low Case) Because of the great concern about eventual restrictions on petroleum supply, S4 (Conservation Case) was built upon the lower economic growth of S3 to explore the effectiveness of fuel shifts and conservation measures for avoiding gaps between petroleum supply and potential demand.

The achievement of emission limits for SO_2 and particulates was coupled to the economic assumptions and growth rates.

IV. SOCIO-ECONOMIC STRUCTURE OF THE SCENARIOS

A. ECONOMICS

In this study, energy demand is a function of sectoral activity and the energy intensiveness of this activity. In the industrial, commercial and service, agricultural, and freight transportation sectors, the activity is measured in economic terms. Projections of economic activity by sector are derived utilizing the AUSTRIA II input-output model*. This medium-term input-output model provides, given a set of assumptions, a complete and consistent description of economic activity at constant prices for each year of the forecasting period.

These results are based on two different categories of assumptions. The first category comprises general assumptions concerning model structure, which cannot be changed. The second category includes more specific assumptions which may be altered from simulation to simulation without major difficulties.

General Assumptions. AUSTRIA II, based on parameters derived from time series analysis, relies on an overall stability in the socio-economic environment. This assumption implies a certain degree of continuity in economic policy: taxation, income distribution, conditions of investment, export promotion, etc. For private consumption, only changes due to rising income are taken into account; extreme evolutions caused by abrupt changes in tastes are not included. Further progress towards a liberalization of world trade is envisaged, while restrictive influences from the international monetary system or from balance of payment difficulties in major trading countries are not expected.

AUSTRIA II is a demand-oriented model. With some minor exceptions (crude oil production and iron ore extraction in Austria), the structure of the model implies that no bottlenecks will occur in supply. Labor force is also assumed not to be a limiting factor. Prices and relative

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*AUSTRIA II Input-Output Model, Josef Richter and Werner Teufelsbauer, Bundeskammer der gewerblichen Wirtschaft.

prices are assumed to have no major influence on the structure of domestic final demand. Changes in technology due to price changes can be taken into account. Fluctuations in the business cycle are largely ignored.

Specific Scenario Assumptions. A constant structure is assumed in the following final demand categories: investment in machinery and equipment, investment in buildings, inventory changes, service exports, service imports, and expenditures by foreign tourists in Austria. The structure of the public consumption is slightly changed over the forecasting period.

A rather constant technological structure is used with the exception of a large number of changes included in the period to 1985 based on information coming from various enterprises. Some additional changes in energy input coefficients do occur after 1985, as noted in the individual demand sector descriptions.

Assumptions regarding the economic development of Austria's trading partners are crucial in determining the development of Austria's economy.

The growth rates of Austria's trading partners are kept constant between 1970 and 1985 at the following levels for all scenarios:

Federal Republic of Germany	2.92%
Switzerland	2.31%
Italy	3.49%
Rest of EEC (members in 1975)	3.82%
COMECON and Yugoslavia	5.66%
Rest of OECD, rest of the world	4.63%

In S2, these growth rates are assumed to remain constant until 2015. They are linearly decreased to 1.70% in S1 and to a value slightly above zero in S3.

The constrained senario, S4, has the same trading partner description as S3 with the added provisos of a significant reduction of the energy intensiveness in industry, fewer and more efficient cars, and better insulation. These assumptions affect mainly the structures of intermediate consumption and of private consumption.

The resulting GNP descriptions for Austria are shown in absolute terms in Figure 4 (of Section V), in per capita terms in Figure 2, and

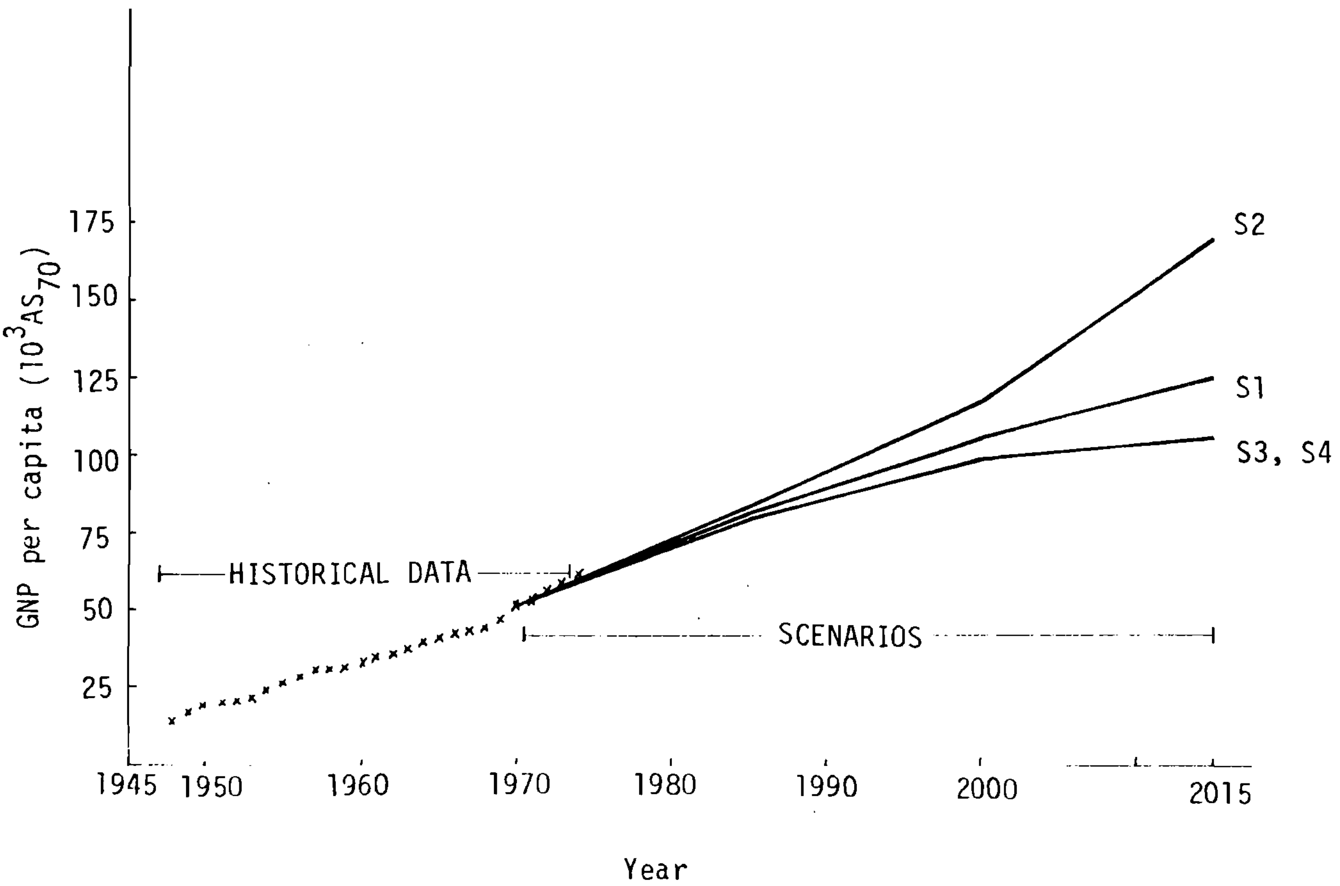

FIGURE 2

AUSTRIAN GNP PER CAPITA

in terms of growth rates in Table 2. As shown in the two figures, the development paths are quite similar to historical trends, especially for the 1970-2000 period.

Table 2

GROWTH OF AUSTRIAN GNP

(%/YR)

	S1	S2	S3	S4
1970-1985	3.3	3.4	3.2	3.3
1985-2000	2.1	2.7	1.7	1.8
2000-2015	1.5	2.8	0.7	0.7

The fastest growing sectors in terms of value-added in all four scenarios are the chemical industry, machinery/steel/light metal construction, and construction of electrical machinery and equipment. There is a strong linkage between economic growth in Austria and the level of exports and imports. Exports, which represented 10.5% of the total consumption in 1970, increase steadily until 2015 to 30.3% in S2, to 24.8% in S1, and to 22.1% in S3 and S4. On the other hand, competitive imports, which represented 12.2% of total supply in 1970, rise by the year 2015 to a level of 23.9% in S2, 21.4% in S1, and 20.8% in S3 and S4.

In conclusion, it should be noted that in scenarios S1 and S2, GNP per capita in 2015 would exceed the present value for any industrialized nation. Scenarios S3 and S4 place Austrian GNP per capita in 2015 at the 1974 level of the leading industrialized nations.

B. POPULATION

Input data about population are required mainly by the residential, transportation, and the health impact models. The initial data are taken from the 1971 census. Population data for later years are derived from an OEIR (Osterreichisches Institut für Raumplanung) projection (Variation 2.1) for 1981 and 1991, by interpolation between 1971/81/91, and by extrapolation beyond that period. Population data is calculated by political district (Bezirk) for three categories: main cities, secondary cities, and rural areas. This spacial disaggregation is important because of the many policy questions concerned with regionalization and migration.

The OEIR projection is the result of a model which uses age-specific fertility, mortality, and migration rates, and is based among other conditions on the assumption that the fertility rates between 1973 and 1991 will be 10% lower than the rates observed between 1971 and 1973. The 1971 population of Austria was 7.46 million, and the OEIR projection for 1991 is 7.69 million. Interpolation and extrapolation result in population estimates of 7.66 million in 1990 and 8.26 million in 2015. Figure 3 shows both historical population data and the future estimates used in scenarios S1-S4.

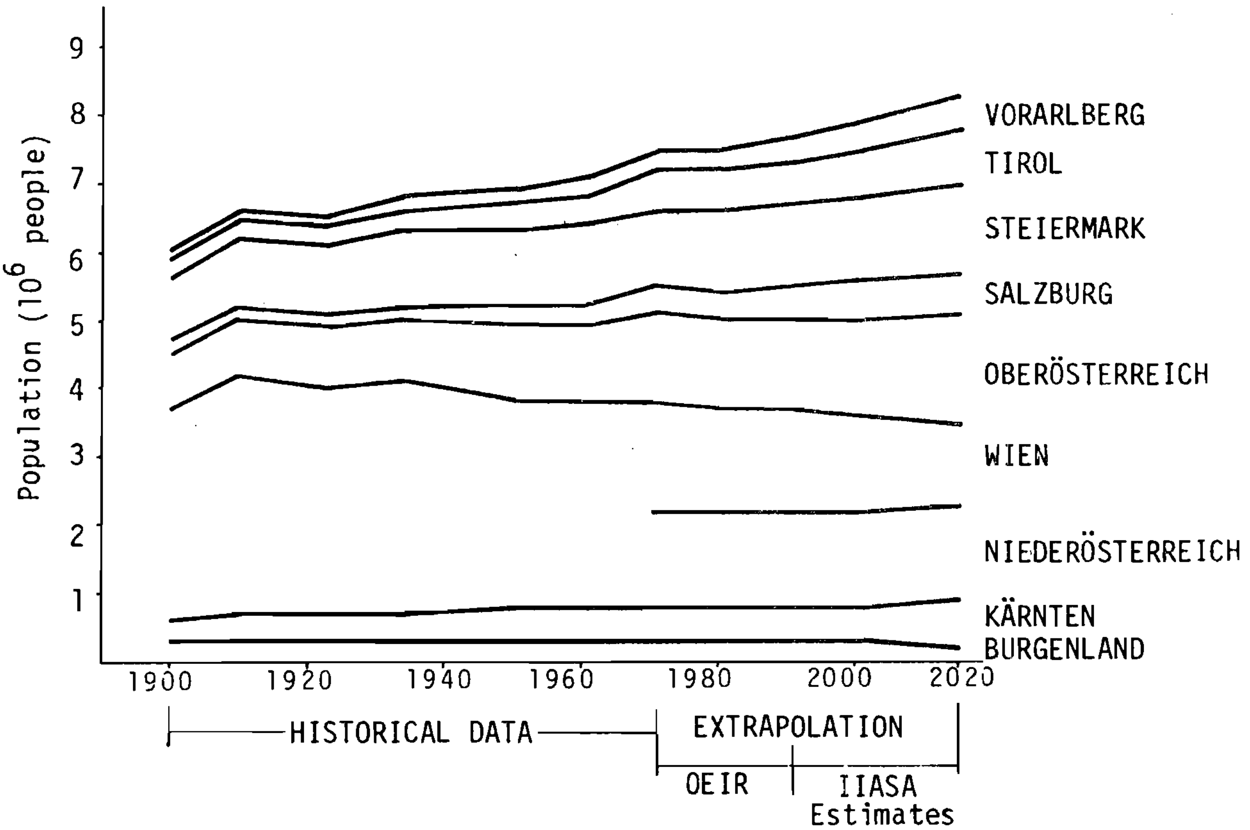

FIGURE 3

POPULATION: HISTORICAL DATA AND OEIR ESTIMATES

V. ENERGY DEMAND

This section presents the energy demand results of this study. Section A gives results for total end-use demand, followed by sections B through D which present individual sectoral demands.

A. TOTAL END-USE DEMAND

The scenario-based investigation shows that a wide range of future energy use is plausible. The future ranges for Gross National Product and end-use energy, along with historical trends, are shown in Figure 4. The fact that much of the range of the energy use falls below

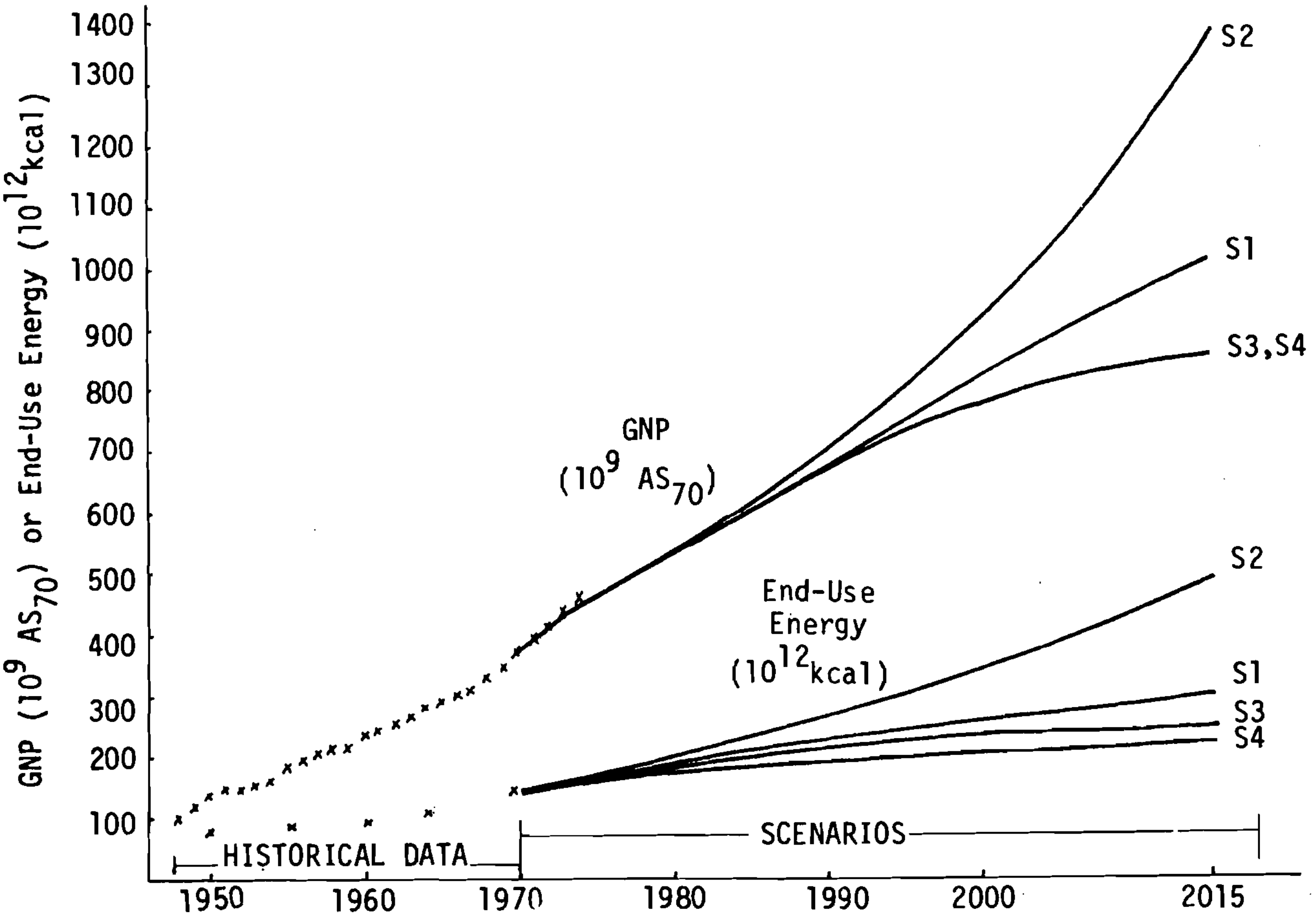

FIGURE 4

AUSTRIAN GNP AND END-USE ENERGY

the levels that would occur if recent historical rates of energy growth were maintained, indicates, in part, the strength of the policy measures that have been combined within the scenarios, as well as saturation effects and slowing of economic growth. This demonstrates the broad discretionary power available to Austrian decision and policy makers.

The wide range of results for end-use energy demands becomes clear if one compares the values for each scenario at the end of the study period with the 1971 values; the ratios for S1, S2, S3, and S4 are 2.1, 3.3, 1.8, and 1.5.

Another way of viewing the end-use energy is to convert the figures to per capita values for comparison to other regions of the world. Figure 5

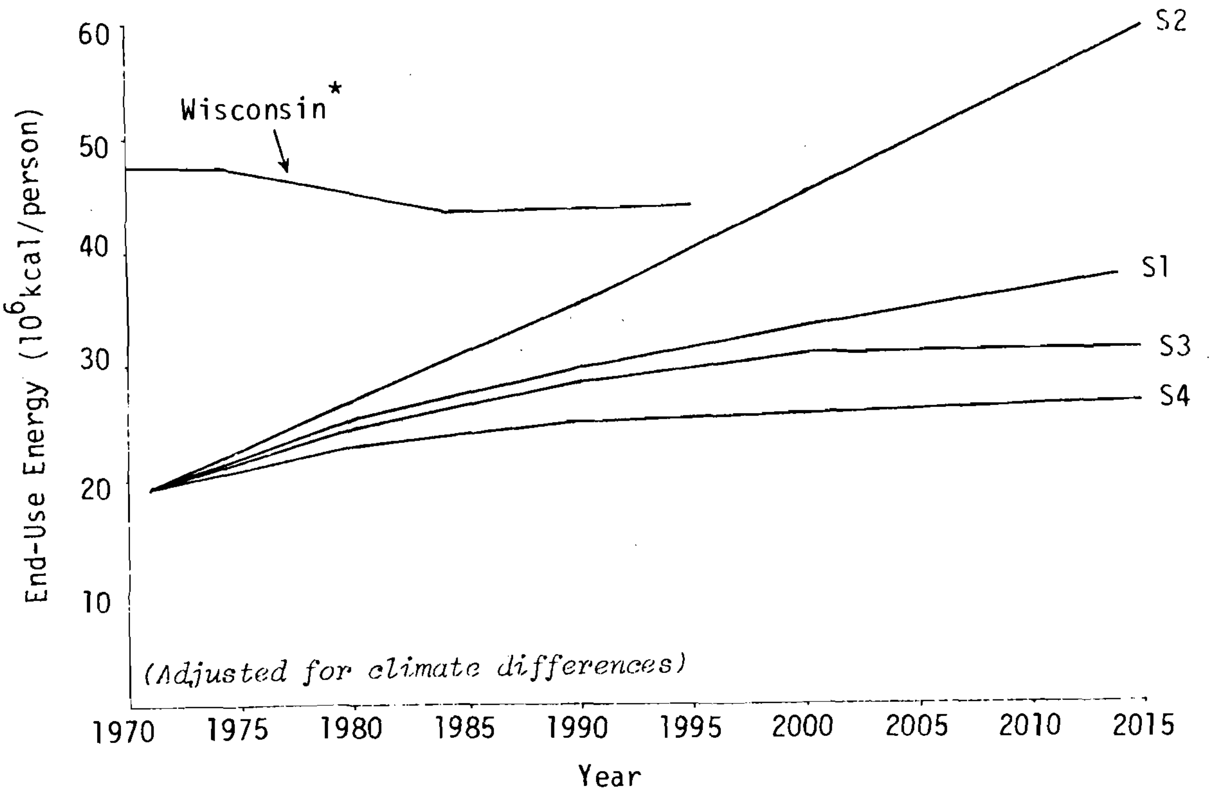

FIGURE 5

AUSTRIAN END-USE ENERGY COMPARED TO WISCONSIN NATIONAL ENERGY PLAN PROJECTION

*"The Potential Impacts of the National Energy Plan on Wisconsin's Energy Figures", Energy Systems and Policy Research Group, Univ. of Wisconsin, June 1977.

shows the four scenarios compared to an Energy System and Policy Research Group projection for Wisconsin based on the U.S. National Energy Plan as proposed by President Carter. Although the present U.S. energy use per capita (Wisconsin is fairly typical) is the highest in the world for any major industrialized nation, the S2 scenario surpasses that value while the S1 scenario is approaching it at the end of the period. Scenarios S3 and S4 would place Austria by 2015 at levels equivalent to or higher than the highest levels now occurring in Europe.

A general trend evident in the study is that the growth rates of end-use energy decline through the period 1971-2015 for all scenarios, as shown in Table 3.

Table 3

GROWTH RATE OF END-USE ENERGY
(%/YR)

	S1	S2	S3	S4
1971-1980	2.7	3.7	2.5	1.5
1980-1990	1.8	2.9	1.6	1.0
1990-2015	1.3	2.4	0.7	0.6

The trend is due to the declining economic growth rates in all scenarios as well as the declining energy intensities during much of the period in the five sectors. An exception is the S2 scenario which does have some constant or increasing intensities. This general trend is also evident in primary energy, as described in Section VI on Energy Supply.

The distribution of end-use energy through time for each of the scenarios is shown in Figures 6 and 7. Petroleum, presently the dominant energy source in Austria, maintains a large share in all scenarios. An analysis shows significant shifts in end-use shares for the various end-use energy forms through time. As shown in Table 4 the share of coal drops severely, with petroleum also showing a decline. Natural gas and electricity have large increases in share, with natural gas showing the largest increase.

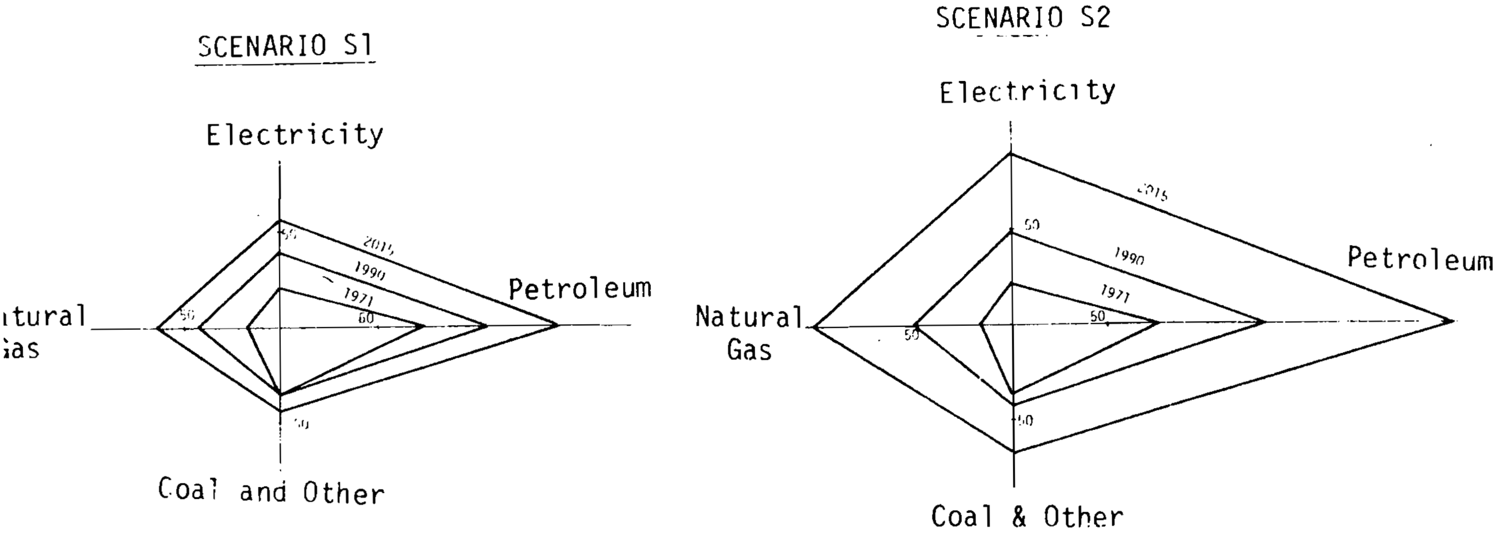

FIGURE 6
AUSTRIAN END-USE ENERGY (S1 and S2)
(10^{12} kcal)

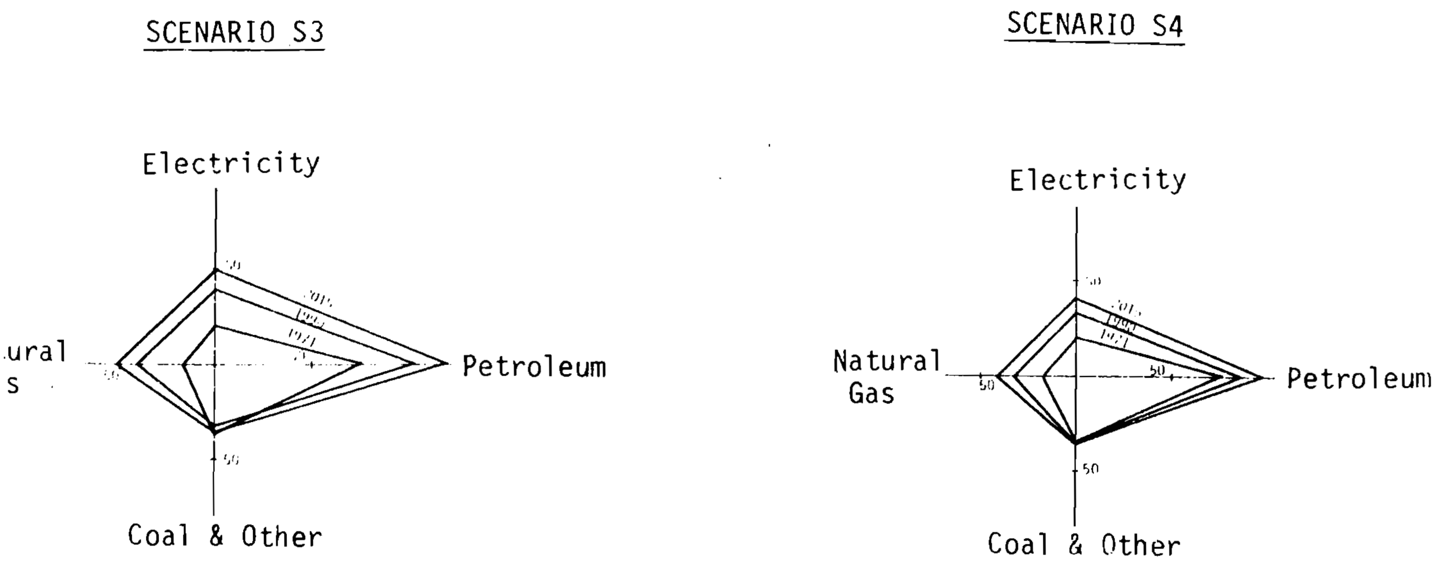

FIGURE 7
AUSTRIAN END-USE ENERGY (S3 and S4)
(10^{12} kcal)

Table 4

SHARE OF END-USE TOTAL (%)

	1971	2015			
		S1	S2	S3	S4
Coal & Other	23	13	14	14	16
Petroleum	51	47	47	47	46
Natural Gas	12	21	21	20	19
Electricity	14	19	18	19	19

An interesting observation is the consistency of the petroleum share within the widely varying total end-use energy levels shown in Figures 6 and 7. While petroleum conservation did occur relative to other energy forms, it was difficult to conserve petroleum so as to reduce its share from one scenario to another. Conservation of petroleum in scenario S4 resulted in conservation of all energy forms.

Trends in primary energy (see Section VI) are not identical to those for end-use energy in Table 4. For example, the growth rate for electricity for the 1971-2015 period is higher than for primary natural gas. The reverse is true for the comparison of electricity to end-use natural gas. The decline in the petroleum share of primary energy is more marked and varied than its decline in the share of end-use energy. The petroleum share of primary energy in 2015 is 45%, 43%, 50%, and 43% for scenarios S1, S2, S3, and S4, respectively, in contrast to the petroleum share of end-use energy shown in Table 4.

The growth of electricity use is an important concern in energy and investment planning in Austria. The growth rates of electricity use followed the same trend as total energy, starting with historical rates for the 1971-1980 period and declining to significantly lower rates for the 1990-2015 period, as shown in Table 5.

Table 5

ELECTRICITY GROWTH RATES
(%/YR)

	S1	S2	S3	S4
1971-1980	5.0	6.2	4.8	3.8
1980-1990	2.5	3.4	2.4	1.8
1990-2015	1.5	2.5	0.9	0.9

The implications of this pattern are shown in Figure 8.

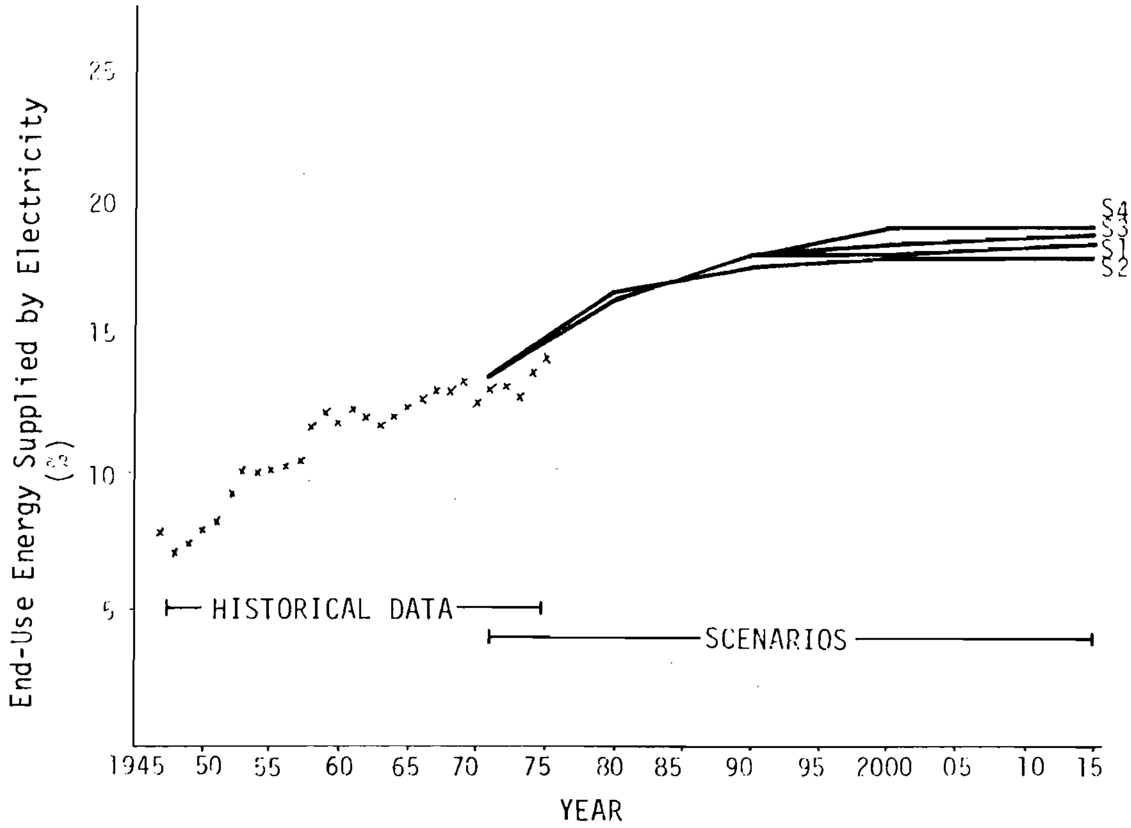

FIGURE 8

PERCENTAGE OF END-USE ENERGY SUPPLIED BY ELECTRICITY

which compares the percentage of electricity of total end-use energy for the four cases with historical development since 1947. The scenarios follow almost identical development starting with a rate exceeding that of the 1960-1970 decade and virtually saturating at 18-19% by the end of the study period. This suggests that within the scenarios the foreseeable uses of this high-quality energy form were fully exploited at this level.

The trends in the shares of end-use energy among the five sectors are shown in Figure 9. Two points stand out in this figure. One is the stability of shares in the four scenarios in 2015 despite the wide divergence of energy use. The second point is that the industrial share increases in each case above its already predominant share of 42%. It is noteworthy that the three economic sectors - industrial, commercial, and agriculture - increase their share at the expense of the private sectors - transportation and residential - from 57% in 1971 to 65%, 65%, 64%, and 63% in case S1, S2, S3, and S4, respectively, in 2015. Even this is understated in that an increasing portion of the transportation end-use energy is devoted to freight use as opposed to personal travel as noted in the transportation energy use assessment.

The fastest growing sector in terms of end-use energy is commercial and service, while the slowest is the transportation. The growth rates shown in Table 6 are consistent with the changes in relative shares.

Table 6

COMMERCIAL AND SERVICE AND TRANSPORTATION GROWTH IN END-USE ENERGY 1971-2015 (%/YR)

	S1	S2	S3	S4
Commercial and Service	2.5	3.2	2.2	1.6
Transportation	1.1	2.4	0.8	0.3

As described in the sectoral descriptions, these opposite trends are due to the growth in value-added and smaller declines in the commercial sector energy intensity versus a sharp drop in energy intensity due to the conservation potential in transportation sector as well as the saturation of automobile ownership.

The dominance of the industrial sector in energy use suggests that policy measures for altering energy use patterns must largely focus on this sector.

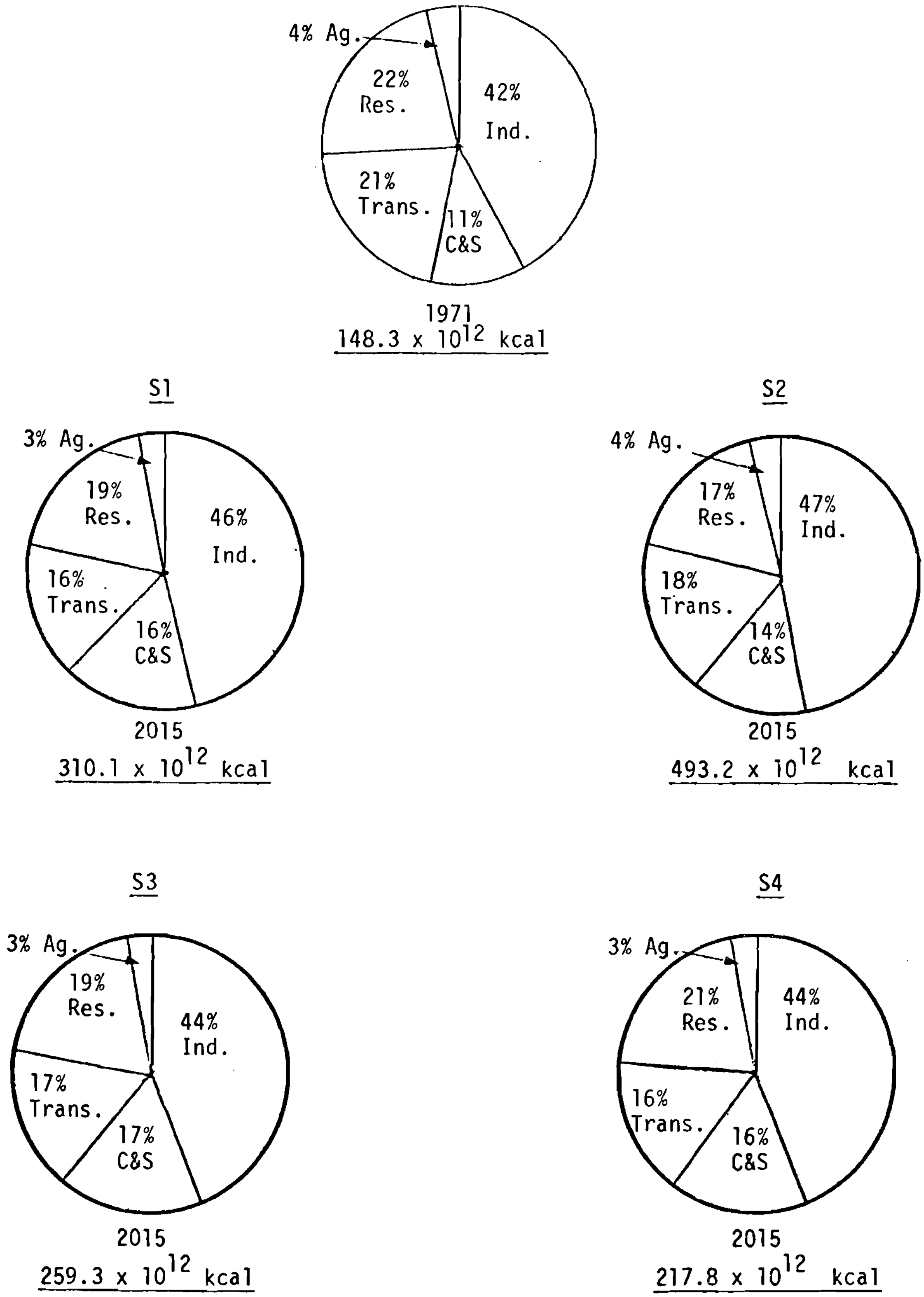

FIGURE 9

END-USE ENERGY SHARES BY SECTOR

B. RESIDENTIAL SECTOR

The residential energy use model for Austria is structured around the number of homes and the average energy consumption per home. The number of homes is related to both population and average family size; the average energy consumption per home is calculated from parameters such as house floor area, average heat loss (insulation levels), and levels of appliance ownership and use.

Main Scenario Assumptions. The following assumptions were used in all scenarios:

(1) Demography: Population projections are based on the OEIR report. The average family size declines by a factor of .997/year from 2.94 in 1971 to 2.77 in 1990 and 2.57 in 2015.

(2) Structure: Each family is assumed to have one home in the future. The fuel mix changes over time as a result of an assumed shift away from coal to more convenient fuels like oil, gas, electricity, and district heat. This shift occurs both through construction of new homes (very few new homes use coal) and through the retro-fitting of older homes.

Another important assumption is that homes with coal- or wood-fired single ovens (approximately two-thirds of all homes in 1971) heat only half of their floor space at any one time. As these homes are demolished and replaced or are retrofitted and move to convenient fuels or coal- or wood-fired central heating units, this assumption is dropped. This whole process is assumed to be nearly complete by the year 2000.

Assumptions which vary over the four scenarios are:

(3) Life-style: The size of newly constructed homes is directly related to economic growth; the annual floor area increase is assumed to be 0.8 m^2/yr until 2000 for S1, 1.0 m^2/yr until 2000 for S2, and 0.4 m^2/yr for S3 and S4. For the scenario S2 additional assumptions have been introduced which indicate less restrained energy-use. The heating hours increase 40% until the year 2000 and the hot water use increases from 40ℓ/capita/day to 70ℓ/capita/day in the year 2000.

Saturation curves define the appliance levels per home for a set of 12 appliances (including washing machines, stoves, televisions, etc.) and two groups of small appliances. The level and rate of saturation for each appliance is related to the growth of GNP as given by the AUSTRIA II model; the energy consumption per appliance per home is constant over the simulation period. For S1, saturation levels are reached by 2000; for S2, higher saturation levels are reached by 1990, and for S3 and S4, the same saturation levels as S1 are reached by 2015.

(4) Applied Technology: The average heat loss per home can be reduced to about 50% of the present level if an efficient insulation policy is applied.* The 1971 insulation standards (120 kcal/m^2/hr heat loss for single-family homes, 90 kcal/m^2/hr for apartments) are retained for S1 and S2. For the other scenarios, heat losses for newly constructed homes are decreased stepwise to 60% of 1971 levels by 2000 for S3 and to 45% of 1971 levels by 2000 for S4. Retrofitting improves pre-1971 homes by 15% for S3 and by 20% by 2000 for S4. Energy efficiencies of appliances are held constant for S1, S2, and S3, while S4 assumes improvements in energy efficiencies for heating units.

(5) Alternative Technologies: Scenarios S1, S2, and S3 assume continuation of current technologies and energy sources, while S4 assumes significant use of alternative technologies and energy sources (heat pumps, solar energy, etc.).

Results and Conclusions. The relative importance of major end-use categories in determining residential energy demand is shown in Table 7. The high fraction of demand due to space heating shows that increase in floor space per capita and heat losses due to insufficient insulation are the most important factors in determining the total amount of energy consumed by the residential sector. Even with a strict conservation policy (S4), space heating is the predominant end-use category in the residential sector.

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*Österreichisches Institut für Bauforschung: "Reduzierung des Energieverbrauchs in Wohnungen".

Table 7

PERCENTAGE OF END-USES IN TOTAL RESIDENTIAL ENERGY DEMAND

	All Scenarios	S1		S2		S3		S4	
	1971	1990	2015	1990	2015	1990	2015	1990	2015
Space heating	≃ 82%	77%	76%	77%	78%	73%	67%	73%	65%
Water heating	≃ 7%	9%	9%	10%	10%	10%	11%	10%	12%
Appliances	≃ 11%	14%	15%	13%	12%	17%	22%	17%	23%

Figure 10 shows the residential demand by energy source for the

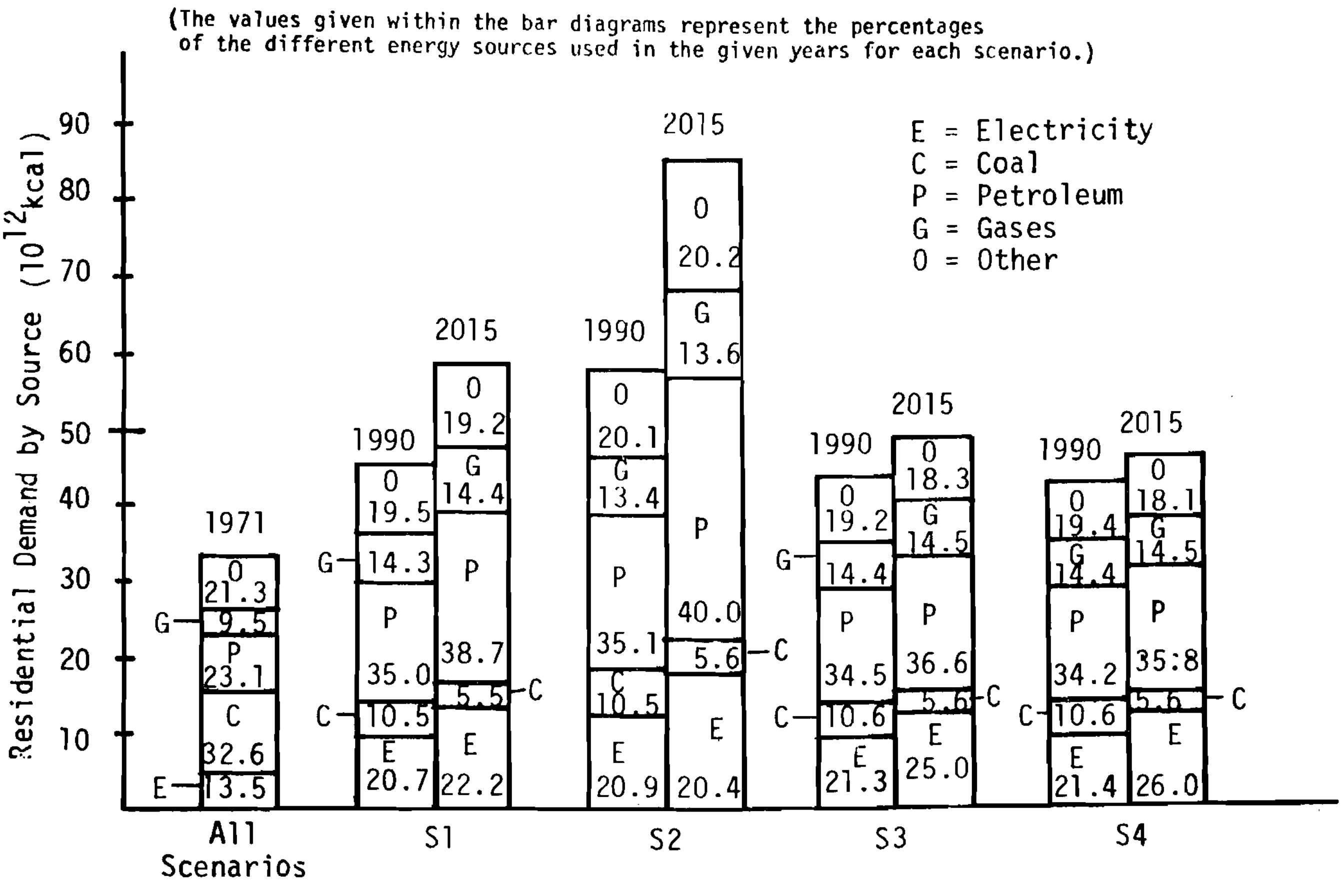

FIGURE 10

RESIDENTIAL DEMAND BY SOURCE

four scenarios, comparing historical 1971 data with the results from 1990 and 2015. It is especially important to note that even with a strict conservation policy as applied in S4, there is a considerable time lag before its effect becomes noticeable in the total residential energy demand.

For 1990 and 2015, the percent of total residential demand for each energy source is essentially constant across the four scenarios. By 2015, roughly 56% of the residential demand is for petroleum and gases, which must be imported. With the expected decline in fossil fuel availability, this high percentage of demand, even in the conservation scenario, is a potential problem.

However, the residential sector is one area where we feel the demand for fossil fuels could be decreased (without sacrificing comfort) by appropriate policies. The key issue is whether or not to control the expected continuing shift from coal and wood to more convenient fuels such as oil, gas, and electricity (assumed in all four scenarios). By formulating policies either to discourage this fuel shift or to encourage a shift to solar energy or heat pumps (even to a greater extent than was assumed in S4), the demand for fossil fuel could be somewhat controlled.

C. AGRICULTURE, INDUSTRY, AND SERVICE SECTORS

An energy consumption submodel, based upon economic activity in Austria, calculates the end-use energy consumption in the agricultural, the industrial, and the commercial and service sectors. Economic projections used in this model are taken from the AUSTRIA II model, while the initial data on energy consumption are extracted from the energy balance published by the OESTZ (Oesterreichischen Statistichen Zentralamt). As a result, data aggregation was necessary for determining a consistent data set. Some masking of trends may occur due to this aggregation, since fuel consumption patterns may vary for the different sectors included in the aggregation. However, if the parameters associated with these aggregates are carefully chosen, the validity of the results is not changed.

There are three main types of variables which need to be specified for each sector and year. These are:

(1) value-added, as an indicator for the activity level of an economic sector;

(2) total energy intensiveness (or specific energy consumption), defined as end-use energy consumed per unit of value-added of a sector; and

(3) the distribution of the energy consumption in an economic sector among the various energy forms (fuel mix).

Scenario Assumptions. The value-added projections are taken from the AUSTRIA II model; they differ in each scenario as shown in Table 8

Table 8

VALUE-ADDED*

	Agriculture (%)	Industry (%)	Services (%)	Total ($10^9 AS_{70}$)
1970:	7.39	33.15	59.46	354.2
2015:				
Base Case (S1)	4.99	34.37	60.64	927.5
High Case (S2)	4.76	36.80	58.44	1242.1
Low Case (S3)	5.06	32.48	62.47	784.9
Low & Energy Conserv. (S4)	5.04	32.62	62.33	786.9

*The structural changes are very moderate on such an aggregated level. However, shifts do occur within the industry and service sectors which do not appear in the table.

The energy intensiveness for each sector is determined using a saturation curve. These curves are specified by three main parameters: (1) the initial value (1974); (2) the ratio between the assumed energy intensiveness in the year 2000 and the initial value; and (3) the fraction of potential change exhausted by the year 2000. The last two parameters are scenario-dependent.

The assumptions with respect to energy intensiveness vary greatly between the scenarios as shown in Table 9 In scenarios S1 and S3,

Table 9

ENERGY INTENSIVENESS

($Kcal/AS_{70}$)

	Agriculture*	Industry*	Services**	Total
1970	370	510	169	297
1974	366	505	184	300
2015:				
Base	366	445	163	270
High	446	507	199	324
Low	366	447	164	266
Conserv.	290	375	128	216

*Includes energy consumption for space heating.

**Includes energy consumption for freight and public mass transportation

it is assumed that most sectors will have an improvement in energy intensiveness of 10% by the year 2000. The exceptions are primary metals and transportation, which show larger decreases in energy intensiveness, and mining, trade and petroleum, which show increasing energy intensiveness.

In scenario S2, an increasing energy intensiveness is assumed in most sectors due to replacement of labor by capital. This assumption implies that sufficient energy will be available at reasonable prices. In scenario S4, a significant reduction in energy intensiveness is assumed to occur due to limited resource availability and high costs.

The figures given in Table 9 for 1970 and 1974 are obtained by dividing the actual fuel consumption in those years by the value-added as calculated from the results of the AUSTRIA II model. Note that the value-added figures extracted from the model do not include import duties, and as a result, the intensiveness figures used in the model are lower than those actually observed between 1970 and 1974. Considering the wide range and fluctuations in observed data in the recent years, the assumptions made in the scenario are considered to be very moderate.

The future fuel mix is estimated with the help of a transition matrix, which is calculated for each sector so as to approximate the observed fuel mix patterns between 1970 and 1974 and become stationary at a pre-specified distribution. The same matrices are used for all scenarios in order to limit the number of factors that differ between scenarios. The assumed future fuel mix suggests a relatively strong growth in electricity and gas consumption coupled with a relative decline in fuel oil use.

Results and Conclusions. Despite the fact that the fuel mix assumptions do not vary between scenarios on the sectoral level, there are a number of significant differences on the aggregated level (industry, services) which are a result of the varying economic structure and the changing specific energy consumption.

In the industrial sector, which is the largest end-use sector in all scenarios, petroleum use decreases from 38% of the total demand in 1971 to 25% of the total by 2015 (all scenarios). However, even with this relative decrease in use, the quantity of petroleum required for scenario S2 in 2015 is nearly 150% greater than the 1971 usage. The petroleum required in the constrained oil scenario (S4) is somewhat less than the 1971 level for all scenario years. The largest increase in fuel demand by the industrial sector is for natural gas, which increases its share of total industrial end-use from 22% in 1971 to about 38% by 2015 in scenarios S1, S2, and S3.

Since the industrial sector continues to dominate in energy use, policy measures for altering energy use patterns must focus on this sector. A detailed breakdown of industrial energy demand by source is shown in Figure 11.

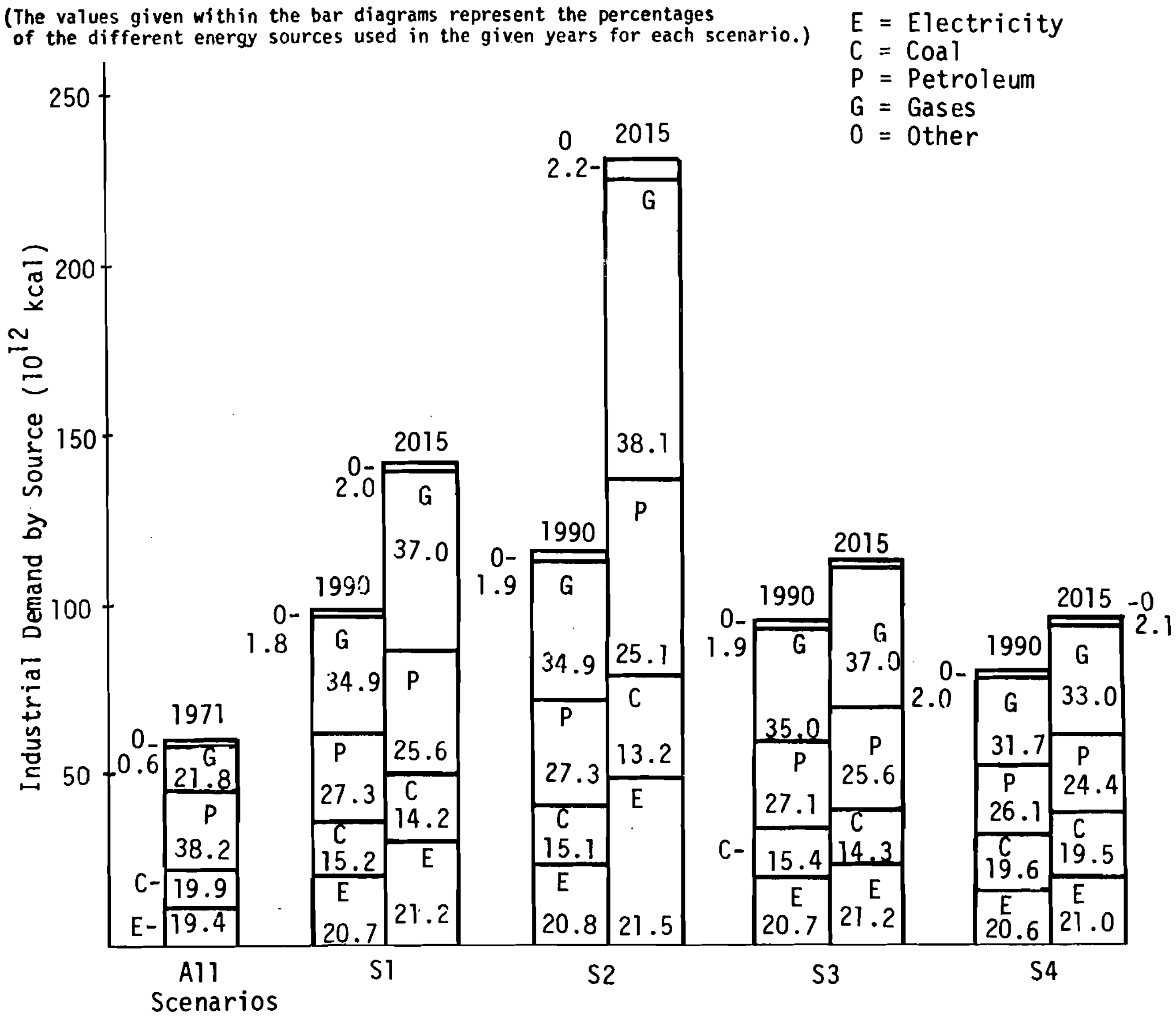

FIGURE 11

INDUSTRIAL DEMAND BY SOURCE

The fuel mix in the commercial and service sector (the fastest growing end-use sector) moves toward a greater reliance on natural gas and electricity over the 1971-2015 time period. However, petroleum remains the dominant fuel used in this sector. Even in the constrained oil scenario (S4), the commercial and service sector requires petroleum for meeting 65% of its end-use needs, nearly the same quantity of petroleum as for the industrial sector. Conservation measures aimed at a further reduction of petroleum demand in the commercial and service sector could have a significant impact on reducing total petroleum requirements.

D. TRANSPORTATION SECTOR

Of the five sectors in the Austrian study, transportation has the slowest end-use energy growth in all cases and all periods except for the S2 scenario where residential grows slower in all periods except 1971-1980. As noted in Figure 9 (Part A), transportation's share of end-use energy declines in all cases from 21% in 1971 to 16% for cases S1 and S4, 18% for case S2, and 17% for case S3 in 2015. This trend is indicative of the conservation potential available in the transportation sector as well as the anticipated saturation of automobile ownership growth.

Scenario Assumptions. The historical development of automobile ownership and the saturation levels used in the scenarios are shown in Figure 12. Increasing fuel costs and taxes are expected to end the growth in the size of the automobile in all cases. In addition, improvements in new automobiles from the current level of fuel economies (12.3ℓ/100 km) to 8.9ℓ/100 km by 1985 is assumed in scenarios S1 and S3, and to 7.0ℓ/100 km by 1990 in scenario S4 due to these trends in cost and taxes as well as to possible policy measures such as fuel standards. Finally, it is expected that the fuel economy standards in the U.S. automotive markets will have a significant carry-over effect on foreign automobile manufacturers who will be required along with their U.S. counterparts to meet the standards in the U.S. market. The U.S. Energy Policy and Conservation Act of 1975 mandates an average yearly standard that reaches 27.5 MPG or 8.6ℓ/100 km for the 1985 model year fleet.

Energy demand for personal transportation was projected using an Austrian version of the Wisconsin transportation model adjusted for Austrian travel behavior. Where personal travel is included in the Commercial and Service Sector of the AUSTRIA II model, measures were taken to avoid double-counting.

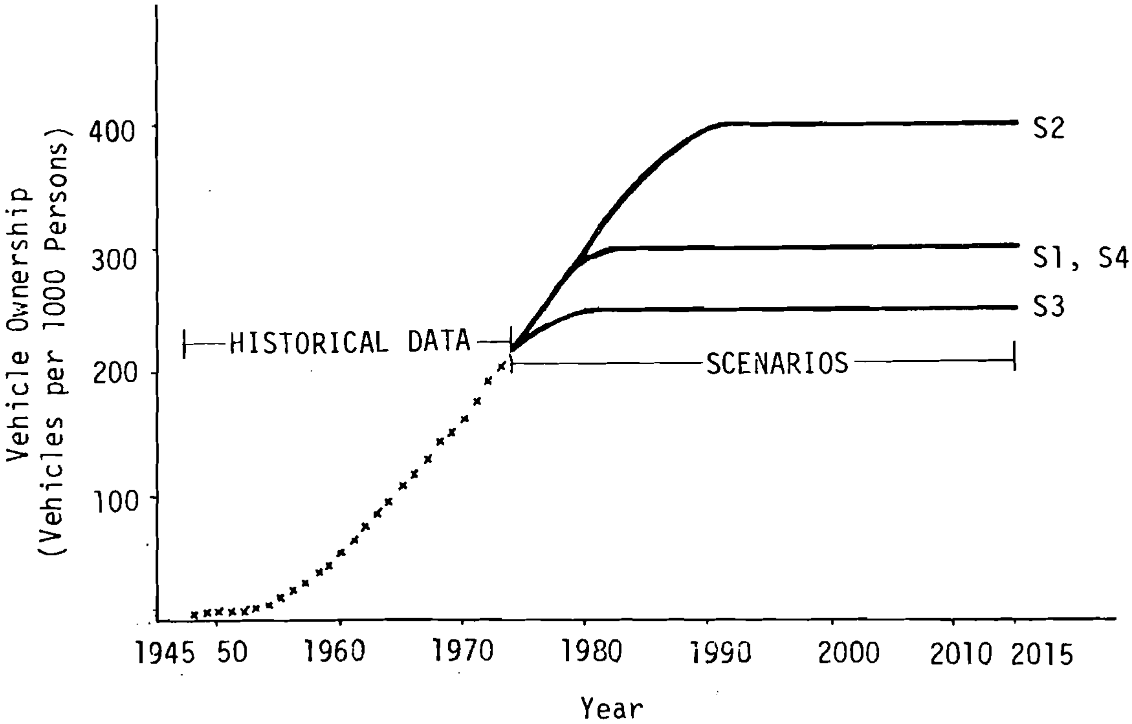

FIGURE 12
AUTOMOBILES AND COMBIWAGEN PER 1000 POPULATION

Freight energy demand was projected in the AUSTRIA II model and the energy consumption submodel. Freight energy intensity was based on the modal distribution of ton-km and the energy intensity by mode. The modal intensities remain at present levels for railroads, barges, and pipelines. Truck intensities decrease 20% by 1995 in scenarios S1 and S3, and 35% by 1995 in S4. The present trends in modal freight distribution shifts are continued, reaching the following distribution of ton-km: railroads - 48.7%, trucks - 23.5%, barges - 6.4%, and pipelines - 21.4%. In the scenario S4, a modal shift is included with the resulting distribution: railroads - 56.4%, trucks - 15%, barges - 8.1%, and pipelines - 20.5%. These compare with the 1975 distribution: railroads - 50.3%, trucks - 21.1%, barges - 8.1%, and pipelines - 20.5%.

Results and Conclusions. The dominant fuel in the transportation sector is petroleum, which is approximately equally divided between gasoline and diesel, a small remaining portion of petroleum being fuel oil for space heating. In 1971, petroleum accounted for 87% of end-use energy in the transportation sector, while in 2015, the share was 90% in each of the cases; the rest is electricity, coal and other fuels for trains and mass transit. This is expected for a transportation sector based on the internal combustion engine.

The growth of energy use in transportation shown in Fig. 13 is dependent on the development of the freight and personal sectors. In general, the rate of growth of end-use energy slows during the 1971-1990 period with a resulting average below the historical rate due to conservation measures taken for automobiles as well as trucks. The S2 case is an exception here in that conservation measures are not taken. The rate of growth picks up again after 1995 in that no further conservation measures are implemented and growth is tied to the continuing population growth for personal transportation and to economic growth for freight transportation.

Due to the greater growth rate of the economy than population and the larger conservation potential in the personal transportation area, the shares of personal and freight transportation energy shift towards freight during the study period. The fraction of gasoline use in automobiles of total transportation energy shrinks from 49% in 1971 to 40% for cases S1, S3, S4, and 41% for S2 in 2015.

The single most effective method to conserve transportation energy in Austria is the adoption of fuel economy standards for automobiles. This allows the reduction of energy use without reducing travel. The primary result of the adoption of standards would be a movement to less powerful, lighter, and smaller automobiles.

Figure 14 indicates the sensitivity of fuel consumption for a given amount of vehicle kilometers. For a base case ownership of 300 vehciles per 1000 population, moving from present average vehicle efficiencies of 12.3 ℓ/100 km to 8.9 ℓ/100 km as in case S1, reduces energy consumption 28% in 2015 from 26.3×10^{12} Kcal to 19.0×10^{12} kcal. An even higher efficiency of 7.0 ℓ/100 km reduces gasoline consumption 43% to 14.9×10^{12} Kcal, for a total savings of 11.4×10^{12} Kcal. This represents 6.7% of total primary petroleum use in scenario S1 in 2015.

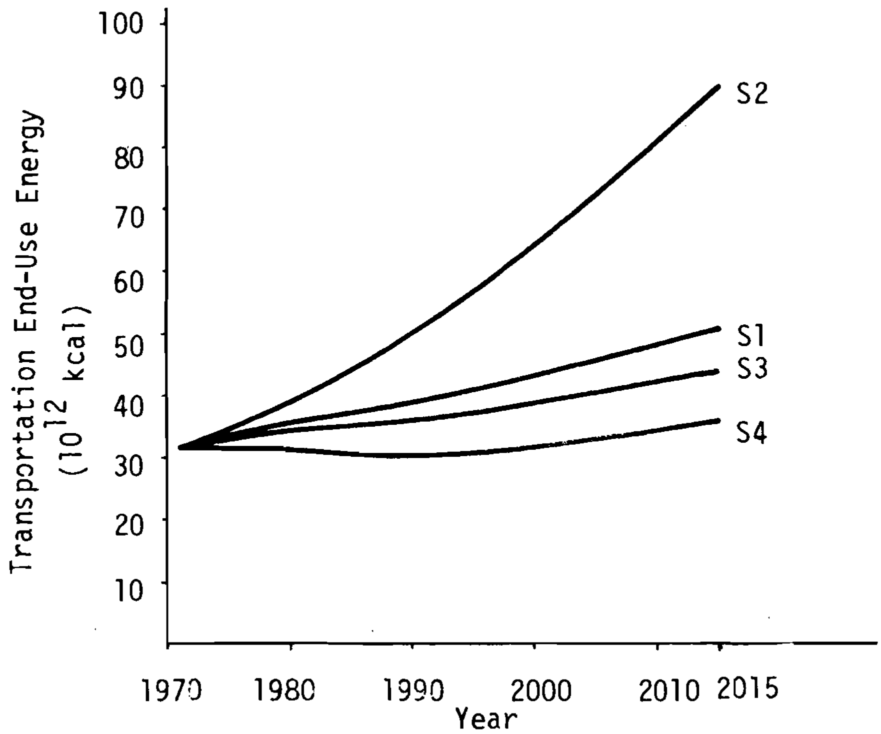

FIGURE 13

TOTAL TRANSPORTATION END-USE ENERGY

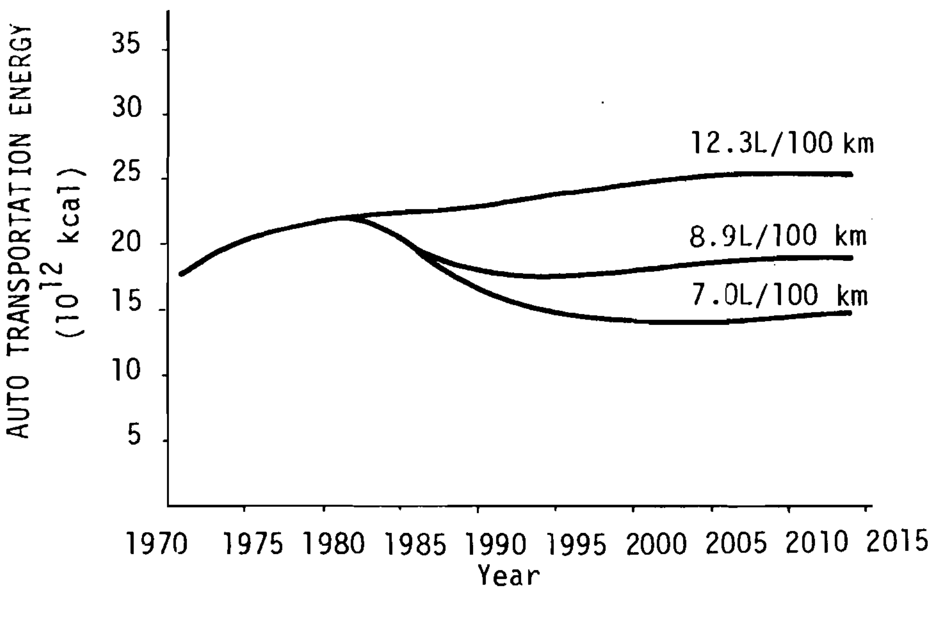

FIGURE 14

AUTO TRANSPORTATION ENERGY: FUEL ECONOMY SENSITIVITY FOR SCENARIO S1

It should be noted that these relative savings for any level of vehicle miles would be available by 2000 if the fuel economy measures were gradually implemented in the 1980-1990 decade, due to the rapid rate of turnover of the automobile stock.

VI. ENERGY SUPPLY

Energy supply in the scenarios was matched to end-use energy demands and was formulated around various alternative energy supply assumptions. Although no formal supply model was used in the development of these scenarios, a wide range of policy issues was examined. The set of supply scenarios presented in Part (A) of this section is not considered to have a greater likelihood than other scenarios which are based on different sets of policy assumptions. However, the scenarios clearly show the future implications of alternative energy supply strategies that result from the policy issues considered.

In addition to the supply scenarios, a formal resource allocation model was applied to the S1, S2, and S3 1990 end-use demands. The model, which examines interfuel substitution strategies, was used to calculate an optimal supply strategy based on economic and resource availability criteria, as described in Part B.

A. SUPPLY SCENARIOS

A number of separate analyses served as a basis in the delineation of policy issues and in the specification of alternative energy supply assumptions. These included: (1) an analysis of the historical Austrian energy supply system; (2) accounting for the announced construction plans of the electric utility companies; (3) an examination of domestic resource supplies (including long-term resource availabilities); (4) an assessment of future fuel import and export contracts; and (5) a review of other energy supply studies and forecasts.*

It was assumed in this analysis that supplies of various energy resources would be unconstrained, i.e., supplies would be adequate for meeting primary energy demands. However, since oil supplies may become more limited in the next 10-15 years, supply scenario S4 assumes the implementation of strict oil conservation measures. The oil demands

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*Energieplan 1976, Bundesministerium fur Handel, Gewerbe, und Industrie, September 1976.

Industrie-, Markt-, und Energiestudie, Austrian Oil Companies, January 1977 ("IMES-IV" Study).

from this scenario were compared with estimates of Austria's future oil imports (based on forecasts of world oil reserves and production rates) in order to elucidate possible petroleum shortfalls in the future.

Scenario demands have been divided into two categories in this analysis, electric and non-electric. In the electric category, primary energy is dependent on fuel mix, conversion efficiencies, and transmission and distribution losses. The non-electric demands, discussed in Section V, are added to the primary energy required by the electric sectors to obtain total primary energy use requirements.

Electricity Assumptions. The main policy issues underlying the alternative electricity futures examined in these scenarios were:

(1) the acceptability of nuclear power; (2) the rate of hydropower expansion; (3) the levels of electricity imports and exports; and (4) expansion of the fossil-fuel generation base. These four key policy issues led to the following set of scenario assumptions:

Scenario S1: Restrained acceptance of nuclear power; one 730 MWe plant operating in 1990 and two 1300 MWe plants operational by 2015. Steady development of hydropower to a saturation limit of 44.1×10^9 kWh in 2015 (10% of which is exported). Imports of electricity increasing from 2.2×10^9 kWh in 1971 to 6.9×10^9 kWh in 1990; constant thereafter. Fossil-fuel generation relatively stable through 2015.

Scenario S2: Large nuclear penetration; one 730 MWe plant operating in 1990 and five 1300 MWe plants operational by 2015. Hydropower fully exploited by 2000 and a gradual reduction in exports from 10% in 2000 to zero in 2015. Imports increase from the 1971 level to 11.7×10^9 kWh by 1990; constant thereafter. Expansion of the fossil-fuel generation base from 12.6×10^9 kWh in 1971 to 21.3×10^9 kWh in 2015.

Scenario S3: Nuclear capacity restricted to one 730 MWe plant which is retired by 2015. Hydropower development and imports and exports as in S1. Expansion of the fossil-fuel generation base from the 1971 level to 17.3×10^9 kWh in 2015.

Scenario S4: No nuclear permitted. Hydropower development and imports and exports as in S1. Petroleum used for electricity phased out between 1990 and 2000. Electricity generation from lignite and gas constant after 1900.

Results and Conclusions. Figure 15 shows total primary energy requirements for scenarios S1-S4, comparing the scenario years 1990 and 2015 with historical 1971 data. The primary energy requirements in 2015 for scenario S1 are 110% greater than the 1971 level, representing a 1.7% average annual growth rate in total primary energy supply requirements. Scenario S2, which is based upon optimistic economic growth rates, shows total requirements increasing to 626.1 x 10^{12}Kcal by 2015, corresponding to an average annual growth rate of 2.9%. The low economic growth scenario S3 exhibits an annual increase of only 1.2% in total primary requirements over the 1971 level. Additional conservation measures imposed in scenario S4 result in a low annual growth rate of .70%.

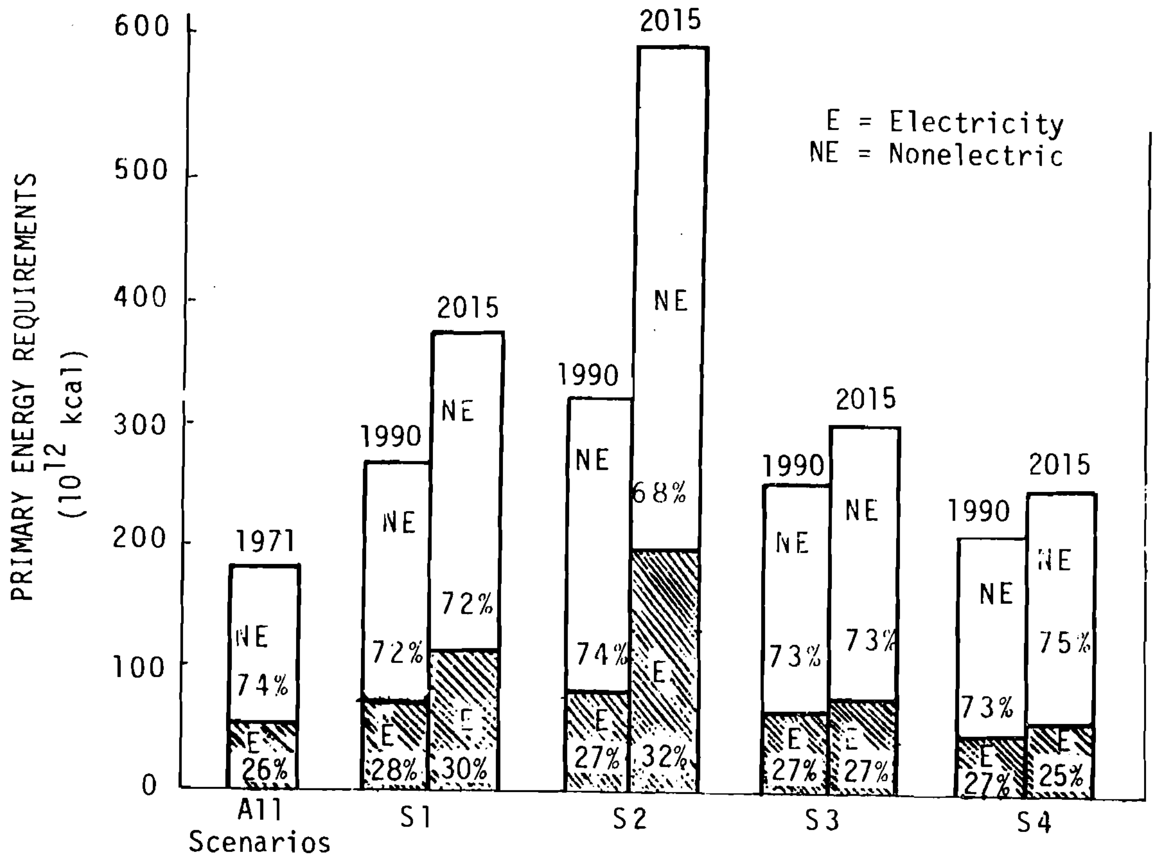

FIGURE 15

TOTAL PRIMARY ENERGY REQUIREMENTS, S1-S4

It should be noted that the growth of the Austrian economy, in terms of GNP, is greater than that for primary energy. The ratio of total primary energy to GNP decreases over time in all scenarios as shown in Table 10. Figure 16 shows historical data and scenario results for GNP and primary energy use.

Table 10
RATIO OF TOTAL PRIMARY ENERGY TO GNP
(100 Kcal/GNP AS_{70})

	S1	S2	S3	S4
1971	4.6	4.6	4.6	4.6
2000	3.9	4.6	3.6	3.0
2015	3.7	4.5	3.5	2.9

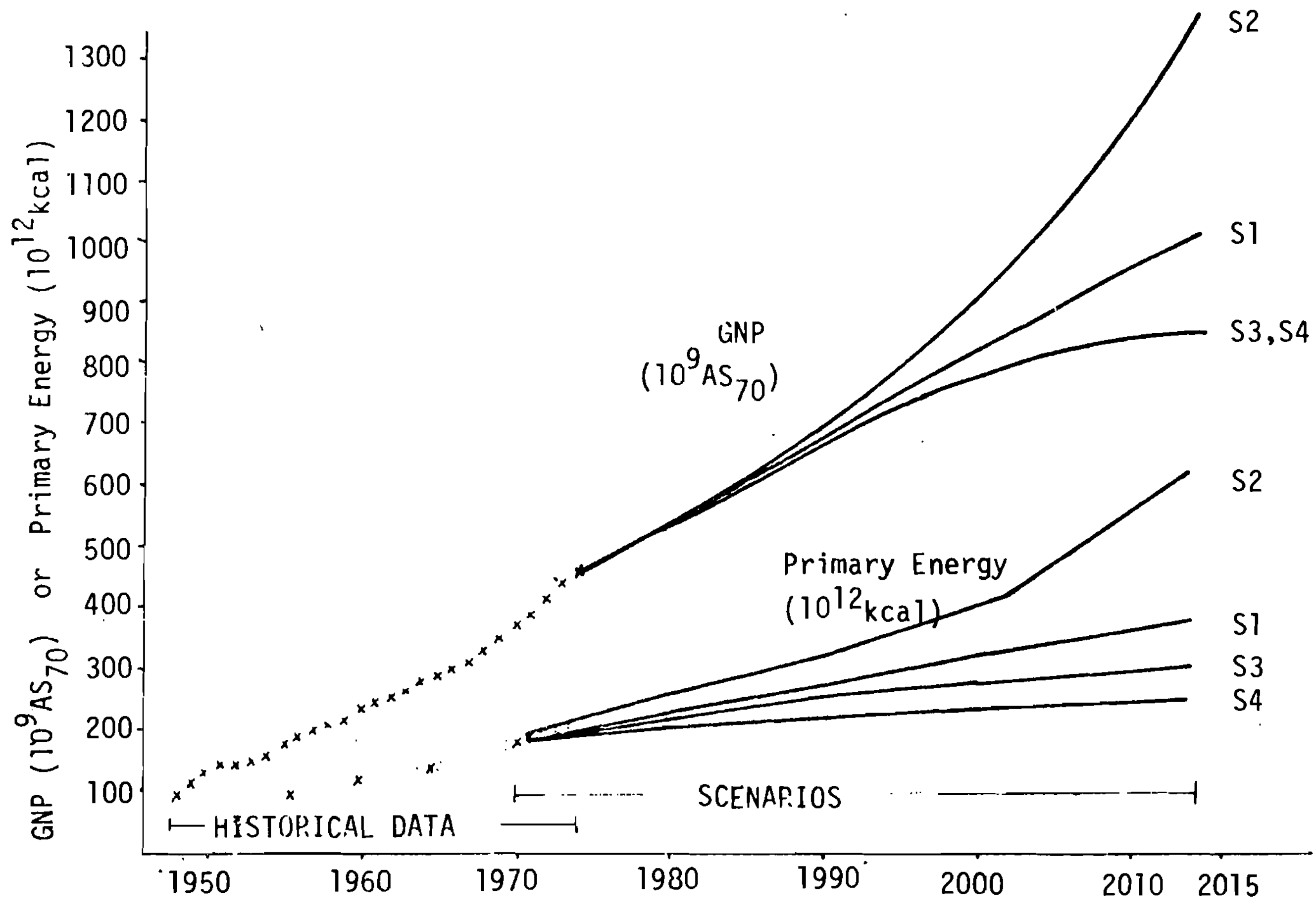

FIGURE 16

AUSTRIAN GNP (AT CONSTANT 1970 PRICES)
AND PRIMARY ENERGY REQUIREMENTS

Total primary energy requirements have been disaggregated by fuel type in Figure 17. The relative importance of fuels and long-range

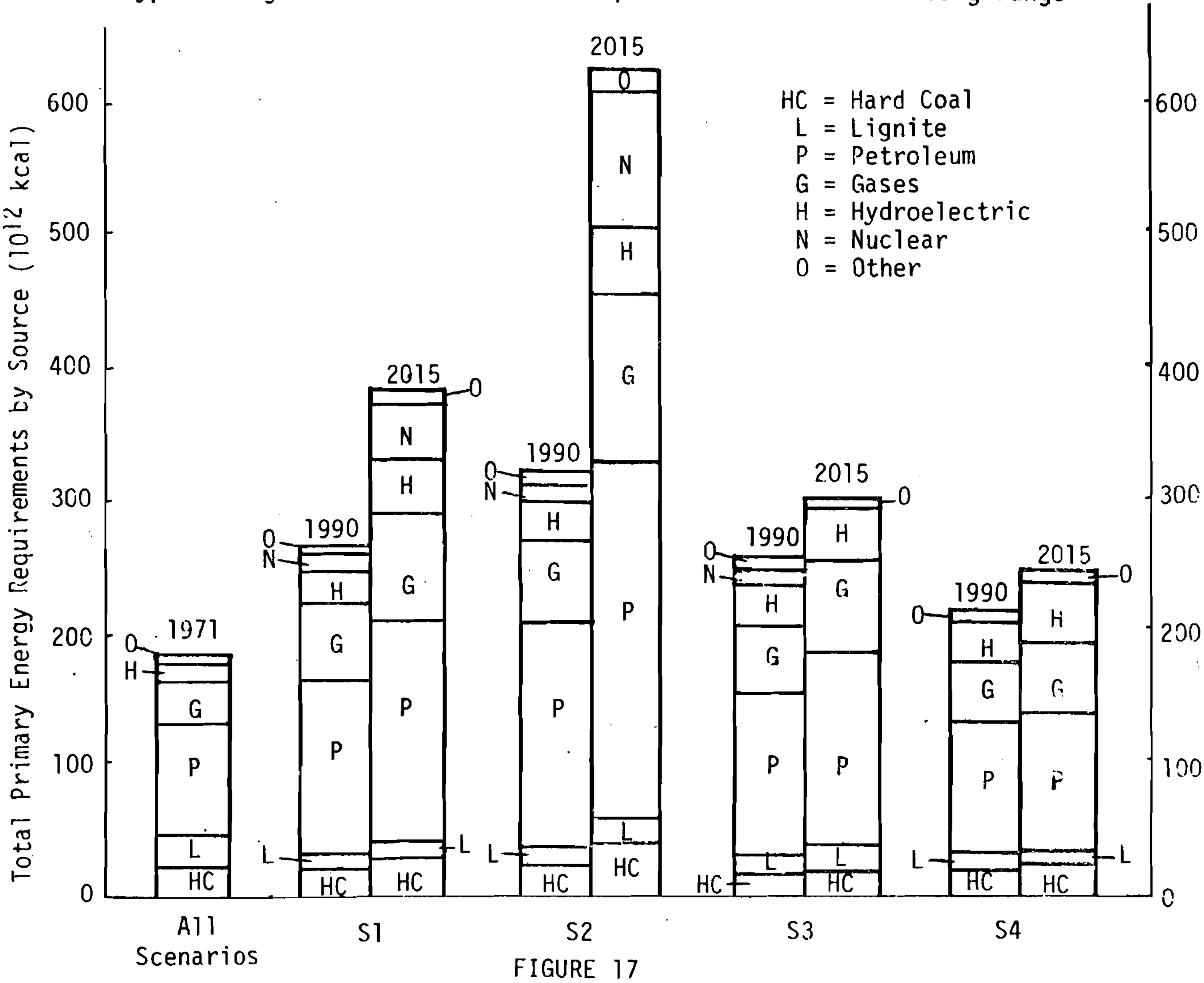

FIGURE 17

TOTAL PRIMARY ENERGY REQUIREMENTS BY FUEL TYPE S1-S4

fuel demand trends are graphically illustrated. Both hard coal and lignite, which each represent 11% of primary energy in 1971, decline in significance by 2015 in all scenarios. The two energy sources which show a clear increase in importance over time are hydropower in the low (S3) and conservation (S4) scenarios, and nuclear power in the base (S1) and high (S2) scenarios.

Total electricity generation requirements for the four scenarios are illustrated in Figure 18, along with historical data for the 1945-1971 period. A comparison between the high growth scenario (S2) and the conservation scenario (S4) shows that S2 requires over twice as much electricity in 2015. This large increase would lead to extremely high levels of fuel imports. In all scenarios, except S2, the growth in electricity is less than historical trends.

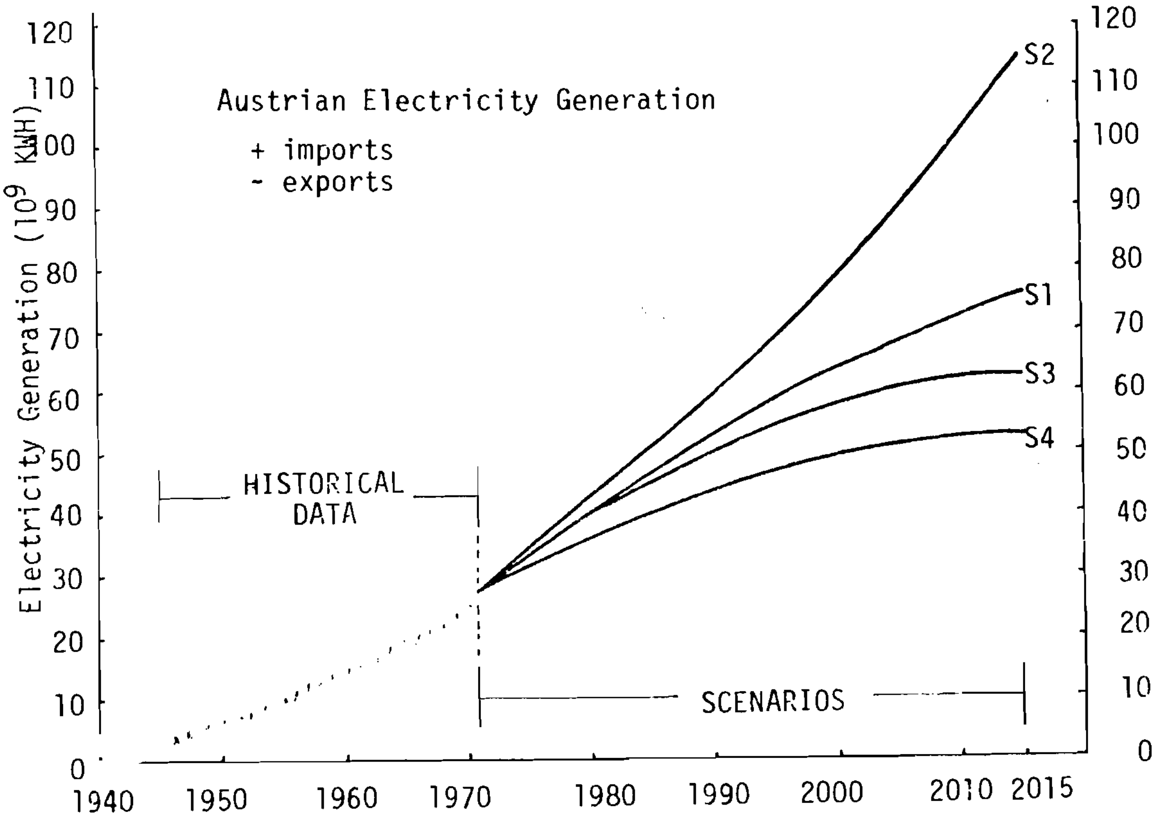

FIGURE 18

ELECTRICITY GENERATION: HISTORICAL DATA AND SCENARIOS, S1-S4

The mix of fuels used in the generation of electricity varies greatly between the four scenarios, as shown in Figure 19. This

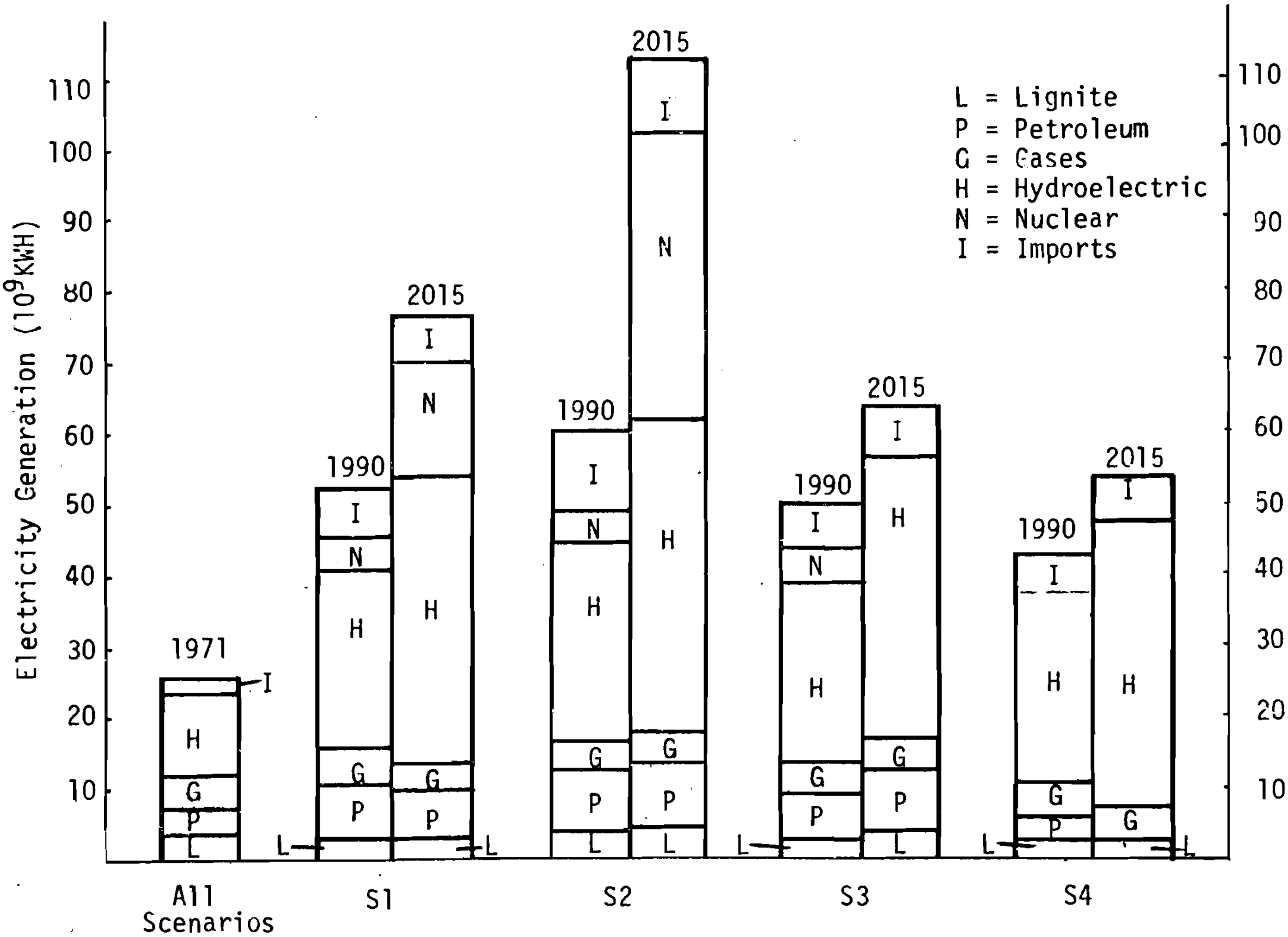

FIGURE 19

ELECTRICITY GENERATION BY SOURCE, S1-S4

variation is a result of the wide range of electricity demands and the fuel use trends that resulted from specific policy assumptions. In the base case scenario, the electricity demand in 2015 was met through full exploitation of hydropower (increasing from 45% in 1971 to 53% of requirement in 2015) the operation of two 1300 MWe nuclear plants (21%), imports of 6.9 x 10^9 kWh (9%), and the operation of fossil-fired plants at levels only slightly higher than in 1971 (17%).

The very high electricity demands in 2015 in scenario S2, nearly four and one-half times the 1971 level, could be supplied through the construction of five 1300 MWe nuclear plants (34% of total), full exploitation of hydropower (38%), high levels of electricity imports (10%), and expansion of the fossil-fuel generation base (18%). This "high" nuclear future could have a number of major environmental and policy implications.

In contrast to these high demand scenarios, the low electricity requirements of S3 could be met with no nuclear power after Zwentendorf. This could be accomplished by fully exploiting hydropower, expanding electricity imports, and by a slow expansion (about 7%) of fossil-fueled capacity between 1971 and 2015.

The still lower electricity requirement of S4 in 2015, only a factor of two greater than the 1971 level, could be met with no nuclear power and no oil-fired generation. This could be accomplished in a manner similar to scenario S3, with the exception that coal- and gas-fired generation could be maintained at 1971 levels.

Petroleum Shortfalls. The present uncertainty surrounding world petroleum reserves and production rates, and its impact on future supply availability, is an extremely important concern in developing a comprehensive energy supply strategy. Results of recent studies forecast potential petroleum shortfalls developing in the mid- to late-1980's. Our study has estimated Austria's future oil supplies using a world forecast developed by the Workshop on Alternative Energy Strategies (WAES).* The petroleum supply curve was based on the 33 Million Barrels of Oil Per Day (MBOD) production limit (non-communist countries) scenario with a reserve addition rate of 10 billion barrels per year and 3% economic growth. The WAES supply curve peaks shortly after 1990.

As a basis of comparison of supply and demand in Austria, petroleum imports to Austria were assumed to decrease at the same rate as total world production. This leads to a petroleum shortfall of 20 million barrels of oil per year (about 0.05 MBOD) by 2015. In scenario S4, as illustrated in Figure 20, this sizeable shortfall develops despite the low growth in energy demand resulting from conservation measures, lower economic growth,

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*Wilson, Carroll. Energy: Global Prospects 1985-2000. McGraw-Hill, New York, 1977.

and the phasing out of petroleum for electrical generation.

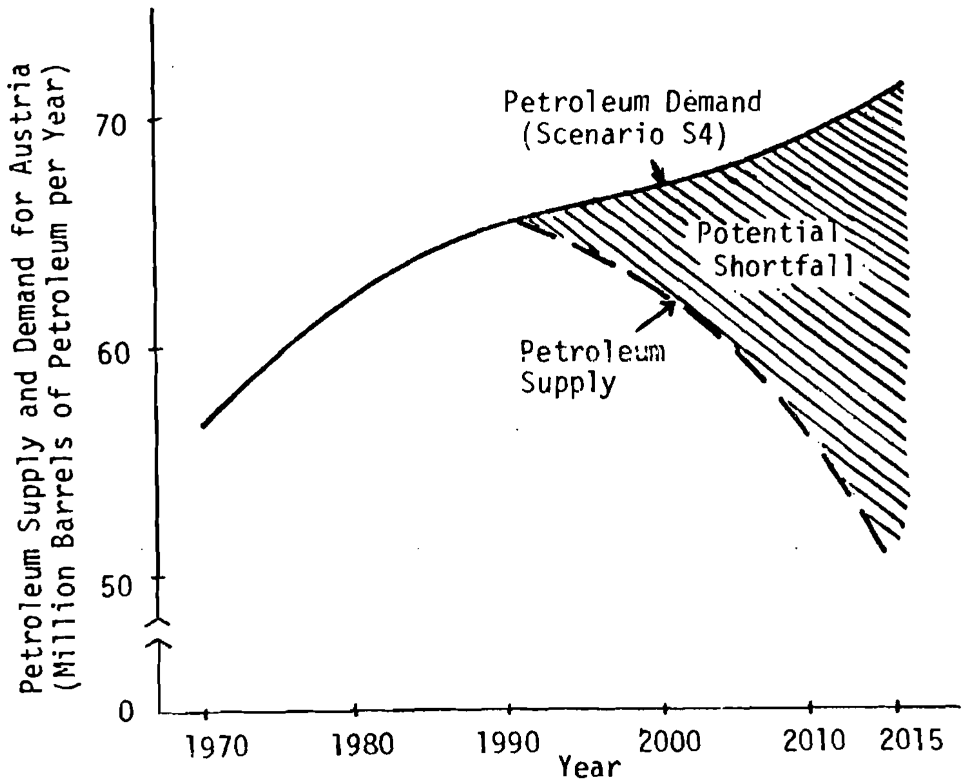

FIGURE 20

DIVERGENCE BETWEEN DEMAND AND ESTIMATED PETROLEUM SUPPLY IN SCENARIO S4

B. RESOURCE SUPPLY OPTIMIZATION

A detailed study of interfuel competition within the Austrian energy supply system was made for the year 1990. Reference energy systems were developed for scenarios S1, S2, and S3. The analysis was performed using the Brookhaven Energy System Optimization Model, BESOM,* which is a resource allocation model designed to examine interfuel substitution within a framework of constraints on the

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*Hoffman, K.C. A Linear Programming Model of the Nation's Energy System, Brookhaven National Laboratory, February 1973.

availability of competing resources and technologies and their associated costs. For this study, a version of the Brookhaven model was modified to reflect the specific characteristics and structure of the Austrian energy system, including appropriate technologies, coefficients, and costs.

Assumptions. Adequate supplies of lignite, oil, and natural gas were assumed, and these fuels were allowed to compete for end-use demands on an economic basis. In addition, hydroelectric power was allowed to actively compete with the fossil fuels for electrical sector demands. Upper fuel use bounds were specified and a maximum hydro generation limit was imposed (34.5×10^9 kWh). This limit represents the hydro generation projected in the revised Energieplan. Direct end-use demands for hard coal, lignite, oil, natural gas, and wood and waste products were constrained to the levels of consumption specified in three 1990 scenarios. Nuclear generation was held fixed in each of the cases.

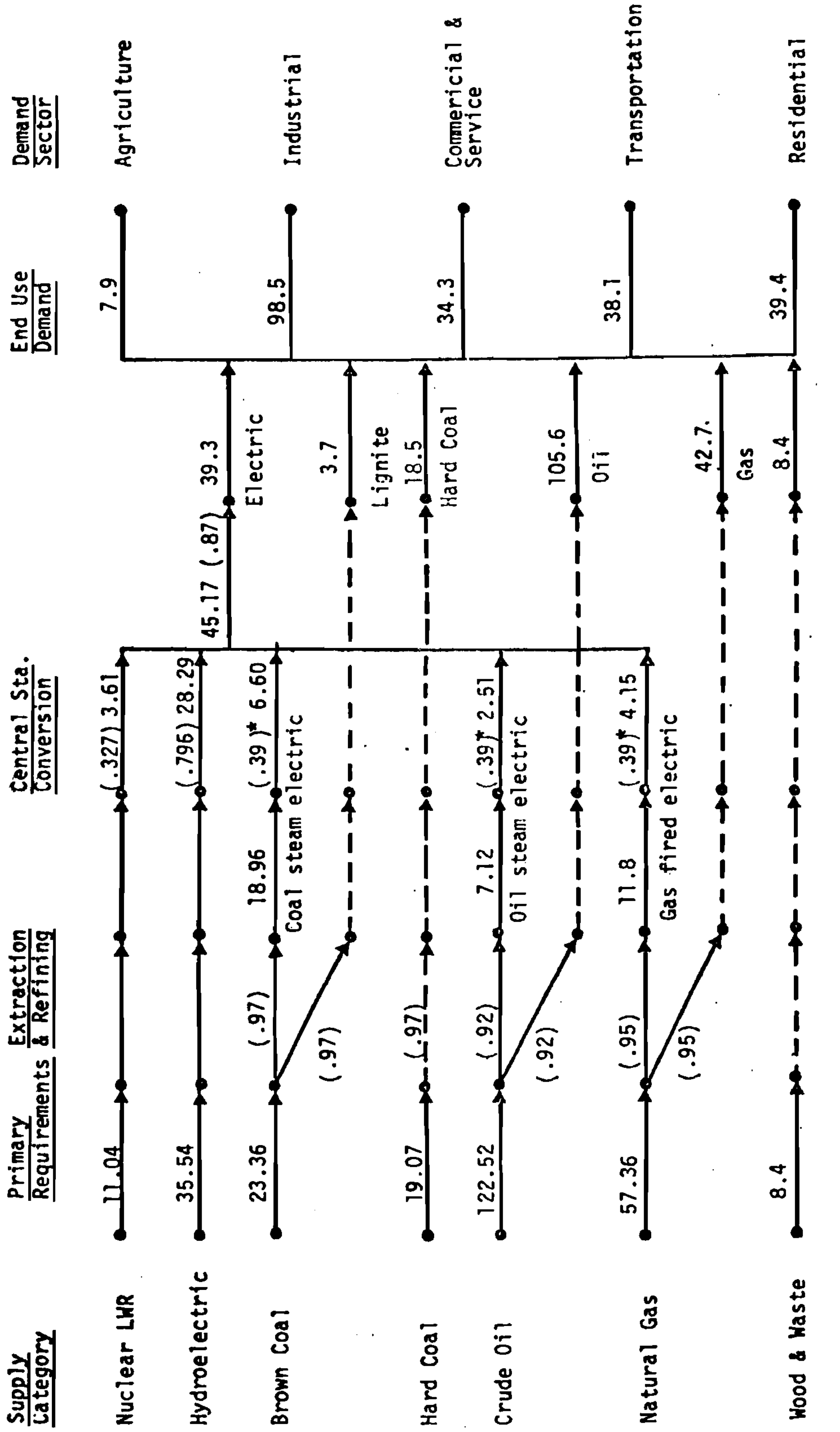
Power plant capital costs for thermal electric generating stations were such that nuclear had the highest cost per kWe installed, followed by coal, oil, and gas. Hydroelectric plants were assigned capital costs of nearly twice that of coal per kWe installed. Annual operation and maintenance costs were generally about 3-4% of the plant capital costs. Fuel prices were set based on a crude oil price of $13/bbl and a uranium price of $35/lb U_3O_8. The objective function minimized in this analysis was total system cost, which reflects capital costs, operation and maintenance costs, and fuel costs.

Results and Conclusions. In each of the three cases, analysis of BESOM results showed lignite providing roughly 14% of the electricity generation in 1990, and accounting for 8% of Austria's total primary energy requirements. In contrast, oil- and gas-fired generation together provided only about 13% of the electrical sector supply needs, although they accounted for nearly 65% of the total energy supply requirements. For perspective, the results of the supply scenarios (Part A) showed lignite meeting only about 6% of the electricity requirements in 1990, while oil- and gas-fired generation supplied between 18-25% of the total electrical sector needs. In effect, the importance of electrical energy supplied by oil- and gas-fired generation and by lignite-fired generation was reversed compared to the results of the scenario analysis.

The main result of the economic optimization procedure was the noticeable fuel shift in the electrical sector away from oil and gas toward a greater use of lignite. This shift is dependent upon several important constraints, including adequate future supply levels of lignite and a competitive pricing structure relative to gas and oil. Further, environmental constraints (not used in this analysis) may play an important role in deciding the future levels of lignite use in the Austrian electrical sector. However, the analysis does suggest the need for a closer examination of lignite use for electricity, and its future use should be carefully considered, especially in light of possible oil supply shortages in the next 10-20 years. The potential curtailment of oil supplies could necessitate a shift in the electrical sector toward a greater reliance on lignite, a reversal from current trends.

Although the market penetration levels of nuclear power were held fixed in each of the three cases, an analysis of the marginal values for uranium indicated that nuclear fuel would be competitive with $13/bbl oil at a U_3O_8 price of up to roughly $40/lb. Results also tended to show a lower level of hydroelectric capacity than was forecast in either the Energieplan of Austria or the "IMES-IV" Study. This trend was probably attributable to the high capital cost estimates used for new hydroelectric plans relative to those used for other central stations. However, the hydro capital costs were offset to some extent by the high conversion efficiency (.796) assumed in the calculations.

A simplified reference energy system diagram corresponding to the 1990 S1-demand scenario is shown in Figure 21. This diagram traces the flow of primary resource energy through the Austrian energy system.



TOTAL RESOURCE CONSUMPTION = 277.3

TOTAL END USE DEMAND = 218.2

*The .39 efficiency refers only to power plants, not to combined-cycle plants.

Notes:
1. Solid element denotes a real activity.
2. Energy flows are indicated in 10^{12} kcal.
3. Conversion efficiencies are in parentheses.
4. The flow diagram is greatly simplified.

FIGURE 21

AUSTRIAN REFERENCE ENERGY SYSTEM

SCENARIO S1 - 1990

VII. ENVIRONMENTAL IMPLICATIONS

A large set of environmental impacts due to energy use in Austria is calculated for each scenario by the environmental simulation models. The models, developed at the University of Wisconsin and IIASA for regional studies, have been reparameterized and adapted to Austrian conditions.

The calculated impacts result from both end-use energy demand and primary energy requirements and include the entire fuel chain. Impacts at each point in the fuel chain are calculated, from impacts at the place of extraction of the raw fuel, through processing and transportation impacts, to impacts from burning the fuel. This means that impacts occurring both inside and outside of Austria are tabulated.

The impacts calculated by the environmental models are called "quantified impacts." They do not represent all of the impacts known to occur; the quantified environmental impacts are those impacts which we judge to have an adequate scientific basis for their evaluation and inclusion in the models. Only those impacts resulting directly from the use of energy are calculated. Impacts are calculated for each simulation year; time-dependent calculated changes, stemming from regulations or technological advances are taken into account.

The environmental models calculate impacts along the fuel chains for coal, nuclear, oil and gas systems, including impacts connected with electricity generation, and air pollution impacts due to end-use combustion of fuels. The air pollution impacts are primarily concerned with human health at the urban level. For manageability, only a small subset of the quantified impacts was chosen for presentation here. Table 11 presents a representative set of impact categories and their measures. Evaluation of this set of impacts presents only one picture of the environmental state of the system; however, it can provide insight for assessing some of the energy-related environmental issues in Austria. A more extensive description of impacts will be presented in the final report for this study. The limited set is discussed briefly below.

Table 11

Selected Quantified Environmental Impacts

(1)	Human Health and Safety	
	Fatalities	Annual Deaths
	Occupational Accidents	Annual PDL*
	Public Accidents	Annual PDL
	Occupational Health	Annual PDL
	Public Health	Annual PDL
(2)	Land Use for Resource Extraction	Km^2/year
(3)	Land Use for Facilities	Km^2
(4)	Radioactive Waste Produced	Tons/year
(5)	SO_2 Emissions	Tons/year

Human Health and Safety is receiving considerable attention in Austria. Many of the current discussions address the setting of environmental standards to protect human health. Occupational accidents, occupational deaths, and occupational health comprise the routine accidents and exposures that occur in the fuel cycle to supply energy; they represent "voluntary" exposure to risk of injury. Public accidents, deaths and health represent the "involuntary" risks society is exposed to from the energy system. The units of measurements are deaths and Person-Days-Lost (PDL). The concept of PDL combines different types of accidents and sickness into one measure. Each type of accident or sickness has, on the average, a characteristic number of days of meaningful interaction per individual that are lost to society. For example, if workers injured in a particular type of industrial operation lose an average of 30 days of work per injury, this represents 30 PDL per injury. Total PDL is divided into "inside" and "outside" Austria, because there is usually more concern with PDL occurring within Austria.

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*PDL = Person-Days-Lost

Land use impacts are included in Table 11 because of the quantities of land devoted to sites of energy facilities. Land use serves as an indicator of many asthetic impacts of the energy system, for example, power plants with tall stacks, cooling towers dotting the landscape, or the increasing number of transmission lines required to transport electricity.

Radioactive waste produced is included in view of the nuclear controversy in Austria, and the associated concern about waste disposal. This impact is one indicator of long-term commitments made by society for the safeguarding of nuclear wastes.

SO_2 emissions are included in response to concern with the setting of air pollution standards in Austria. They are one indication of the issues and problems involved in pollution abatement strategies, including standard setting, where human health is an important consideration.

Results and Conclusions. Table 12 compares results for selected annual impacts within Austria in the years 1971 and 2015.

Table 12

SCENARIO RESULTS OF SELECTED ENVIRONMENTAL IMPACTS

	1971	2015			
		S1	S2	S3	S4
Fatalities within Austria (Deaths/year)	18	2.4	3.9	2.0	1.5
Total PDL within Austria (10^3 PDL/year)	290	130	200	100	85
Land Use for Resource Extraction (km^2/year)	16	23	36	21	17
Land Use for Facilities (km^2)	110	320	380	290	280
Radioactive Waste (Tons/year)	0.0	6.9	17	0.0	0.0
SO_2 Emissions (Tons/year)	300	200	280	190	150

Austrian human health and safety impacts decrease compared to 1971, primarily because of improved environmental technology and because of the importation by 2015 of all coal, which has a large occupational health and safety risk relative to oil and gas. Facility land use is the fastest growing impact, growing faster than energy use. This is mainly due to hydropower. We conclude that land use should be given increasingly greater attention in determining Austria's energy policies.

Radioactive waste production is an important impact that cannot be ignored because of the Austrian government's decision that nc nuclear power plant should begin operation until the waste storage questions in Austria have been solved. There are large differences in annual waste production among the four scenarios. Although the annual quantities of radioactive waste produced appear small, cumulative effects must be considered.

SO_2 emissions in S1 decrease by 33% over 1971 because of the regulations assumed in the scenarios. Public health impacts inside Austria in 2015, due mainly to air pollution, decrease however only by 16% relative to 1971.

In 1971, five major cities, (Vienna, Linz, Graz, Salzburg and Innsbruck) account for 87% of this air pollution health impact. By 2015, these same cities account for 80% of the air pollution impact. The major factors in this decline from 1971 are the movement of people away from Vienna and a slight improvement in Vienna's air pollution levels; no significant change occurs in the other cities.

Table 13 presents results for scenario S1 for selected impacts on human health and safety, categorized according to whether they occur inside or outside Austria. Total human health and safety impacts

TABLE 13

HUMAN HEALTH AND SAFETY INSIDE AND OUTSIDE AUSTRIA*

Scenario S1

	1971			2015		
	Inside	Outside	Total	Inside	Outside	Total
Fatalities (Deaths/year)	18	23	41	2.4	40	43
Occ. Accidents (10^3 PDL/year)	100	140	230	18	240	260
Public Accidents (10^3 PDL/year)	3.9	23	27	4.8	32	37
Occ. Health (10^3 PDL/year)	60	82	140	3.7	140	150
Public Health (10^3 PDL/year)	120	0.6	120	100	0.7	100
TOTAL PDL (10^3 PDL/year)	290	240	530	130	420	540

*Columns may not add because of rounding.

outside Austria increase, because all coal is imported by 2015. For the same reason, the indicator for total human health and safety within Austria improves. Nevertheless, an important change in the character of the human health impact within Austria takes place. In 1971, the Public Health PDL, which is only an indication of the total air pollution impacts, was 43% of the total. By 2015, it is 79% of the total. Health impacts, which currently have a large occupational fraction, become in the future mostly societal health impacts through air pollution.

The total human health and safety impacts in Table 13 can be given some perspective by comparing them with accident statistics for Austria. For example, in 1974, some 2,860 pedestrians were severely injured in street accidents; if six months of lost time are associated with each accident, the person-days-lost equal 510,000 PDL. The total energy-related human health and safety impacts attributable to Austria, shown in the total columns of Table 13, has an almost equivalent impact. Thus, although these impact estimates are not meant to serve as forecasts, we must conclude that energy-related impacts on human health and safety are significant and may require even stricter pollution control measures than currently anticipated.

One important environmental issue in Austria is the setting of air pollution standards. Three sets of standards are assumed in our scenarios:

Stage 1: Complete implementation by 1981 of desulfurization of oil to new limits set by the Austrian ministry of health and environment.
Stage 2: For all emission sources, implementation, starting in 1985 and completed by 2000, of the present U.S. emission standard of 2.16 kg of $SO_2/10^6$ kcal on all emission sources.
Stage 3: For all point sources, implementation starting in 2000 and completed by 2015, of the more stringent U.S. emission standards anticipated for 2000 (0.91-1.08 kg of $SO_2/10^6$ kcal), modified by economic growth considerations:

S1: reduction to 1.08 kg $SO_2/10^6$ kcal
S2: reduction to 0.91 kg $SO_2/10^6$ kcal
S3, S4: reduction to 1.53 kg $SO_2/10^6$ kcal.

The present U.S. standard would require a further 44% reduction of heavy oil sulfur content to 1.13%, a reduction of sulfur content by 11% for hard coal and up to 23% for brown coal. This would be achieved through the use of sulfur removal systems at the stack, some chemical cleaning of the coal used by industry and electricity plants, or by setting import restrictions. It is important to note that imposing the U.S. emission standard only affects industrial and electricity generating sources. After the oil desulfurization of Stage 1, standards of fuel sulfur content for residential and commercial fuels in Austria are already equivalent to the present U.S. Standard.

In a sensitivity study designed to address the effectiveness of the SO_2 emission standards, the U.S. standards and the oil desulfurization policy in scenario S1 were sequentially removed to evaluate the effect of these regulations on emissions and on human health. The results are presented graphically in Figures 22 and 23. While all standards

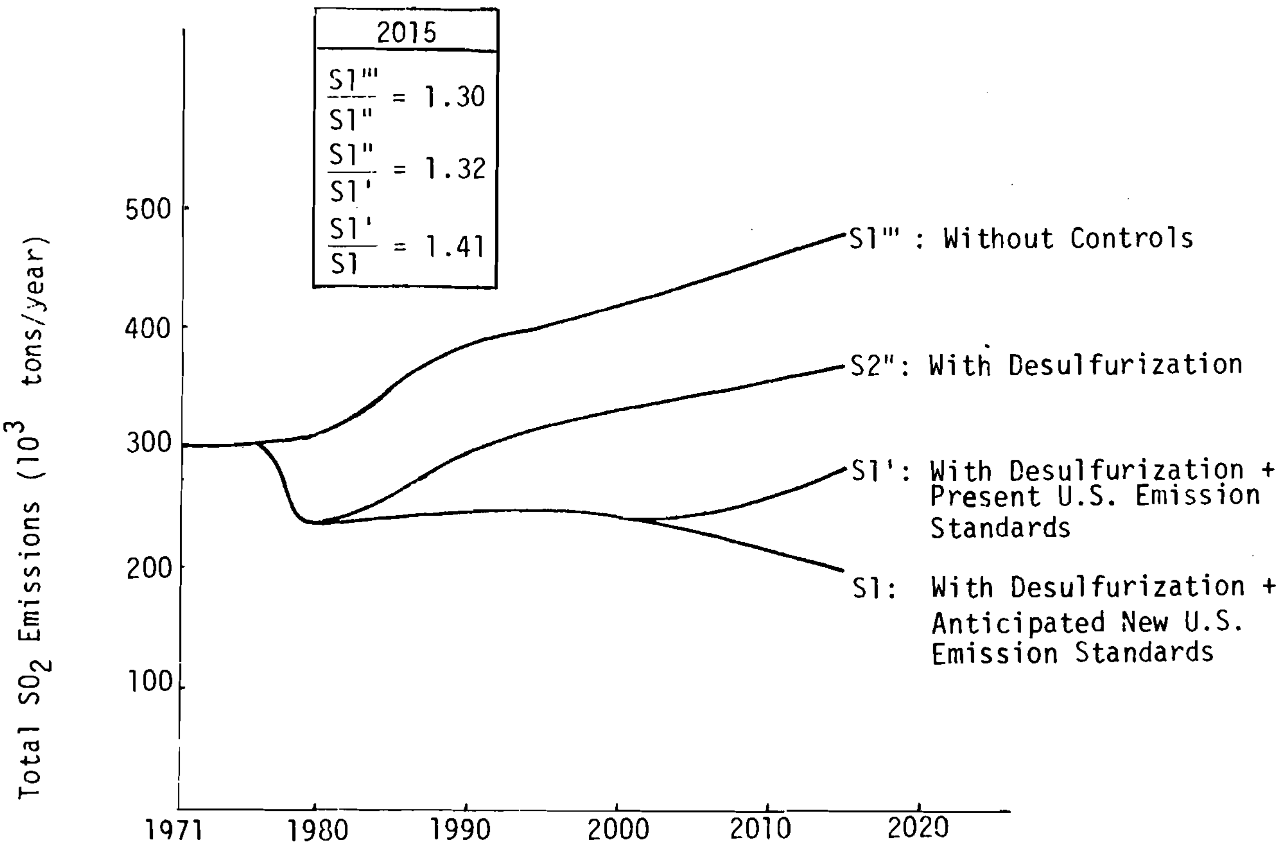

FIGURE 22

SENSITIVITY OF SO_2 EMISSIONS TO SO_2 REGULATIONS

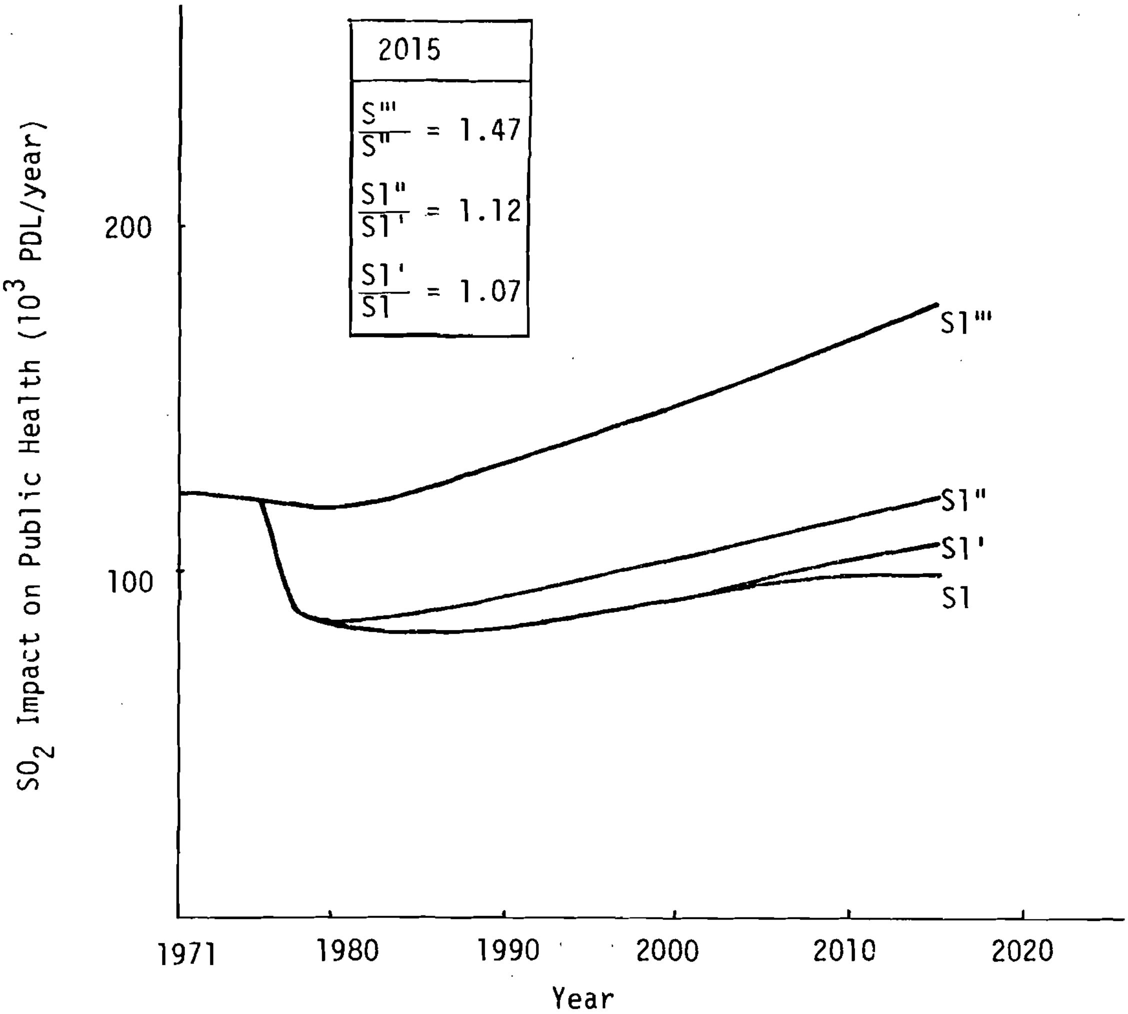

FIGURE 23

SENSITIVITY OF AIR POLLUTION PUBLIC HEALTH IMPACTS TO SO_2 REGULATIONS

have a significant effect on SO_2 emissions, only the petroleum desulfurization has a significant effect on health impact. This is because residential and commercial emissions (not affected by the U.S. standards) more strongly affect health in urban areas per unit of emissions than industrial or electrical plant sources of emissions. A further significant reduction in the human health impact would require more stringent standards than assumed here for the sulfur content of the fuels used by the commercial and service and the residential sectors.

Another strategy to further reduce health impacts would be to implement conservation programs and insulation standards in the residential and commercial sectors to reduce the amount of fuel required for space heating; this would have the same effect as setting more stringent SO_2 emission standards. However, there can be a long time lag before any conservation effect is seen, due to the length of the time involved in implementing insulation standards. Therefore, the SO_2 regulations of the nature described here should be considered as an effective means for protection of public health.

VIII. SOME CONCLUDING OBSERVATIONS

This Executive Summary has presented the essence of the results of our study of the past 14 months. It has focussed on the examination of alternative energy futures and strategies for Austria and some of their environmental implications. A final report will be published at the beginning of 1978. It will contain more detailed results and descriptions of methodology. A current list and copies of documentation of methods, models, etc. used in this and our previous studies are available at IIASA and should be considered a supplement to this Executive Summary. The results of the study will also be presented in more detail at a conference for Austrian planners and energy/environment specialists in November 1977.

This Executive Summary has excluded any discussion of the second major objective of our study, namely, the investigation and implementation of methodologies for energy/environment management and policy design in Austria. We do believe this second objective is of great importance, and that Austria could derive benefits from incorporating some of these concepts and analytical tools into its existing set of policy design techniques. The link of this study with various Austrian institutions has already initiated that process in an informal way. During the concluding months, we will devote major attention to the documentation of models, data bases, and information systems, both at IIASA and at the collaborating institutions in the U.S.A. A major report on methodology will be published in early 1978. The appropriate Austrian agencies and institutions should examine their specific needs and capabilities to make the strong commitment that would be required for a successful transfer of methodology.

APPENDIX A

End-Use Total Energy Demands *

(10^{12} Kcal)

	All Scenarios	S1		S2		S3		S4	
	1971	1990	2015	1990	2015	1990	2015	1990	2015
Agriculture	5.2 3.5%	7.9 3.5%	10.2 3.3%	9.6 3.5%	17.6 3.6%	7.8 3.6%	8.8 3.4%	6.4 3.4%	7.0 3.2%
Industrial	61.8 41.7%	98.5 44.0%	142.3 45.8%	116.2 42.6%	231.9 47.0%	95.7 44.3%	114.0 44.0%	81.1 43.4%	96.2 44.2%
Commercial and Service	17.0 11.5%	34.3 15.3%	49.4 15.9%	39.0 14.3%	69.1 14.0%	33.8 15.6%	44.2 17.1%	27.1 14.5%	33.5 15.4%
Transportation	31.5 21.2%	38.1 17.0%	50.8 16.3%	50.4 18.5%	89.4 18.1%	35.7 16.5%	43.8 16.9%	29.7 15.9%	35.3 16.2%
Residential	32.8 22.1%	45.2 20.2%	58.0 18.7%	57.4 21.1%	85.2 17.3%	43.2 20.0%	48.5 18.7%	42.7 22.8%	45.8 21.0%
TOTAL	148.3	224.0	310.8	272.5	493.2	216.2	259.2	187.0	217.8

*Columns may not add because of rounding.

APPENDIX B

Primary Energy Demands by Fuel *

(10^{12} Kcal)

	All Scenarios	S1		S2		S3		S4	
	1971	1990	2015	1990	2015	1990	2015	1990	2015
Hard Coal**	20.9 11.5%	20.2 7.6%	25.2 6.6%	23.9 7.5%	37.7 6.0%	19.6 7.6%	20.7 6.8%	20.3 9.4%	22.5 9.1%
Brown Coal	19.2 10.6%	11.5 4.3%	11.9 3.1%	15.6 4.9%	19.1 3.1%	10.7 4.2%	13.3 4.4%	11.1 5.2%	10.6 4.3%
Petroleum	89.4 49.3%	129.3 48.4%	170.5 44.8%	161.2 50.2%	271.2 43.3%	123.1 47.9%	151.1 49.7%	100.0 46.5%	106.9 43.4%
Gases	31.7 17.5%	58.4 21.8%	77.4 20.3%	67.1 20.9%	126.0 20.1%	56.2 21.9%	67.2 22.1%	47.4 22.0%	54.9 22.3%
Hydropower ***	13.0 7.2%	27.7 10.4%	43.0 11.3%	29.9 9.3%	47.6 7.6%	27.7 10.8%	43.0 14.1%	27.7 12.9%	43.4 17.6%
Nuclear	- -	11.0 4.1%	42.1 11.0%	11.0 3.4%	105.2 16.8%	11.0 4.3%	- -	- -	- -
Waste Products	7.0 3.9%	9.3 3.5%	10.9 2.9%	12.1 3.8%	19.3 3.1%	8.9 3.5%	8.9 2.9%	8.5 4.0%	8.0 3.2%
TOTAL	181.2	267.4	381.0	320.8	626.1	257.2	304.2	215.0	246.3

* Columns may not add because of rounding.

** Including coke.

*** Conversion factor: 1 GWH = 1.08 Tcal

APPENDIX C

PAPERS IN THE IIASA PUBLICATION SERIES ON MANAGEMENT OF ENERGY/ENVIRONMENT SYSTEMS

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