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ASSESSMENT OF ALTERNATIVE ENERGY/ ENVIRONMENT FUTURES FOR AUSTRIA: 1977–2015

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PREFACE

The Austrian Regional Energy/Environment Study was initiated in August 1976 at the International Institute for Applied Systems Analysis (IIASA), and is the fourth in a series of IIASA studies on regional energy and environmental systems. The regions studied previously were the German Democratic Republic (GDR), the Rhone-Alpes Region in France, and the state of Wisconsin in the U.S. The Austrian case study, regional in scope, complements the work of the IIASA Energy Systems Program which focuses primarily on global aspects of energy.

The study has been supported by a generous grant from the Austrian National Bank as well as by IIASA internal funding. It has been conducted by the scientific staff of the IIASA Resources and Environment Area, in collaboration with the University of Wisconsin-Madison, U.S., and with the cooperation of many individuals and institutions in the Austrian energy and environment communities. Although inputs to the research were provided by a large number of people, responsibility for the major findings and conclusions stated here rests solely with the authors.

The study was concluded in early 1978. This final report contains the study's major findings. An Executive Summary (Foell *et al.*, 1977), preliminary in form but containing essentially the same conclusions as this report, was published in English and German in late 1977. A report describing the methods used in this study and in the other three regional energy/environment case studies is in preparation.

In response to the public debate which surrounded the proposed opening of Austria's first nuclear power plant at Zwentendorf, Austria, the Austrian government called for a referendum to be held on November 5, 1978, after the study was concluded. On this occasion a majority voted against putting the plant into operation.

As a result of the outcome of the referendum, plans for developing nuclear power in Austria have been laid aside. In light of these events, the energy future examined in the Conservation Case, scenario S4, of the Austrian case study deserves close attention. Under the conditions of low energy demand examined in this low growth scenario, it appeared feasible to meet the electricity requirements of the coming decades *without* nuclear power, if coal or hydropower were exploited fully. Because of the possibility of a nonnuclear future for Austria, the methods for slowing growth in energy demand described in S4 deserve careful attention.

The limited time period over which the Austrian case study was conducted restricted both the breadth and the depth of the issues addressed. However, the authors believe that the study has provided a framework within which many of the central issues can be assessed and discussed, and that it identified major points for which information is lacking. The final report refrains from making specific policy recommendations. We have, however, explicitly laid out the conclusions so as to focus upon possible courses of action. We hope that public discussion can continue along these lines.

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- Bureau of the Provincial Government of Carinthia, Department of Land Use Planning (Amt der Kaerntner Landesregierung, Abteilung Landesplanung), Klagenfurt, Austria
- Federal Chamber of Commerce (Bundeskammer der gewerblichen Wirtschaft), Vienna, Austria
- Federal Ministry for Health and the Environment (Bundesministerium fuer Gesundheit und Umweltschutz), Vienna, Austria
- Federal Ministry for Commerce, Trade, and Industry, Energy Section (Bundesministerium fuer Handel, Gewerbe, und Industrie, Energiesektion), Vienna, Austria
- Brookhaven National Laboratories, Upton, New York, U.S.
- Energy Research Center, University of Wisconsin-Madison, Wisconsin, U.S.
- Institute for Environmental Studies, University of Wisconsin-Madison, Wisconsin, U.S.
- Nuclear Power Planning Company Ltd. (Kernkraftwerk Planungsgesellschaft m.b.H.), Vienna, Austria
- Municipality of Linz, Institute of Hygiene (Magistrat Linz, Hygieneinstitut), Linz, Austria

- Austrian Electricity Generating Board (Oesterreichische Elektrizitaetswirtschafts AG, Verbundgesellschaft), Vienna, Austria
- Austrian Institute for Building Research (Oesterreichisches Institut fuer Bauforschung, Vienna, Austria
- Austrian Institute of Regional and Urban Planning (Oesterreichisches Institut fuer Raumplanung) (OeIR), Vienna, Austria
- Austrian Petroleum Administration (Oesterreichische Mineraloelverwaltung (OeMV), Vienna, Austria
- Austrian Central Statistical Office (Oesterreichisches Statistisches Zentralamt) (OeStZ), Vienna, Austria
- Austrian Institute for Economic Research (Oesterreichisches Wirtschaftsforschungsinstitut) (WIFO), Vienna, Austria
- Vienna Municipal Utilities Corporation (Wiener Stadtwerke, Energiereferat), Vienna, Austria

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

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

CONTENTS

1 SUMMARY AND CONCLUSIONS

The study of alternative energy/environment futures for Austria for the period 1977–2015 had two primary objectives:

- To examine alternative energy futures and strategies for Austria and to consider some of their environmental implications
- To investigate and implement appropriate concepts and methodologies for energy/environment management and policy design in Austria

The principal issues studied were: energy demand, energy conservation, energy supply options and strategies, and environmental impacts and protection strategies. The issues examined were chosen in concert with a large number of members of the Austrian energy/environment communities.

The analytical approach of this study was based on a set of models developed at IIASA and at the University of Wisconsin-Madison, U.S., for long-term energy/environment management at the regional level. The models, primarily of the simulation type, were applied within a scenario framework in which several alternative scenarios through the year 2015 and sensitivity studies were conducted. The extensive data base with which the models were paramaterized was derived from a number of sources, including the Austrian Central Statistical Office (OeStZ), the Austrian Institute for Economic Research (WIFO), the Austrian Electricity Generating Board, the Economic Chamber of Austria, and the Austrian Institute of Regional and Urban Planning (OeIR).

Four scenarios of energy demand and supply were developed within a range of economic patterns; energy demand implications of population and economic factors, of selected lifestyle patterns, and of some energy-use technologies were inferred from the scenarios and the associated sensitivity studies. The major findings of the study are presented below in qualitative terms.

1.1 ENERGY DEMAND

Total energy demand will increase at a rate considerably lower than that of 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.

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

Electricity will supply an increasing fraction of total end-use energy. Nevertheless, the growth of electricity generation will be much lower than historical rates. Needs for future facilities should be examined in light of this finding.

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 over the next few decades appears to be greatest in the commercial and service sector of the economy, with the lowest growth likely in the transportation and communication sector.

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.

1.2 ENERGY SUPPLY

Extrapolation of the current Austrian energy forecasts shows a continuation of the trend toward greater reliance on petroleum and natural gas. The assessment of world petroleum resources and future demands indicates that a gap will exist in the 1990s between petroleum demand and supply in Austria, even under the assumption of low growth (the Conservation Case, scenario S4). It would be possible, from a technical standpoint, to close the gap in the Conservation Case by shifting to coal in the industrial sector. In the commercial and service and the residential sectors, a continued reliance upon, or shift back to, coal and wood could help to avoid shortfalls in rural areas. In urban areas, a shift to district heat (possibly coal-fired) could decrease the reliance on petroleum.

Coal is generally considered an unattractive long-term supply option for Austria. However, the authors' 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. However, the associated environmental impact would be significant.

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

1.3 ENVIRONMENT

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

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: Vienna, Salzburg, Graz, Linz, and Innsbruck.

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

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 caused by carbon dioxide (CO_2) emissions from the 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 in order to avoid the "tragedy of the commons" on a global scale.

2 INTRODUCTION

In Austria, as in most countries and regions, there is a need for developing and applying methods for the study of regional energy systems and for testing the impact of alternative policies. Since energy plays a major role in determining environmental quality, the Austrian case study was designed to aid in the integration of energy/environment management from a systems perspective.

"Regional," in the context of the three previous case studies (Foell, 1977), is not defined as subnational or as a class of geographic units; rather, it refers to a region, appropriately bounded so that it is possible to consider energy and environmental systems from a physical, or a socioeconomic, or an administrative perspective, or from all three. Initially, we intended to limit the scope of the study to a selected few Austrian regions (Bundeslaender); we realized quickly that Austria's size and vigorous interregional links precluded anything less than a national study.

2.1 INSTITUTIONAL FORMAT OF THE STUDY

The study was conducted in an institutional format that promoted frequent interaction between the study team and the individuals and institutions for whom the results are intended. After the completion of the initial organizational phase of the study with IIASA, a 3-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, at both the regional and the national levels. This workshop helped to determine the issues addressed by the study, and served to establish an information flow between the IIASA team and members of the participating institutions, some of whom provided data or conducted analyses. A second workshop, in July, 1977, served to evaluate the study to that point, and to establish priorities for the final phase. The Austrian participants in that workshop suggested the format for disseminating to the energy/environment community the conclusions and methods resulting from the study. The final results of the study were presented to the Austrian energy/environment community at a conference held at IIASA in November, 1978.

2.2 ISSUES STUDIED

The issues studied were chosen through an iterative procedure, beginning with suggestions by participants at the first workshop, followed with exploration by the IIASA study team to see whether the issues could be analyzed within the time and the resource limitations. It was decided to address broad medium- to long-term strategies and policies rather than issues related to day-to-day operational problems. Consequently, the time horizon of the study is 1977–2015, with greater attention devoted to the earlier part of the period. Although there was a broad spectrum of issues raised, the four categories of issues studied were:

- Energy demand
- Energy conservation
- Energy supply options and strategies
- Environmental impacts and protection strategies

The probable and *possible levels of future energy demand* in Austria is a central issue. 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, to transportation systems design, to industrial structure and technology, and to energy-use technologies in general. In Austria, as in many other countries, the relationship between energy use and social well-being is being debated.

Potential energy conservation measures and their impact are major issues. Although some conservation measures have been implemented in Austria, this topic is being extensively debated.

The choice of fuels and energy supply technologies is a third priority issue, closely linked to the two above. Decisions on the 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 could weaken some of the arguments for expanding the nuclear system. Similarly, 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. Austria's reliance for fuels on other countries or regions of the world is an important economic and political issue. The feasibility of alternative fuels, e.g., coal and solar, playing a major role over the next several decades is under discussion.

There is concern about the *environmental impacts of energy use*, especially on public health and safety; 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 trade-offs associated with them.

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

3 DESCRIPTION OF METHODOLOGY AND OVERVIEW OF ENERGY SCENARIOS

3.1 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. The Austrian case study uses *scenario building* as a formal quantitative approach to policy analysis and to the examination of energy/ environment strategies.

Broadly described, scenario building is an examination of possible futures and the consequences of alternative assumptions about them. This set of futures may provide a better view of what should 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. Policy issues and related trade-offs 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. Table 1 gives an overview of these characteristics for the four scenarios analyzed in this study. As shown in the first column of Table 1, we relate those characteristics to four scenario properties: socioeconomic structure, lifestyle, technology, and environment. Within these four categories, a larger number of assumptions about future events and/or policies and strategies are built into the scenarios. Tables A.1–A.4 give a more detailed formulation of the characteristics of the four scenarios.

TABLE 1 Overview of scenarios S1–S4.

Summary characteristics		Scenario S1 (Base Case)	Scenario S2 (High Case)	Scenario S3 (Low Case)	Scenario S4 (Conservation Case)
Socio-economic 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: 3.23%/yr 1985–2015: 1.21%/yr
Lifestyle	Personal consumption	Current trends in personal consumption	Higher consumption than in S1	Lower consumption than in S1	Lower consumption than in S1
	Transportation	Car ownership 300 vehicles/1,000 population	Car ownership 400 vehicles/1,000 population	Car ownership 250 vehicles/1,000 population	Car ownership 300 vehicles/1,000 population
	Housing	Bigger new homes ($0.8\ m^2/yr$)	New home size increases faster than in S1	New home size increases more slowly than in S1	Same as S3
		Emphasis on electrical appliances and convenient fuels	High emphasis on electrical appliances and convenient fuels	Less emphasis on electrical appliances and convenient fuels	
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 and implementation of energy conserving technology

	Transportation	Car efficiency 8.9 liter/100 km	Car efficiency 12.3 liter/100 km	Car efficiency 8.9 liter/100 km	Car efficiency 7.0 liter/100 km
	Housing	1971 insulation standard	1971 insulation standard	By 2000 new homes 40% better than 1971 insulation standard	By 2000 new homes 55% better than 1971 insulation standard
	Energy supply	Decreased emphasis on coal			
		Electricity demand grows more rapidly than total end-use energy demand			
		Medium nuclear growth	High nuclear growth	Low nuclear growth	No nuclear growth
		Adequate oil and gas supply	Adequate oil and gas supply	Adequate oil and gas supply	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			
		0.50 of U.S. emission limits on SO_2, point sources, by 2015	0.42 of U.S. emission limits on SO_2, point sources, by 2015	0.71 of U.S. emission limits on SO_2, point sources, by 2015	Same as S3
		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
		U.S. emission limits of particulates, electric power plants, by 2015			

The framework summarized in column 1 of Table 1 gives 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 detailed representation of the information flow that occurs in the calculation of energy demand and pollutant emission for the residential sector of the economy.

The major assumptions underlying the four scenarios were chosen primarily on the basis of the first IIASA Workshop on Austrian Energy/ Environment Systems, in January 1977, which had the participation of many members of the Austrian private and public sectors. Many of the exogenous inputs, particularly in the socioeconomic area, were provided by collaborating individuals or institutions in Austria.

This report does not describe the analytical techniques used in the Austrian case study. The concepts and the quantitative methods used in this study and in three other regional energy/environment case studies are described by Foell *et al.* in a research report that is in preparation. Several method-oriented reports that have been published at IIASA and at the University of Wisconsin-Madison are referenced throughout the following chapters.

3.2 SCENARIO OVERVIEW

The four energy scenarios were chosen with a view to examining the four issues enumerated in Chapter 2 of this report. In order to study energy demand in Austria, the scenarios were based upon alternative world and regional economic assumptions. This resulted in three different energy growth rates for the Austrian economy: medium, high, and low. These assumptions, coupled with other policies and assumptions, were used to develop the following scenarios:

S1 (the Base Case), S2 (the High Case), and S3 (the Low Case)

Because of the concern about the eventual restriction on petroleum supply, S4 (the Conservation Case) was built upon the lower economic growth of S3 in order to explore the effectiveness of fuel shifts and conservation measures for avoiding gaps between petroleum supply and potential demand. Emission limits for sulfur dioxide (SO_2) and for particulates (PM) were also taken into account in developing the scenarios.

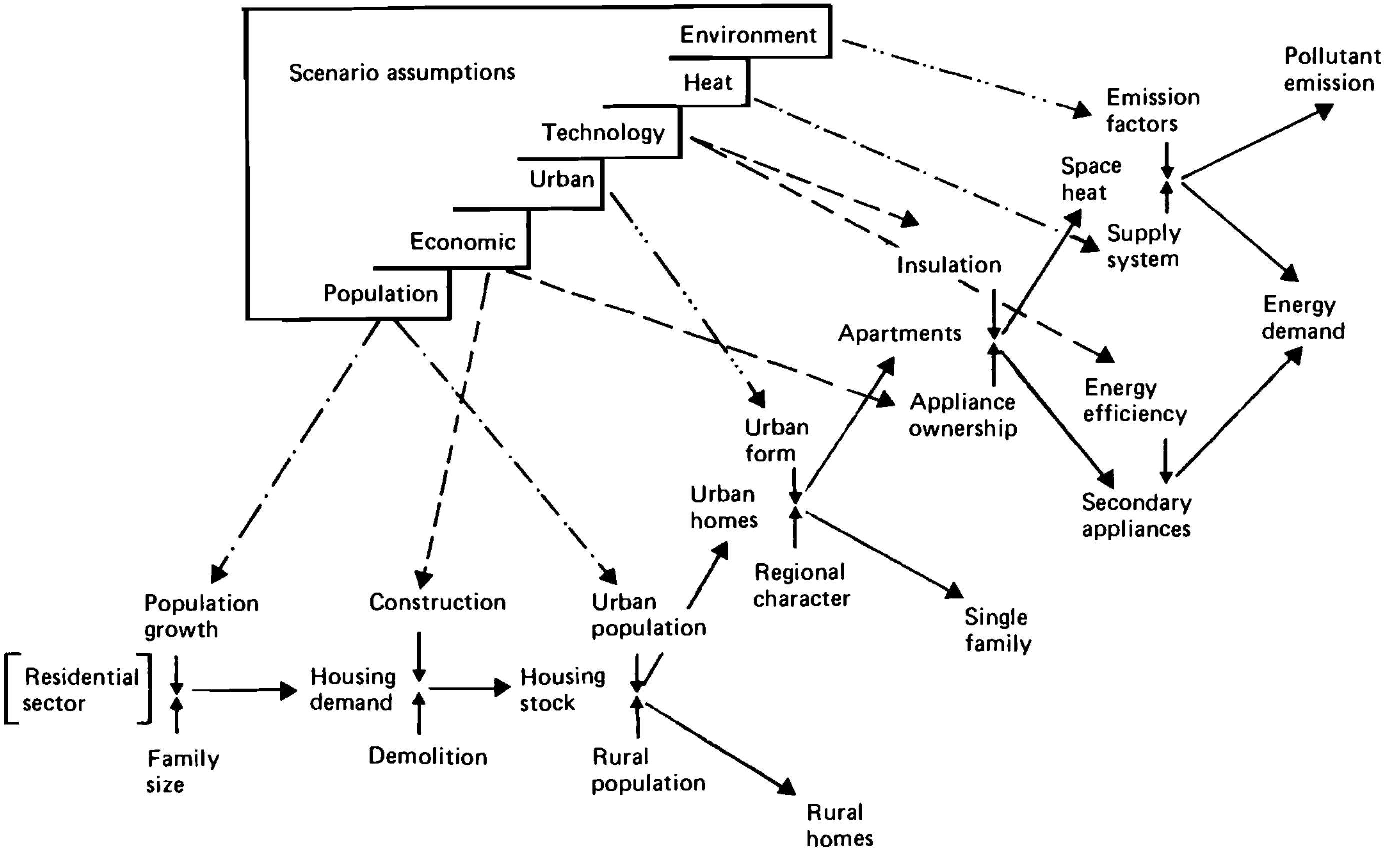

FIGURE 1 Information flow in the residential energy demand model.

4 SOCIOECONOMIC STRUCTURE OF THE SCENARIOS

4.1 ECONOMICS

Energy demand, in the Austrian case study, is a function of sectoral activity and the energy intensiveness of this activity. The activities of the private sectors – residential and personal transportation – are treated separately in models that describe activity in terms of physical characteristics (e.g., number of homes; age distribution; equipment of homes dependent on age and location, etc.; number of cars; trip length; fuel economy). For the other sectors – agriculture, extraction and manufacturing, commerce and services, and freight and mass transit transportation – the activity is measured in terms of value added. Projections of economic activity by sector are derived by means of the AUSTRIA II input/output model (Richter and Teufelsbauer, 1973). This medium-term model provides, given a set of assumptions, a complete and internally consistent description of economic activity at constant prices for each year of the forecasting period.*

Two different categories of assumptions are used in AUSTRIA II. The first category comprises general assumptions on model structure, which cannot be changed. The second category includes more specific assumptions that may be altered from simulation to simulation without major difficulties.

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*AUSTRIA II is designed for a projection period of 15 years. For this special application, the period was expanded to 45 years. The most crucial aspect of this time transformation is the extrapolation of investment and private consumption functions over a range of gross domestic product (GDP) significantly greater than the historical range from which these functions are estimated. The GDP reaches approximately three times the current level by the end of the period in the scenario with highest economic growth (S2).

4.1.1 General Assumptions

AUSTRIA II, which is based on parameters derived from time-series analysis, relies on overall stability in the socioeconomic environment. This assumption implies a degree of continuity in economic policy: taxation, income distribution, conditions of investment, export promotion, etc. For private consumption, only changes resulting from rising income are taken into account; evolutions caused by changes in tastes are not included. Further progress toward 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 (e.g., crude oil production and iron ore extraction in Austria), where the limits of domestic capacity are known, the structure of the model implies that no bottlenecks will occur in supply. Labor force is also assumed to be a nonlimiting factor. Prices and relative prices are assumed to have no major influence on the structure of domestic final demand.* Changes in technology resulting from price changes can be taken into account. Fluctuations in the business cycle are largely ignored.

4.1.2 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 public consumption changes slightly over the forecasting period.

The technological structure is rather constant, with the exception of a large number of changes during the period 1977–1985, based on information from various enterprises. For instance, in the input structure of the food industry, a relative decline of inputs from agriculture and an increase of inputs from the chemical and the fabricated metal industries is anticipated. Additional changes in energy input coefficients occur after 1985, as noted in the individual demand sector descriptions.

Assumptions regarding the economic development of Austria's trading partners are crucial to decisions on the development of the Austrian

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*Some minor modifications of the final demand structure were introduced, especially in scenario S4, in order to reflect the assumptions concerning the insulation of homes and the efficiency and ownership of automobiles.

economy. Specifically, the real growth rates of Austria's trading partners are kept constant over the period 1970–1985, at the levels for all scenarios as shown in Table 2. In S2, these growth rates are assumed to remain constant until 2015; they decrease linearly to 1.70% in S1, and to a value slightly above zero in S3. Based on these assumptions, different rates for the Austrian GNP have been estimated for all four scenarios.

The description of the trading partners is the same in S3 and in S4, with the added provisos that in S4 there is significantly reduced energy intensiveness in industry, more energy efficient automobiles, and better insulation. These assumptions affect mainly the input structure of the intermediate sectors, private consumption, and the structure of investment in buildings.

The resulting GNP descriptions for Austria are shown in per capita terms in Figure 2, and in absolute terms in Figure 4. Table 3 shows for the four scenarios the projections of the Austrian GNP for selected years and the average annual growth rates during these periods. As shown in the two figures, the development paths are similar to historical trends, especially for the period 1970–2000.

The fastest growing sectors in terms of value added for all four scenarios are the chemical industry, machinery/steel/light metal construction, and construction of electrical machinery and equipment. In Austria, there is strong linkage between economic growth and the level of exports and imports. Exports, which in 1970 represented 10.5% of the total demand (intermediate plus final demand), increase steadily until 2015 at which time they are 30.3% in S2, 24.8% in S1, and 22.1% in S3 and in S4. Competitive imports, which in 1970 represented 12.2% of total supply, increase by the year 2015 to a level of 23.9% in S2, 21.4% in S1, and 20.8% in S3

TABLE 2 Real growth rates of Austria's trading partners, 1970–1985.

Partner	Percentage
Federal Republic of Germany	2.92
Switzerland	2.31
Italy	3.49
Member countries of the European Community (as of 1975) not listed above	3.82
Yugoslavia and member countries of the Council of Mutual Economic Assistance (CMEA)	5.66
Member countries of the Organisation for Economic Cooperation and Development (OECD) not listed above	4.63
Rest of world	4.63

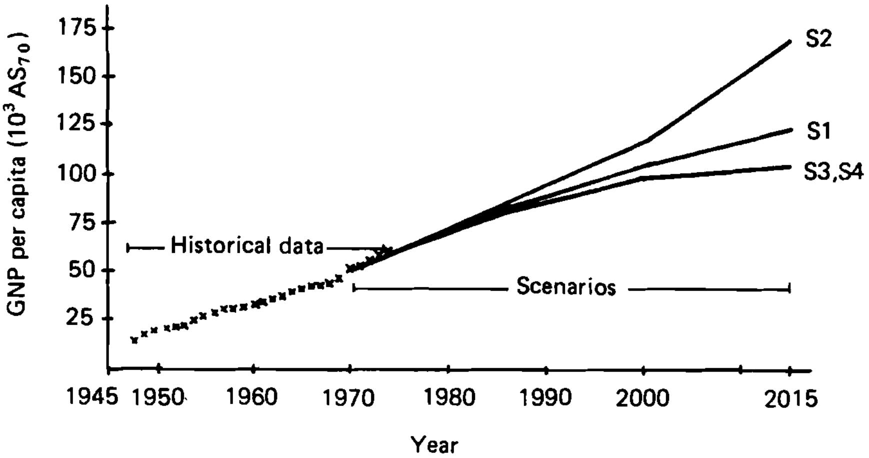

FIGURE 2 Austrian gross national product (GNP) per capita, by scenario, 1970–2015. AS_{70} means Austrian schillings at 1970 values.

and in S4. Comparisons in greater sectoral detail are given in Appendix B. Appendix C defines the intermediate sectors of AUSTRIA II.

In conclusion, 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.

4.2 POPULATION

Population data are required by the residential, the transportation, and the health impact models. The demographic variables needed as input to these models are: total population, total number of households, and number of new households. These data must be disaggregated into subregional and urban/rural categories.

TABLE 3 Austrian GNP projections for selected years.

	GNP projections for Austria in scenarios S1–S4 (10^9 AS$_{70}$)[a]					Growth rates of Austrian GNP (%/yr)			
Year	S1	S2	S3	S4	Period	S1	S2	S3	S4
1971[b]	391	391	391	391	1971–1980	3.5	3.7	3.4	3.4
1980[c]	534	540	529	529	1980–1990	2.4	2.6	2.3	2.3
1990[c]	676	701	663	664	1990–2000	1.9	2.7	1.6	1.6
2000	820	912	775	777	2000–2015	1.5	2.8	0.7	0.7
2015	1,019	1,381	858	860					
GNP_{2015} : GNP_{1971}	2.6	3.5	2.2	2.2					

[a] Austrian schillings at 1970 values.

[b] Actual value.

[c] Derived from model results by linear interpolation between 1979 and 1982 and between 1988 and 1991.

4.2.1 Initial Population Data and Projections to 2015

The initial population data are taken from the Austrian Census of 1971. Population data for later years are derived from a projection for 1981 and 1991 (Variante 2.1) by the Austrian Institute of Regional and Urban Planning (OeIR), by interpolation between 1971/1981/1991, and by extrapolation beyond that period.

The OeIR projection underlying the population scenarios is derived from a model that uses sex- and age-specific (5-year age groups) fertility, mortality, and migration rates by political district (politischer Bezirk).* Death rates are calculated on the basis of 1970–1972 life expectancy data. Rates of migration are based on a study of internal migration for the period 1966–1971, which was carried out in conjunction with the 1971 Austrian Census. The projection assumes no change of migration rates over the projection period. International migration is neglected; it is assumed that there is a compensatory migration balance between political districts and foreign countries. The fertility rates used in the projection are those observed between 1971 and 1973. For a complete description of the method and the assumptions underlying the OeIR scenarios, see Sauberer *et al.* (1976).

In 1971, the population of Austria was 7.46 million, and the OeIR projection for 1991 (Variante 2.1) is 7.69 million. Interpolation and extrapolation result in population estimates of 7.66 million in 1990, 7.90 million in 2000, and 8.26 million in 2015, which seem high in the light of current child-bearing patterns. A more recent OeIR projection (Variante 4.3) takes into account the decrease of the fertility rates observed during the last few years; the resulting population projection for 1991 is 7.34 million. Applying the same inter- and extrapolation procedure as in the case of the former projection, one obtains population estimates of 7.35 million in 1990, 7.30 million in 2000, and 7.24 million in 2015. This value is 13% lower than that used for all four scenarios of the Austrian case study. Figure 3 shows both historical population data and the estimates used in scenarios S1–S4. In order to indicate the extent to which energy demand projections might change if one were to use lower population projections, the main input data are summarized for the two scenarios in Appendix E. The residential sector, together with personal transportation, account for approximately 35% of end-use energy demand

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*Austria is divided administratively into 97 political districts. Because of the idiosyncracies of the data available, several districts had to be aggregated (e.g., Eisenstadt-Stadt, Eisenstadt-Umgebung, and Rust in Burgenland; Dornbirn and Feldkirch in Vorarlberg), resulting in a total of 94 "districts" for the purposes of the population model.

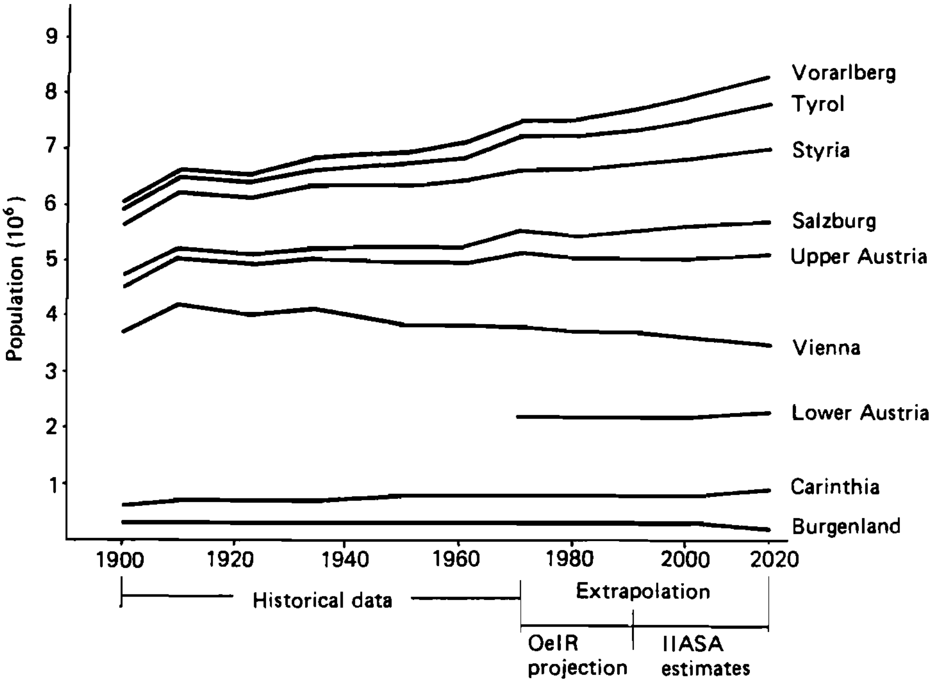

FIGURE 3 Population in Austria: historical data and scenario assumptions, 1900–2020.

by 2025. A 13% decrease in population would in a first approximation cause an almost proportional decrease in the energy demand of these sectors. Thus total energy demand might be 4 to 6% lower than that specified in the scenarios.

4.2.2 Estimation of the Number of Households

The number of households is calculated using the assumption that the average household size would decrease at a rate of 0.3% per year in every district. This number is taken from a projection of the average household size in Austria until the year 2000 by the Austrian Central Statistical Office (OeStZ).

4.2.3 Subregional Disaggregation of the Population Data

In the Austrian case study, the lowest level of disaggregation used for the population data was the political district. Disaggregation at the district level made it possible to account for migration and to reaggregate the data into various types of subregions. The residential model is based on population data at the provincial level. The transportation and the health impact models are based on population projections for "functional subregions." (A functional subregion is defined in terms of an urban center – core – with a concentration of the industrial and the commercial activities of the region, a surrounding area – ring 1 – with a large fraction of the working population commuting into the urban center, and an outer ring – ring 2 – with little commuting. The outer ring is split, if it does not fall into a single political region, in order to allow for an aggregation of the results by political region.) The concept of functional regions is based on an analysis of commuting data by Sherrill (1976). The definition of the functional regions in terms of political districts is given in Appendix D.

4.2.4 Urban/Rural Split: Conceptualization and Projection

The distinction between urban and rural areas is necessary because each has significantly different characteristics with respect to factors affecting energy consumption, such as average family size, type and size of housing units, equipment of housing units, mode and frequency of travel, and exposure to air pollution. In the Austrian case study, the urban category comprised communities with 3,000 and more inhabitants in 1971. This dividing point was chosen for two reasons: (a) the underproportional growth of small communities because of migration to urban centers, and (b) the high fraction of agricultural population in these communities. An analysis of the relationship between community size and the fraction of the population dependent on agriculture (Agrarquote) in 1971 showed that a community size of 3,000 is a good approximation of the dividing point between communities with less than 10% and those with more than 10% agricultural population. This is, in turn, a reasonable dividing point between communities with a heavy reliance on wood and communities using mainly oil and gas (and to some extent coal) for space heating. Cities with more than 5,000 inhabitants in 1971 were considered explicitly urban, while the population in communities with 3,000 to 5,000 inhabitants was calculated according to the following decision rule: in districts with numerous communities, 32.5% of the total population was classified as urban; in districts with few communities, 50% was considered urban; if the urban population figure was smaller than the actual population living in cities of more than 5,000 population, the latter figure was used for the urban category. Because of the area redefinitions and the resulting arbitrariness in choosing the community size in a particular year so as to distinguish between rural and urban areas, the approximation was believed satisfactory.

The projection of the urban/rural split is made as follows: if the population of a district is growing, the increase is allocated to the urban categories (i.e., the main city and secondary cities) proportional to their size; if the population is declining, the decline is taken first from the rural category; if the decline is larger than the rural population of the district, the excess is taken from the urban categories proportional to their size. This procedure reflects the assumption of a strong shift toward urban areas. The household size is assumed to be the same for the urban and the rural categories on a district level. The error introduced by this assumption is small because the largest cities represent a single district – i.e., the rural category is absent in these cases. For the functional or political regions, the difference in average household size between rural and urban areas is reasonably well reflected.

5 ENERGY DEMAND

This chapter presents the energy demand results of the Austrian case study. Section 5.1 gives results for total end-use demand, followed by sections 5.2 through 5.4 which present individual sectoral demands.

5.1 TOTAL END-USE DEMAND

The scenario-based investigation shows the plausibility of a wide range of future energy use. The future ranges for GNP and end-use energy, along with historical trends, are shown in Figure 4. The fact that much of the range of energy use falls below the levels that would occur if recent historical rates of energy growth were maintained indicates, in part, the strength of the policy measures that were combined within the scenarios as well as the saturation effects and the slowing of economic growth. This demonstrates the broad discretionary power available to Austrian decision makers and policy makers.

The wide range of results for end-use energy demands is demonstrated by comparing the four scenarios in terms of the level of end-use energy in 2015 with the 1971 level of energy use. The ratios for scenarios S1, S2, S3, and S4 are 2.1, 3.3, 1.8, and 1.5, respectively.

The range of end-use energy levels in 2015 is greater than the range of levels of GNP, indicating a large disassociation of energy growth and economic growth. This disassociation may be expressed in terms of the implicit elasticity of energy to GNP

$$\text{Implicit elasticity} = (\Delta E/E_{1971})/(\Delta \mathrm{GNP}/\mathrm{GNP}_{1971})$$

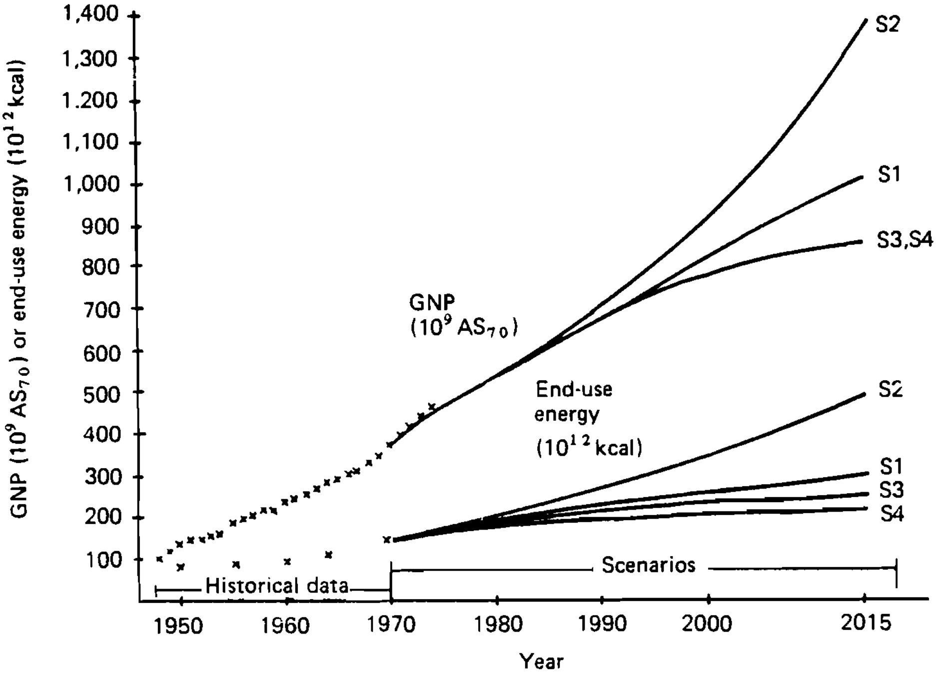

FIGURE 4 Austrian gross national product (GNP) and end-use energy by scenario, 1970–2015. AS_{70} means Austrian schillings at 1970 values.

where E is the end-use energy consumption and Δ is the difference between the 1971 and the 2015 levels of E and GNP, respectively. The implicit elasticities for scenarios S1, S2, S3, and S4 are 0.75, 0.92, 0.67, and 0.42, respectively.

Scenario S2 and, to a lesser degree, S1 show a close relationship between economic growth and energy growth. Scenarios S3 and especially S4 demonstrate that a significant disassociation can be achieved during the study period. In other words, a given economic growth rate over the next 38 years would require much lower rates of energy growth. Similar results have been reported in studies of the United States economy by CONAES (1978).

One method for interpreting the significance of these end-use energy consumption levels is to compare energy use in Austria to that in other regions on a per capita basis.

Figure 5 compares the end-use energy consumption levels for the four scenarios to the levels projected for the state of Wisconsin by the Energy Systems and Policy Research Group (1977), which are based on

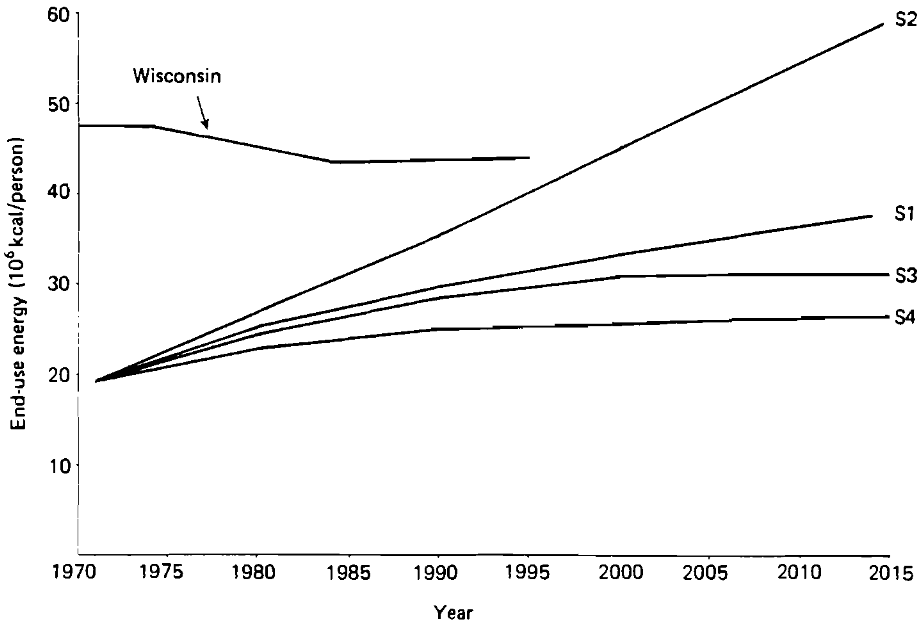

FIGURE 5 Comparison of Austrian end-use energy, by scenario, and Wisconsin projection, 1970–2015. The Wisconsin projection was adjusted for climate differences.

the U.S. National Energy Plan as proposed by President Carter (Executive Office of the President, 1977). Although the current U.S. energy use per capita is the highest in the world for any major industrialized nation (with the Wisconsin levels being typical), the S2 scenario surpasses that value while the S1 scenario is approaching it by the end of the period. According to scenarios S3 and S4, by 2015 Austria would be at levels equivalent to or higher than the highest levels now occurring in Europe.

A tabulation of the rates of change for population, economic output, end-use energy demand by end-use sector, and energy supply by fuel is presented in Tables 4, 5, 6, and 7 (see also Appendix F). The data are presented for four time periods: 1971–1980, 1980–1990, 1990–2015, and 1971–2015; and for the four scenarios.

A trend observed in the study is that the *growth rates of end-use energy decline through the period 1971–2015 for all scenarios*, as summarized in Table 8. This trend may be traced to the declining economic growth rates in all scenarios as well as to the declining energy intensities in the five sectors over much of this period. An exception is the S2 scenario which has some constant or increasing intensities. This trend is also evident with respect to primary energy.

TABLE 4 Austrian annual average growth rates, 1971–1980 (percentage per year).

	Scenario			
	S1	S2	S3	S4
Socioeconomic				
Population	0.1	0.1	0.1	0.1
Total value added	3.3	3.4	3.2	3.2
Industrial value added	3.2	3.2	3.0	3.0
Commercial and service value added	3.6	3.7	3.5	3.5
Agriculture value added	1.7	1.7	1.6	1.6
Energy				
Primary energy use	2.7	4.0	2.5	1.4
End-use energy				
Total	2.7	3.7	2.5	1.5
Industrial	2.7	3.6	2.5	1.3
Commercial and service	5.8	6.4	5.7	4.2
Agriculture	2.9	4.0	2.7	1.6
Transportation	1.4	2.4	0.9	-0.1
Residential	2.1	3.5	1.9	1.9
Energy supply				
Hard coal	-1.3	-0.5	-1.5	-1.2
Lignite	-3.9	-1.3	-4.5	-3.7
Petroleum	2.0	3.3	1.8	0.9
Gases	4.7	6.4	4.4	3.3
Electricity (supplied for final use)	5.0	6.2	4.8	3.8
Nuclear	–[a]	–[a]	–[a]	–
Hydro	7.4	7.4	7.4	7.4
Wastes	1.0	1.0	1.0	1.0

[a] One nuclear power plant assumed to be commissioned.

The distribution of end-use energy by energy form through time for each of the scenarios is shown in Figure 6. Petroleum, currently the dominant energy source in Austria, maintains a large share for all scenarios. There are, however, significant shifts in end-use energy shares. As shown in Table 9, the share of coal drops considerably, with petroleum also showing a decline. Natural gas and electricity increase their share substantially, with natural gas showing the largest increase. An interesting observation is the consistency of the end-use energy shares within the widely varying total end-use energy levels shown in Figure 4.

TABLE 5 Austrian annual average growth rates, 1980-1990 (percentage per year).

	Scenario			
	S1	S2	S3	S4
Socioeconomic				
Population	0.2	0.2	0.2	0.2
Total value added	2.3	2.5	2.2	2.2
Industrial value added	2.5	2.9	2.4	2.4
Commercial and service value added	2.2	2.4	2.1	2.1
Agriculture value added	1.4	1.6	1.4	1.4
Energy				
Primary energy use	1.5	2.2	1.3	0.5
End-use energy				
Total	1.8	2.9	1.6	1.0
Industrial	2.3	3.2	2.1	1.5
Commercial and service	1.9	2.7	1.9	0.9
Agriculture	1.7	2.5	1.7	0.7
Transportation	0.7	2.6	0.5	-0.5
Residential	1.3	2.5	1.1	1.0
Energy supply				
Hard coal	0.8	1.9	0.7	0.8
Lignite	-1.5	-0.9	-1.7	-2.1
Petroleum	1.9	3.0	1.7	0.3
Gases	2.0	2.0	1.9	1.1
Electricity (supplied for final use)	2.5	3.4	2.4	1.8
Nuclear	—[a]	—[a]	—[a]	—
Hydro	1.2	1.9	1.2	1.2
Wastes	1.0	2.2	0.7	1.2

[a] One nuclear power plant assumed to be commissioned.

Trends observed with respect to primary energy (see Chapter 6) are not identical to those shown for end-use energy in Table 8. For example, the growth rate for electricity for the period 1971–2015 is higher than that 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 for scenarios S1, S2, S3, and S4 is 45%, 43%, 50%, and 43% respectively; the petroleum share of end-use energy in 2015 for the four scenarios is shown in Table 9.

TABLE 6 Austrian annual average growth rates, 1990–2015 (percentage per year).

	Scenario			
	S1	S2	S3	S4
Socioeconomic				
Population	0.3	0.3	0.3	0.3
Total value added	1.6	2.7	1.0	0.3
Industrial value added	1.7	3.0	0.9	1.0
Commercial and service value added	1.6	2.5	1.1	1.1
Agriculture value added	1.1	1.9	0.5	0.5
Energy				
Primary energy use	1.4	2.7	0.7	0.6
End-use energy				
Total	1.3	2.4	0.7	0.6
Industrial	1.5	2.8	0.7	0.7
Commercial and service	1.5	2.3	1.1	0.9
Agriculture	1.0	2.5	0.5	0.4
Transportation	1.2	2.3	0.8	0.7
Residential	1.0	1.6	0.5	0.3
Energy supply				
Hard coal	0.9	1.8	0.2	0.4
Lignite	0.1	0.8	0.9	-0.2
Petroleum	1.1	2.1	0.8	0.3
Gases	1.1	2.6	0.7	0.6
Electricity (supplied for final use)	1.5	2.5	0.9	0.9
Nuclear	5.5	9.5	–[a]	–
Hydro	1.8	1.9	1.8	1.8
Wastes	0.6	1.9	1.8	-0.2

[a] One nuclear power plant assumed to be decommissioned.

The growth of electricity use is an important factor considered in energy and investment planning in Austria. The growth rates of electricity use followed a similar trend as was observed for total end-use energy, starting with historical rates for the period 1971–1980 and declining to significantly lower rates for the period 1990–2015, as shown in Table 10.

The implications of this pattern are shown in Figure 7, which compares the percentage of electricity of total end-use energy for the four scenarios with historical development since 1947. The scenarios follow almost identical development, starting with the percentage level of electricity increasing at a rapid rate typical of the 1950–1970 period; the

TABLE 7 Austrian annual average growth rates, 1971–2015 (percentage per year).

	Scenario			
	S1	S2	S3	S4
Socioeconomic				
Population	0.2	0.2	0.2	0.2
Total value added	2.1	2.8	1.7	1.7
Industrial value added	2.2	3.0	1.7	1.7
Commercial and service value added	2.1	2.7	1.8	1.8
Agriculture value added	1.3	1.8	0.9	0.9
Energy				
Primary energy use	1.7	2.9	1.2	0.7
End-use energy				
Total	1.7	2.9	1.3	0.9
Industrial	1.9	3.1	1.4	1.0
Commercial and service	2.5	3.2	2.2	1.6
Agriculture	1.5	2.8	1.2	0.7
Transportation	1.1	2.4	0.8	0.3
Residential	1.3	2.2	0.9	0.8
Energy supply				
Hard coal	0.4	1.4	0.0	0.2
Lignite	-1.1	0.0	-0.8	-1.3
Petroleum	1.5	2.6	1.2	0.4
Gases	2.1	3.2	1.7	1.3
Electricity (supplied for final use)	2.4	3.5	2.1	1.7
Nuclear	–[a]	–[b]	–[c]	–
Hydro	2.8	3.0	2.8	2.8
Wastes	1.0	2.3	0.6	0.3

[a] 2015 production is 16 x 10^9 kWh/yr.

[b] 2015 production is 40 x 10^9 kWh/yr.

[c] One nuclear power plant assumed to be decommissioned, with no further additions of nuclear capacity.

growth in the percentage declines in the decade 1980–1990, and virtually saturates at 18 to 19% by the end of the study period. This suggests that within the scenarios the foreseeable uses of this high-quality energy form were exploited fully at this level.

The trends observed with respect to the shares of end-use energy among the five sectors are shown in Figure 8 and Appendix F. Two points stand out in this figure. The first point is the stability of the shares in the four scenarios in 2015, despite the wide divergence of energy use.

TABLE 8 Growth rates of end-use energy (percentage per year).

Time period	Scenario 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 second one is that the industrial share increases in each scenario above its already predominant share of 42%. The three economic sectors – industrial, commercial and service, and agriculture – increase their share at the expense of the private sectors – personal transportation and residential – from 57% in 1971 to 65%, 65%, 64%, and 63% in 2015 for scenarios S1, S2, S3, and S4, respectively. Even this is an understatement in that an increasing percentage of the transportation end-use energy is devoted to freight use as opposed to personal travel, as noted in the transportation energy use assessment in Section 5.4.

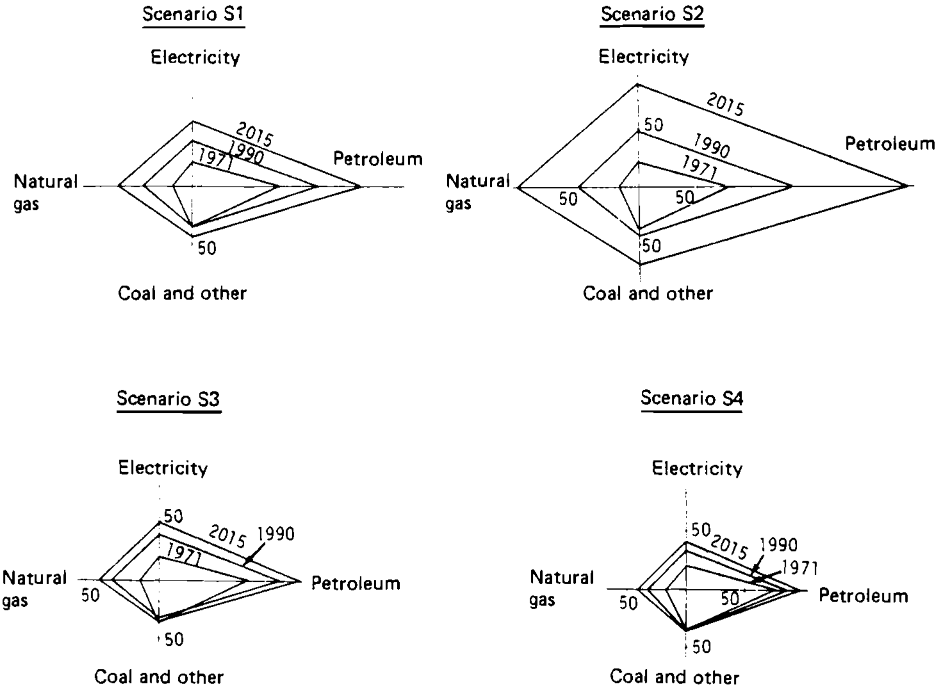

FIGURE 6 Austrian end-use energy, by fuel type.

TABLE 9 Share of end-use energy (percentage).

		2015			
	1971	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
TOTAL	100	100	100	100	100

TABLE 10 Growth rates of electricity use (percentage per year).

	Scenario			
Time period	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 commercial and service sector is the fastest growing sector in terms of end-use energy, while the slowest is the transportation sector. The growth rates for the period 1971–2015, shown in Table 7, are consistent with the changes in relative shares.

As described in the sectoral descriptions, these divergent trends are the result of the growth in value added and of the smaller decline in the energy intensity of the commercial and service sector versus a sharp drop in the energy intensity of the transportation sector because of the conservation potential and the saturation of automobile ownership.

The dominance of the industrial sector in energy use suggests that policy measures for altering energy use patterns must focus mainly on this sector. The commercial and service sector is important to any conservation effort since compared with other sectors it has the most rapid growth in energy demand.

5.2 RESIDENTIAL SECTOR

The major factors influencing energy demand in the residential sector are: the number, size, and characteristics of dwellings; the associated energy-consuming appliances; and the climate in which they are located.

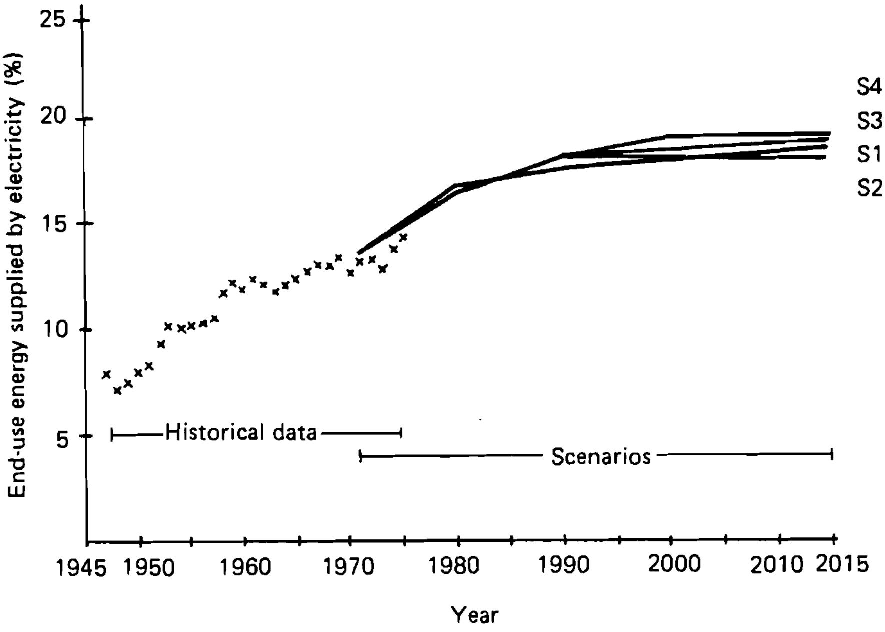

FIGURE 7 Percentage of end-use energy supplied by electricity.

The four scenarios for the residential sector have been defined so as to be consistent with economic growth assumptions. The major variables defining the alternative residential energy use futures are:

- Projected number and types of occupied housing units (the principal driving forces being construction, demolition, and population growth)
- Fuel mix for space and water heating
- Heating patterns, i.e., the amount of heated floor space
- Lifestyle, including attitudes toward energy use for space and water heating, household appliance ownership and use, and the size of new housing units
- Technological changes, including efficiencies of equipment and thermal integrity of housing units
- Use of unconventional energy sources

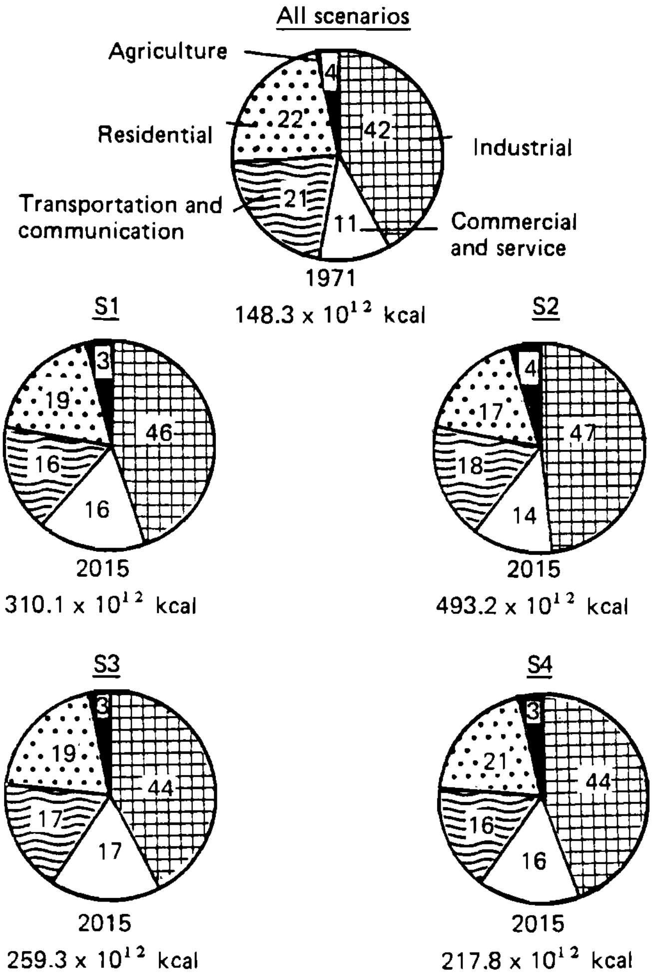

FIGURE 8 End-use energy percentages, by sector.

5.2.1 Residential Sector Scenarios

Scenario S1: Base Case. The average floor space per capita increases until 2015 at an annual rate of 0.25 m^2. No measures for insulation are taken. The saturation level in the household appliance area is reached by about the year 2000.

Scenario S2: High Case. The average floor space per capita increases at an annual rate of 0.30 m^2. No measures for insulation are taken. There is less restrained energy use (and thus more heating hours per year) and high growth in the household appliances area, with the saturation level being achieved by the year 1990.

Scenario S3: Low Case. The average floor space per capita grows annually by 0.20 m^2. Insulation standards are applied to new construction and existing buildings. Improvements in heating system efficiencies are assumed on a moderate scale. The saturation level of the household appliance area is reached by the year 2010.

Scenario S4: Conservation Case. Floor space assumptions are similar to those for S3; however, even stricter insulation and efficiency improvements are assumed. The level of household appliances is assumed to be the same as that in S3. A sensitivity study examining the penetration of alternative fuel technologies has been carried out on the basis of S4. (Sensitivity studies permit the evaluation of the effects of variations in one policy variable while holding the others constant.)

5.2.2 Scenario Assumptions

The scenario assumptions can be broken down into two groups: (a) those that remain constant for the four scenarios, and (b) those that vary; more detailed descriptions are given in Appendix G.

The assumptions that remain constant for all four scenarios are:

> *Demography.* Population projections are based on the OeIR report (Sauberer, *et al.*, 1976). The average family size declines by a factor of 0.997/yr from 2.94 in 1971 to 2.77 in 1990 and to 2.57 in 2015. Each family is assumed to occupy one housing unit.
>
> *Choice of fuel and base appliances.* The fuel mix changes over time as a result of an assumed shift away from coal to more convenient fuels such as oil, gas, electricity, and district heat. This shift occurs both through the construction of new housing units (since a small number of new housing units use coal) and through the retrofitting of older units.

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

The assumptions that vary over the four scenarios are:

> *Lifestyle.* The size of newly constructed housing units is related directly to economic growth; the annual increase in floor area 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 for S4. For scenario S2, additional assumptions have been introduced which indicate less restrained energy use. The heating hours increase 40% until the year 2000, and hot water use increases from 40 liters/person/day to 70 liters/person/day in the year 2000.

Saturation curves define the ownership levels for a set of 12 appliances (including washing machines, stoves, and television sets) and for two groups of small appliances. The level and the rate of saturation for each appliance are related to the growth of GNP as given by the AUSTRIA II model; 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 for S4, the same saturation levels as in S1 are reached by 2015.

> *Applied technology.* The average heat loss per home can be reduced to about 50% of the present level provided an efficient insulation policy is applied (Oesterreichisches Institut fuer Bauforschung, 1976). The 1971 insulation standards (120 kcal/m^2/h heat loss for single-family units, 90 kcal/m^2/h for apartments) are retained for S1 and for S2. For the other two scenarios, heat losses for newly constructed housing units 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 units by 15% for S3, and by 20% for S4 by 2015. Energy efficiencies of appliances are held constant for S1, S2, and S3, while S4 assumes improvements in energy efficiencies for heating units.

> *Alternative technologies.* Scenarios S1, S2, and S3 assume the continuation of current technologies and energy sources, while S4 assumes the significant use of alternative technologies and energy sources (e.g., heat pumps, solar energy).

5.2.3 Results and Conclusions

Figure 9 shows the residential sector demand by energy source for the four scenarios, comparing 1971 data to the scenario results from 1990 and 2015.

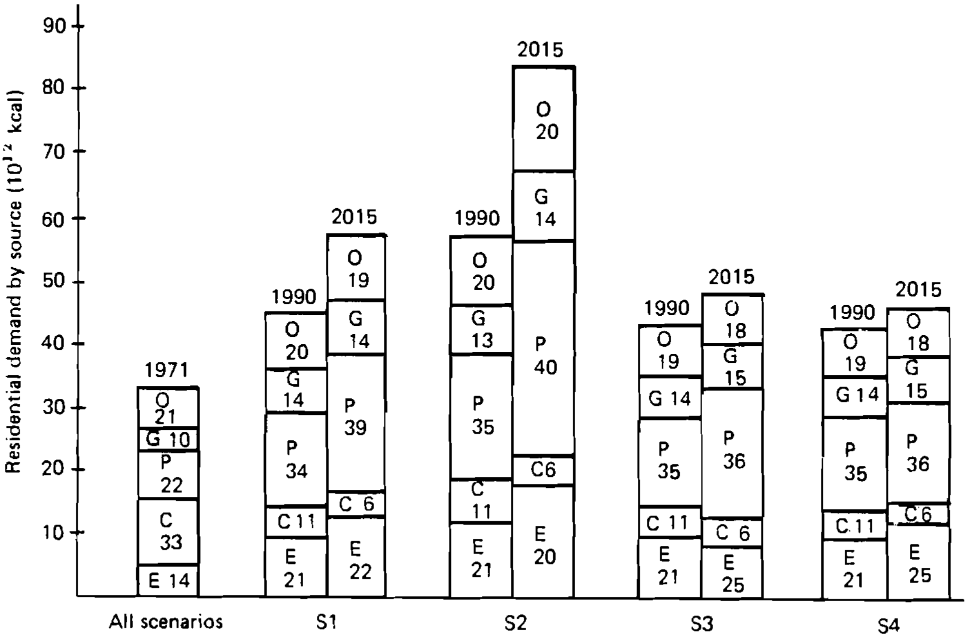

FIGURE 9 Residential demand, by source. The values within the bar diagrams represent the percentages of different energy sources for each scenario. E is electricity; C is coal; P is petroleum; G is gases; and O is other.

For 1990 and 2015, the percentage of total residential demand for each energy source is constant across the four scenarios. This is because the fuel mix for space and water heating remains constant for all 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 case (scenario S4), is a potential problem. However, the residential sector is one area where the demand for fossil fuels could be decreased (without sacrificing comfort) by the adoption of 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, which has been assumed in all four scenarios. Policies encouraging the reduction of heat losses through improved insulation for homes as well as policies either discouraging this fuel shift or encouraging a shift to district heat, solar energy, or heat pumps, could reduce the demand for fossil fuels.

The relative importance of major end-use categories in determining residential energy demand is shown in Table 11. The high fraction of demand due to space heating indicates that increases in floor space per capita and heat losses resulting from insufficient insulation are important for determining the total amount of energy consumed by the residential sector. Even with a strict conservation policy (S4), space heating remains the predominant end-use category in the residential sector.

The increasing share of water heating and secondary appliances in total residential energy consumption points to the growth potential of these end-use groups in comparison with space heating. By about 1990, all housing units are assumed to be fitted with either a bath or a shower. The increasing share of the household appliance area is because an increasing number of households are acquiring them, and not because of the increased consumption per appliance. The increasing share of end-use energy (especially for S3 and S4) is because the assumed vigorous insulation policies for these two scenarios have not been matched with equally vigorous policies for reduced energy use by the household appliance area. This indicates that a policy aimed at less energy use for secondary appliances per hour of use would be necessary to complement a strict conservation policy.

The absolute increase in space heating is because of the increase in heated floor area per capita: this almost doubles between 1971 and 2000 for all scenarios. However, the results for S3 and for S4 show that a vigorous policy supporting the use of applied technologies, such as insulation and efficiency improvements, could stem the increasing need for space heating without sacrificing personal convenience.

5.2.4 Special Issues and Sensitivities

Sensitivity studies have been made in order to demonstrate the possible impact of certain types of measures. The technique used was to make two model runs: (a) a base case run, and (b) a second run in which the parameters describing the investigated policy were changed. Conclusions about the potential impacts from these measures can be drawn from a comparison of the results of these two model runs.

5.2.4.1 THE IMPORTANCE OF INSULATION

The great importance of insulation measures can be shown provided all assumed reductions of heat loss are removed from scenario S4 and these results compared to regular scenario S4 results.

Figure 10 shows a comparison of outputs from these two runs. The

TABLE 11 Total residential energy demand by end-use categories (percentage).

	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

shaded areas in the figure are the potential savings of the simulated insulation measures for each fuel. It is important to note the time lag involved before the effect of insulation measures becomes noticeable in the total residential energy demand. An immediate investment has to be made in order to achieve a reduction in the amount of heat losses in homes, which will pay off only in accumulated fuel savings over decades. Nevertheless, insulation provides one robust current solution, leaving all options open for the future. Added advantages of insulation policies are that they decrease peak demands, reduce the national energy bill, decrease pollution, and are, especially in the case of retrofitting of old homes, labor intensive and thus have a favorable impact upon employment. According to a recent study by Wagner and Turowski (1977) the payback time for the energy invested in insulation material is only about 0.1 year. Even in the most unlikely case of declining energy prices, environmental considerations would still be an important and decisive argument, especially in urban areas.

5.2.4.2 UNCONVENTIONAL ENERGY SOURCES

The impact of the use of alternative energy sources – solar, biogas, and wind – on the demand for conventional forms of energy has been calculated as a sensitivity study for scenario S4. Clearly the results depend upon the boldness of the assumptions. It is generally believed that by fitting 50% of all single-family units with appropriate backup systems for space or water heating, alternative energy sources can be adopted, thus reducing oil requirements substantially by the year 2010. This assumption has been made based on the belief that oil, which is easily stored and transported and is network independent, will be used as a heating fuel by a large percentage of the single-family units, provided that oil is available at reasonable prices.

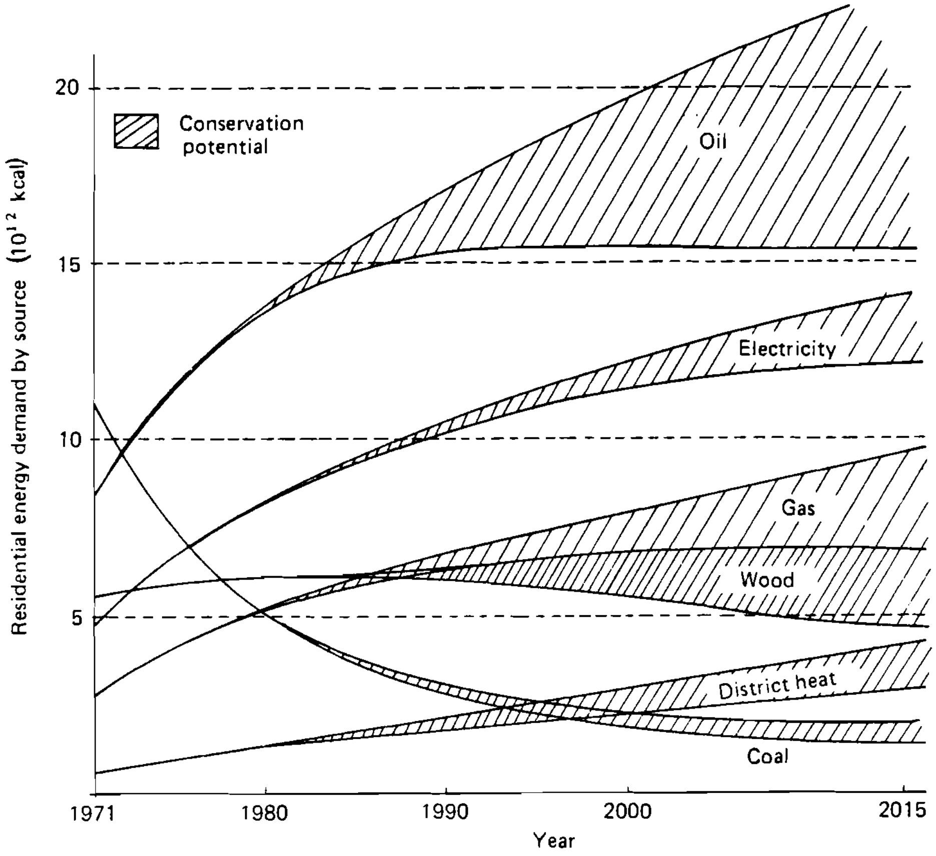

FIGURE 10 Potential savings from insulation measures and efficiency improvement.

Figure 11 shows a possible market penetration curve of the new technology, the slope, and the penetration limit. This function shows the rate at which single-family units, with the prerequisite backup systems, will use an alternative fuel technology. (The curve pertains only to units with characteristics appropriate for alternative technologies, i.e., single-family units with electricity, gas, and oil central heating systems; the 50% penetration refers only to these homes and not to the housing stock as a whole.)

Figure 12 shows as the shaded areas the potential savings from the use of an alternative fuel technology. By 2015, 0.24 million single-family homes (8% of all homes, 18% of all single-family homes) are assumed to have solar space heating, and 0.54 million single-family homes (17% of all homes, 41% of single-family homes) have solar water heating. Solar space heating is assumed to replace 60% of the annual heating requirements, and

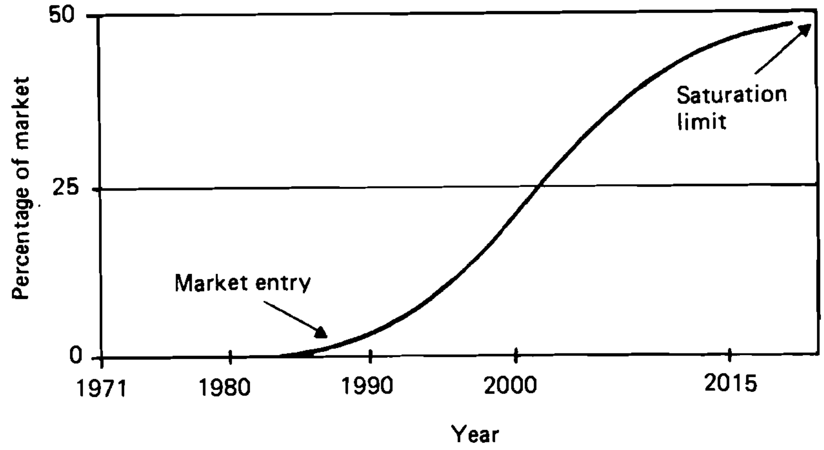

FIGURE 11 Market penetration curve for alternative energy.

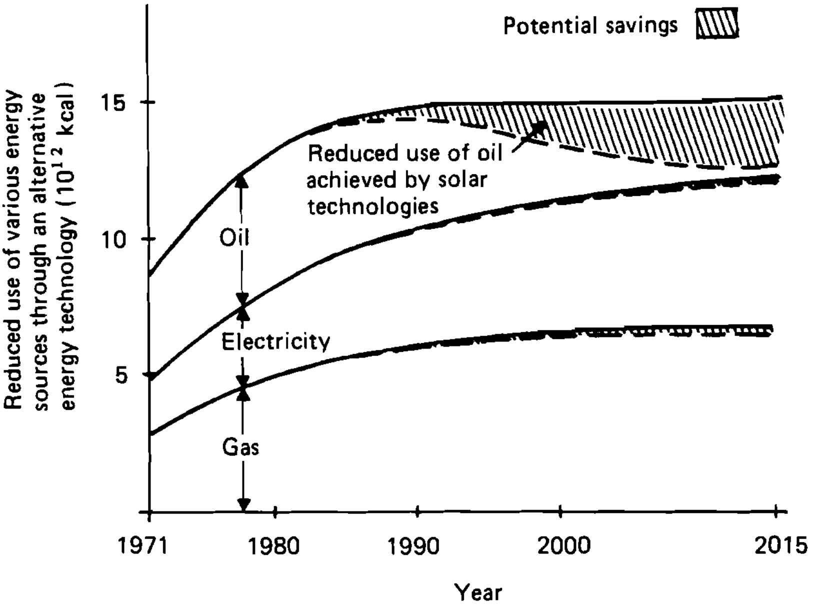

FIGURE 12 Potential savings by alternative fuel technology.

solar water heating 70% of the annual energy use for water heating. Under this assumption, 7% of the total residential energy demand would be provided by solar energy; 86% of these savings are in the form of oil, which accounts for 17% of the residential oil requirements by 2015.

5.3 AGRICULTURAL, INDUSTRIAL, AND COMMERCIAL AND SERVICE SECTORS

The agricultural, the industrial, and the commercial and service sectors are responsible for the major share of energy use in Austria. Within this analysis, this share increases from 57% of end-use energy in 1971 to 65%, 65%, 64%, and 63% in 2015 in scenarios S1, S2, S3, and S4, respectively. The sectoral shares of end-use energy are shown in Figure 8.

The energy demand of these sectors is calculated on the bases of projections of their economic activity and assumptions about the evolution of their specific energy consumption and of the breakdown of their energy consumption by energy source. The economy is disaggregated into a reasonably large number of sectors that can be considered homogeneous with respect to energy-use patterns.

The economic projections are taken from AUSTRIA II, while the initial data on energy consumption are extracted from the data on the energy balance published for the years 1970–1975 by OeStZ (Turetschek, 1972; 1973; 1974; 1975; 1976; 1977).

As a result of the aggregation required for this analysis, some masking of trends may occur in that energy consumption patterns may vary among the different components of these sectors. (This problem is illustrated in Appendix M, using the primary metals sector as an example.)

There are three principal types of variables on which the energy demand calculations are based, and which have to be specified for each sector and for every year of the period under consideration. These are:

- Value added – as an indicator for the activity level of an economic sector
- Total energy intensiveness (or specific energy consumption) – defined as end-use energy consumed per unit of value-added in an economic sector
- Distribution of the energy consumption in an economic sector among the various energy forms (fuel mix)

In the following sections, the assumptions made in the four scenarios about the evolution of the energy requirements in the intermediate sectors of the economy will be explained; additional information is given in Appendixes B–F.

5.3.1 Scenario Assumptions

5.3.1.1 VALUE ADDED

Table 12 gives an overview of the value-added projections used for the four scenarios, by comparing the contributions of four major sectors in the base year and in the last year of the projection period. (The base year for the economic projections is 1970; the values for 1971 are model results.) The structural shifts are very moderate on such an aggregated level. However, shifts occurring within the industrial and the commercial and service sectors do not appear in the table. These structural shifts cause a change in the level and in the structure of energy demand. In all four scenarios the fastest growing subsectors are chemicals, and mechanical and electrical machinery and equipment, the energy intensiveness of which is lower than the average for the whole industrial sector. (This is especially true for the equipment goods subsector.) This factor contributes to the under-proportional growth in energy demand that can be observed in the national economy.

The value-added projections are dependent on assumptions concerning both the level and the structure of final demand and the technological structure. There is no formal link between AUSTRIA II and the energy demand models.

In scenarios S1, S2, and S3, the assumptions regarding automobile and household appliance ownership levels were made so as to be consistent with the expected growth of GNP and personal disposable income. The technological assumptions in these scenarios were moderate, so that a modification of the final demand structure or additional modifications of input/output coefficients (beyond those included in AUSTRIA II) were not necessary.

Major changes were considered in scenario S4, which had to be reflected in AUSTRIA II. However, the resulting differences between the value-added structures of scenarios S3 and of S4 are moderate because of compensating effects. The assumed improvement of insulation levels and efficiencies lowers the demand for energy and therefore the value added by energy supply sectors, but it increases the value-added share of energy consuming sectors.

5.3.1.2 ENERGY INTENSIVENESS

Energy intensiveness is determined for each sector by anticipated trends within the scenarios, which are represented by saturation curves. These

TABLE 12 Comparison of value-added projections.

	Agriculture sector (%)	Industrial sector (%)	Transportation and communication sector (%)	Commercial and service sector (%)	Total 10^9 AS_{70}[a]
1970	7.39	33.15	6.61	52.85	354.2
2015					
Base Case (S1)	4.99	34.15	7.55	53.09	927.5
High Case (S2)	4.76	36.80	7.08	51.36	1,242.1
Low Case (S3)	5.06	32.48	7.92	54.55	784.9
Conservation Case (S4)[b]	5.04	32.62	7.88	54.45	786.9

[a] Austrian schillings at 1970 values.

[b] The differences between the value-added structure in this scenario and the structure in scenario S3 are because of the assumptions of better insulation and more efficient energy use. This lowers the demand for energy and therefore the value added by energy supply sectors; on the other hand, it increases the value added of energy conserving sectors.

curves are specified by three principal parameters: the initial value (1974); the ratio between the assumed energy intensiveness in the year 2000 and the initial value; and the fraction of the potential changes assumed to be exhausted by the year 2000. The last two parameters are scenario dependent. (The year 1974 was used as reference because the energy consumption data for this year are more reliable than those for previous years, especially in some service sectors such as trade, hotels, and restaurants.)

The assumed energy intensiveness is summarized in Table 13 for four major sectors of the economy. The figures given in the table for 1970 and 1974 are obtained by dividing the actual energy consumption in those years by the value-added figures deduced from the model; import duties are not included. As a result, the intensiveness figures given in the table are higher than those obtained by using the value-added data from national accounts statistics.

The energy intensity figures given in Table 14 for the industrial and the commercial and service sectors are weighted averages; the assumptions for individual branches are listed in Appendix C. In scenarios S1 and S3, it is assumed that most of the industrial sector will achieve a 10% reduction of its energy intensiveness by the year 2000. The exceptions are primary metals subsector and the transportation and communication sector, which are assumed to achieve reductions of about 20% of their specific energy requirements; and mining, petroleum, and natural gas, and the trade subsectors. In these latter subsectors, an increase of energy intensiveness is anticipated for several reasons: (a) mining has been and probably will continue to be a declining subsector, so that only urgent investments will be made; (b) the petroleum industry experienced a shift from extraction to refining activities, causing higher energy inputs (and this shift will continue because the known crude oil and natural gas reserves in Austria are being depleted); and (c) in the trade sector it is assumed that the trend toward larger stores with more electrical appliances and more heating and cooling requirements will continue. The assumption of a major decline of the energy intensiveness of the primary metals subsector and the transport and communication sector seems justified because energy inputs make up a large percentage of the production costs in these sectors. With the expected increase in energy prices, the motivation for energy conserving measures is likely to be even stronger in the future.

In scenario S2, an increasing energy intensiveness on the order of 10% by the year 2000 is assumed for most of the sectors and subsectors. The exceptions are an increase of 20% for agriculture, wood products, leather products, and trade, and an increase of 30% for mining and petroleum and natural gas. Only a 4% increase is assumed for the transportation

TABLE 13 Energy intensity assumptions (kcal/AS_{70}).[a]

	Agriculture sector[b]	Industrial sector	Transportation and communication sector[c]	Commercial and service sector	Total
1970	370	510	866	82	297
1974	366	505	819	105	300
2015					
Base Case (S1)	366	445	602	100	270
High Case (S2)	446	507	855	109	324
Low Case (S3)	366	447	581	103	266
Conservation Case (S4)	290	375	469	78	216

[a] Austrian schillings at 1970 values.

[b] Including wood. In the end-use energy consumption tables given in Appendix F, wood has been removed because it is included in the residential sector. According to the energy balance of the OeStZ, between 40% and 45% of the energy consumption in agriculture is supplied by wood; the rest is covered by diesel (40%), gasoline (7%), and electricity (7%).

[c] Currently, communication contributes about one-third of the value added of the two aggregated sectors, but its energy consumption is only 2% of the total energy consumption of the two sectors. The shift toward the communication sector (1964, 26%, 1973, 31% of the value added) with its lower energy intensiveness also contributes to a decrease of the energy intensiveness in this aggregate.

TABLE 14 Energy intensiveness assumptions in the industrial sector.

Subsectors	1974[a]	Factors of change between 1974 and 2000 S1	S2	S3	S4	Change factor 1960–1973[b]
Primary metals	1,700	0.8	0.9	0.8	0.75	(0.63)
Mining	1,249	1.1	1.3	1.1	0.9	(0.99)
Stone, clay, cement	1,174	0.9	1.1	0.9	0.7	(0.79)
Glass	982	0.9	1.1	0.9	0.8	(0.71)
Petroleum	933	1.2	1.3	1.2	0.7	(1.64)
Paper	831	0.9	1.0	0.9	0.8	(0.83)
Chemicals	632	0.9	1.1	0.9	0.7	(0.48)
Textiles	306	0.9	1.1	0.9	0.7	(0.95)
Food	205	0.9	1.1	0.9	0.8	(0.70)
Wood products	193	1.0	1.2	1.0	0.8	(1.28)
Machinery/metal products/ vehicles	144	0.9	1.0	0.9	0.8	(0.81)
Electrical machinery and equipment	110	1.0	1.1	1.0	0.8	(0.53)
Clothes	88	0.9	1.1	0.9	0.7	(1.50)
Leather	80	1.0	1.2	1.0	0.8	(0.62)

[a] kcal/Austrian schilling value added; data for industry and handicraft trade.
[b] Data for industry only.

and communication sector, and a 10% decrease for the primary metals subsector. No change is anticipated in the remaining sectors. During the period 1960–1973, there has been an increase in the energy intensiveness of some industrial subsectors (e.g., fabricated metal products, leather products, casting, wood products, clothing, and petroleum and natural gas) either because of a shift in the product mix or because of increased automation. Nevertheless, the assumptions in scenario S2 are extreme, so that the calculated energy demand can be considered an upper bound.

Assumptions implying major energy conservation efforts are made only in scenario S4. In this scenario, reductions in energy intensiveness on the order of 20% are anticipated for most sectors. The exceptions are primary metals (25%); petroleum, stone and clay and cement, chemicals, textiles, clothing, electricity, and gas and water supply (30%); banking and insurance, hotels and restaurants, and transportation and communication (40%).

The assumption in S4 concerning the petroleum subsector is ambitious in that the effects of the shift from extraction to refining would have to be offset by a highly improved refinery efficiency. The assumption of a 40% decrease in energy intensiveness in the transportation and communication sector implies large-scale improvements in the fuel economy of trucks and a slight modal shift back to rail. The assumptions concerning this sector are laid out in more detail in the section on transportation energy.

Historical data on energy consumption in the commercial and service sector and the handicraft industry subsector are poor, but there are good data on energy consumption in industry. In order to put into context the energy intensiveness assumptions made in this study, a comparison was made of the changes in energy consumption during the period 1960–1973 and the scenario assumptions (see Table 14). Such a comparison, however, cannot be made for all subsectors, and the comparison is biased because the historical data refer to industry in the strict sense, whereas the subsectors used in this study include both industry and handicrafts. The assumed changes are moderate compared to the changes in the past, partly because the growth rates of the economy in the scenarios are considerably lower than the historical rates in the period after 1985.

A statistical analysis (Bayer, 1970) of economic activity and energy consumption in the Austrian industrial sector during the period 1960–1974 showed that this sector has considerably reduced its specific energy consumption. This reduction is largely because of overproportional growth of subsectors which are not very energy intensive, such as equipment goods industries. Within most of the branches, a high correlation exists between gross investments and the reduction in energy intensiveness. However, in some branches, a shift toward more energy intensive products had a greater impact than had the rationalization of the production. (See Appendix H for a summary of the analysis of the effects of the product mix; and Appendix I for a discussion of the factors determining energy demand in the commercial and service sector.)

5.3.1.3 FUEL MIX

The term *fuel mix* is used here to denote the distribution of the total end-use energy consumption among various energy sources. The energy sources considered are: electricity, hard coal, coke, lignite, fuel oil, gases, gasoline, diesel, and other energy sources.* This aggregation is determined

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*As noted earlier, the initial data on energy consumption in the intermediate sectors of the national economy are taken from the energy balance published by the OeStZ. The data on end-use energy consumption (Einsatz beim Letztverbraucher) are converted into thermal units, using the lower in part by the need to separate energy sources with different emission characteristics in order to facilitate the analysis of air pollution effects.

While historical data offer some guidance, it is difficult to model the future evolution of the fuel mix. The future fuel mix in a given sector depends on the types of processes applied, the ability to substitute fuels, the prices of the various fuels, and the ability to substitute technologies (Chateau and Lapillonne, 1977; Hoffman, 1973; Hoffman and Cherniavsky, 1975). An additional consideration is the economic health of a given sector which may determine whether an advantageous process can be adopted.

These considerations are taken into account in only a limited way in this study. The evolution of the fuel mix is projected for each sector with the help of a transition matrix with constant coefficients. The matrix is calculated so that the resulting trajectories approximate the fuel mix shifts observed between 1970–1974, and become stationary at a prespecified distribution. This approach, based on the available information on specific sectors and on the judgment of the research team, was felt to be superior to extrapolating historical trends.

The actual fuel mix in the years 1970 and 1975, and the model figures for the years 1975 (for comparison) and 2015 are given in Appendix J for each sector. The same fuel mix evolution is assumed within each sector for all scenarios, in order to limit the number of factors that differ between the scenarios. There are, however, differences in the aggregated sectors (industrial, commercial and service) because the evolution of the value-added structure and the energy intensiveness differs from scenario to scenario.

5.3.2 Results and Conclusions

The industrial sector has the largest end-use energy demand of the five sectors. As shown in Figure 8, the industrial share increases from 42% of end-use energy in 1971 to 46%, 47%, 44%, and 44% in 2015 in the S1, S2, S3, and S4 scenarios, respectively.

Petroleum use, mainly in the form of fuel oil, decreases from 38% of total industrial demand in 1971 to 25% of the total by 2015 in all

heat content of the energy sources as given in the energy balance. Data for 1970–1974 are considered; data for 1975 were available only near the end of the study. In addition to the aggregation into the sectors as defined in Appendix C, several energy sources are lumped together: lignite plus lignite briquettes to "lignite"; kerosene and jet fuel plus gasoil to "diesel"; various types of gases (including liquid petroleum gas and refinery gas) to "gases"; wood plus waste plus district heat plus mechanical hydropower to "other".

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 study years. The largest increase in fuel demand by the industrial sector is for natural gas, which increases its share of total manufacturing end use from 22% in 1971 to 38% by 2015 in scenarios S1, S2, and S3, because of the assumed substitution of oil by gas.

Since the industrial sector continues to dominate in energy use, policy measures for altering energy-use patterns should focus on this sector. A breakdown of energy demand by source in the industrial sector is shown in Figure 13.

Of all sectors analyzed in this study, we believe the industrial sector has the greatest uncertainty in future energy demand. The largest contributor to this uncertainty lies in the sector's energy intensiveness (Table 14).

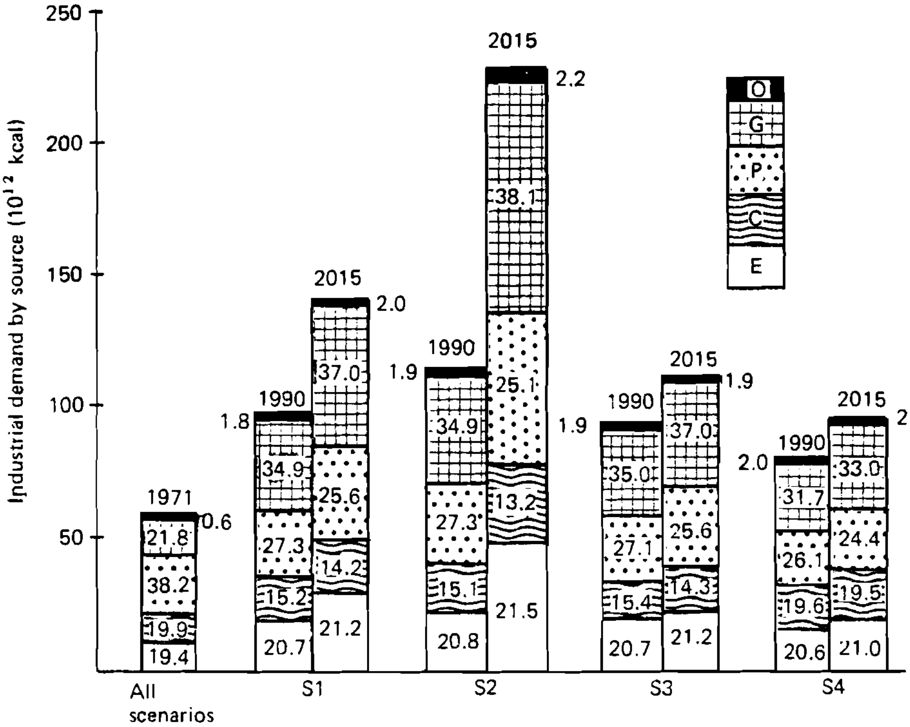

FIGURE 13 Energy demand in the industrial sector by source. The values within the bar diagrams represent the percentages of different energy sources used in the given years for each scenario. E is electricity; C is coal; P is petroleum; G is gases; and O is other.

It is probable that continuing reduction of this factor will require greater capital investments for new technology in many of the industrial subsectors. Motivation for these improvements can come from the continued increase of energy prices (especially if severe constraints in petroleum supplies should occur in the late 1980s), or from other financial incentives (e.g., tax credits). However, the extent to which these investments will occur under alternative conditions is difficult to estimate without a more detailed examination of the most important components of the industrial sector. One recommendation by the study team for further work is that the industrial sector be investigated in more detail, with close attention given to the most important technical processes, including questions of fuel substitutability, capital required to implement conservation measures or to alter the product mix. Because of the importance of this sector, such an investigation should receive priority in future research.

During the period 1971–2015, 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, with petroleum remaining 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 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.

5.4 TRANSPORTATION AND COMMUNICATION SECTOR

Of the five sectors in the Austrian case study, the *transportation and communication sector experiences in general the slowest end-use energy growth.* However, transportation energy growth is not the lowest for the S2 scenario after 1980 and for all scenarios after 1990. For the entire study period (1971–2015), the average energy growth rate for transportation is the slowest in all scenarios except S2, where residential energy growth is 2.2%/yr versus 2.4%/yr for transportation (see Tables 4–7).

As noted in Figure 8, transportation's share of end-use energy declines in all scenarios from 21% in 1971 to 16% for scenarios S1 and S4, to 18% for scenario S2, and to 17% for scenario S3 in 2015. This trend is indicative of the conservation potential available in the transportation and communication sector as well as of the anticipated saturation of automobile ownership growth.

The transportation and communication sector consists of two components: personal travel, and freight. For the first component, personal travel is estimated and converted into vehicle kilometers on the basis of vehicle use data (Hanson and Mitchell, 1975). Vehicle kilometers are converted to energy use and emissions on the basis of vehicle characteristics and operating conditions.

This estimation procedure was done on a spatially disaggregated basis. The spatial disaggregation consisted of core regions focusing on the principle cities of Austria (see section 4.2). The thirteen core regions were divided into cores and two concentric rings, each of which in turn consists of one or more of the four types of communities: core cities, main cities, other cities, and rural communities. Energy and emissions were estimated at the community level.

Freight energy demand was projected using AUSTRIA II. (Where personal transportation is included in the commercial and service sector of AUSTRIA II, measures were taken to avoid double counting.) AUSTRIA II, using economic projections of Austria's trading partners, forecasts activity in the transportation and communications sector consistently with the rest of the Austrian economy. The level of activity in this sector, combined with the energy use per unit of activity, provides an estimate of energy use. Freight energy intensity is based on projections of modal distribution of ton-kilometers and on trends in modal efficiency.

5.4.1 Scenario Assumptions: Personal Transportation

The historical development of automobile ownership and the saturation levels used in the four scenarios are shown in Figure 14 (Oesterreichisches Statistisches Zentralamt, 1975). The levels of automobile ownership, in terms of vehicles per 1,000 population, are tied to the rates of economic activity in Austria. Thus, in the S2 scenario with the highest economic growth, ownership is assumed to rise to 400 vehicles per 1,000 population. This level is viewed as an upper limit because within the time span of the study, the number of licensed drivers per 1,000 population is unlikely to exceed 500 – the current figure in the U.S. (Shonka *et al.*, 1977). This seemed to be a plausible assumption noting the age distribution of the Austrian population. It was also felt that vehicle ownership per licensed driver would not reach 1.0. Thus, 400 vehicles per 1,000 population formed an upper limit in this study.

In the S1 scenario, vehicle ownership reaches 300 vehicles per 1,000 population in the early 1980s and is assumed to hold constant at that level. With this assumption, the vehicle ownership level is similar to that

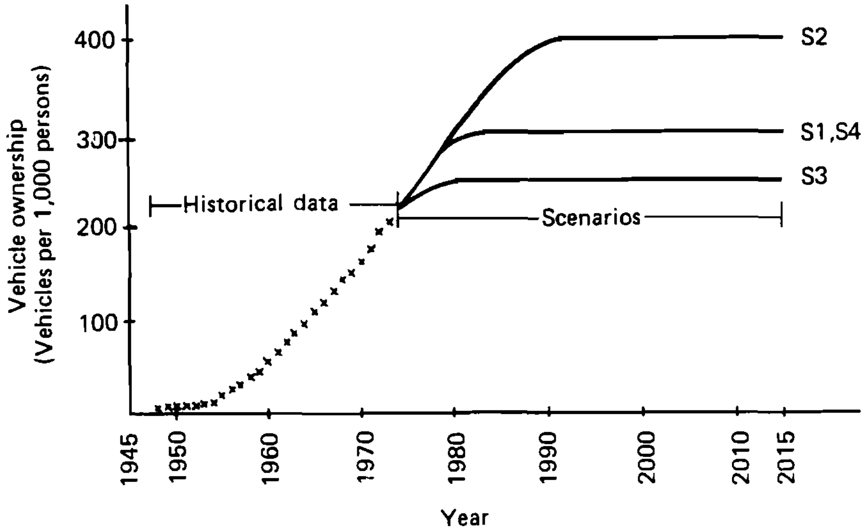

FIGURE 14 Automobiles and stationwagons per 1,000 population in Austria.

in Sweden, where there are 400 licensed drivers per 1,000 population and 300 vehicles per 1,000 population (Schipper and Lichtenberg, 1976). For scenario S3 with the lowest economic growth, 250 vehicles per 1,000 population was used to reflect even lower economic activity. As shown in Figure 14, this level is reached at or shortly after 1980. (The figure for 1973 was 208 vehicles.)

Finally, the S4 scenario, or the conservation case, is assessed at the 300 vehicles per 1,000 population level. The purpose is to assess the impact of conservation measures from the base case level of ownership. This is in contrast to other assumptions in the S4 scenario which are based on the S3 economic assumptions.

Increasing fuel costs and taxes are expected to stop the growth in the size of the automobile in Austria in all scenarios. In addition, because of these trends in cost and taxes, improvements in new automobiles from the current level of fuel economy (12.3 liters/100 km) to 8.9 liters/100 km by 1985 is assumed in scenarios S1 and S3, and to 7.0 liters/100 km by 1990 in scenario S4.

Additional policy measures, such as fuel economy standards, could potentially offer strong impetus for improving automobile performance. Such measures would most likely be brought to bear in the event of shortfalls in world petroleum supplies (see Chapter 6). A second plausible situation for implementing such standards would be if there are serious trade deficits resulting in part from the cost of imported petroleum.

Another impetus for increased fuel economy is the expectation that the fuel economy standards in the U.S. automotive markets will have a significant carry-over effect on non-U.S. manufacturers who will be required, along with their U.S. counterparts, to meet the standards of the U.S. market. The U.S. Energy Policy and Conservation Act of 1975 mandates an average annual standard that reaches 27.5 MPG (miles per gallon) or 8.6 liters/100 km for the 1985 model year fleet for each manufacturer's vehicle in the U.S. market (U.S. Congress, 1975). Standards currently being discussed for 1990 push the fuel economy to the 7 liters/100 km level.

5.4.2 Scenario Assumptions: Freight Transportation

The freight transportation assumptions pertain to modal distributions, modal energy intensities, and the level of activity in the transportation and communications sector of AUSTRIA II. The level of activity in the transportation and communications sector and how it was arrived at for the four scenarios is described in Section 5.3. No attempt was made to separate the communications aspect from this sector; thus only the modal split and intensities are described here.

The historical development of the modal shares since 1960, with a projection by Kohlhauser, is shown in Figure 15. The scenarios assume that present trends in freight modal distribution shifts are continued, reaching the following distribution of ton-kilometer: railroads, 48.7%; trucks, 23.5%; barges, 6.4%; and pipelines, 21.4%. In 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%.

On the basis of these modal distributions, an overall normalized freight energy intensity per ton-kilometer was set using U.S. data on modal intensity (Hirst, 1973). (Detailed modal intensities were not available for Austria.) Future overall freight intensity relative to present intensity was a function of modal shifts and trends in intensiveness by mode. Finally, the resulting intensity was used to adjust the energy intensity in the transportation sector.

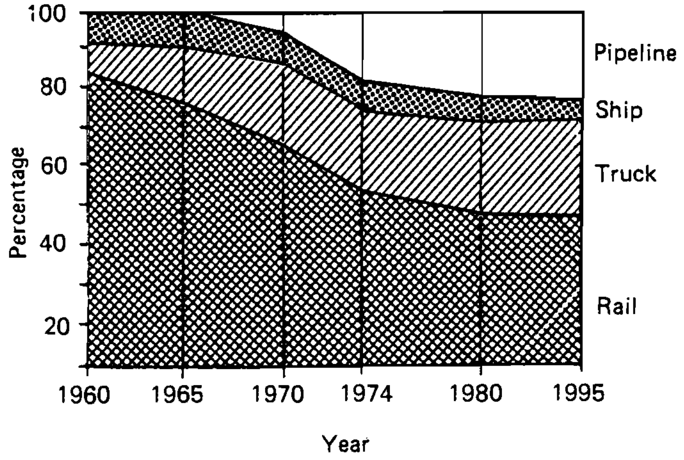

FIGURE 15 Distribution of freight transport (net ton-kilometer) by mode. Source: Kohlhauser (1976).

In all four scenarios, the individual modal intensities remain constant for rail, barge, and pipeline. Truck intensity remains constant in the S2 scenario; but by 1995, it decreases 20% in scenarios S1 and S3, and 35% in scenario S4. These savings in truck energy use could be the result of a reduction in the number of vehicles and in vehicle use modifications including changes in aerodynamic design, the use of wind deflectors, radial tires, reduced speed, and the matching of engine, transmission, and axle (Cummins, 1973).

5.4.3 Results and Conclusions

The dominant fuel in the transportation sector is petroleum, which is divided about equally between gasoline and diesel, a small percentage 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 of petroleum was 90% in each of the scenarios; electricity, coal, and other fuels for trains and mass transit accounted for the rest. This is to be expected for a transportation sector based on the internal combustion engine.

The growth of energy use in the transportation sector, as shown in Figure 16, depends on the development of the freight and personal transportation areas. In general, the rate of growth of end-use energy slows during the period 1971–1990, with a resulting average below the historical rate because of conservation measures taken for automobiles as well as for trucks. The S2 scenario is an exception since conservation measures are not taken. The rate of growth picks up again after 1995 for all scenarios, since no further conservation measures are implemented and growth is tied to both the continuing population growth for personal transportation and economic growth for freight transportation.

Because the economy grows faster than population and because of the larger conservation potential in the personal transportation area, during the study period the shares of personal and freight transportation energy shift toward freight. The fraction of gasoline use for automobiles, as compared to total transportation energy, decreases from 49% in 1971 to 40% in 2015 for scenarios S1, S3, S4, and to 41% for S2.

The single most effective method for conserving transportation energy in Austria is the adoption of fuel economy standards for automobiles. This allows the reduction of energy use without reducing travel. The principal result of the adoption of standards would be a movement to less powerful, lighter, and smaller automobiles. Another strategy for reducing fuel consumption would be a massive shift to diesel engines in automobiles.

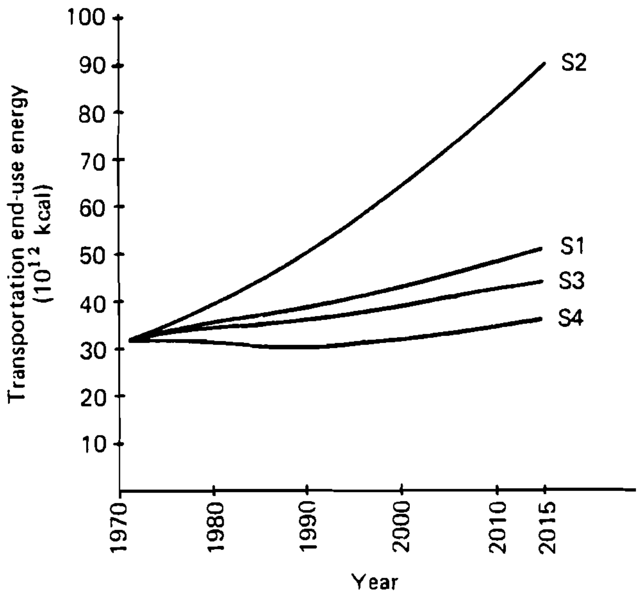

FIGURE 16 Total transportation end-use energy, by scenario.

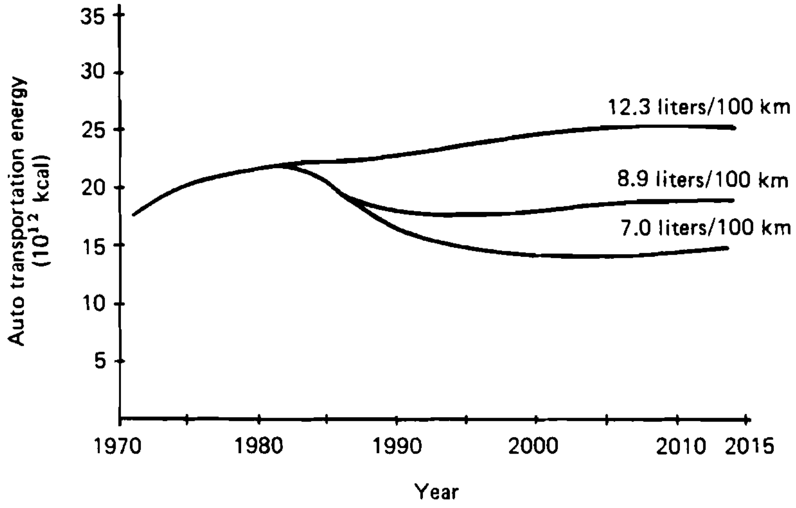

FIGURE 17 Automobile transportation energy: fuel economy sensitivity for scenario S1.

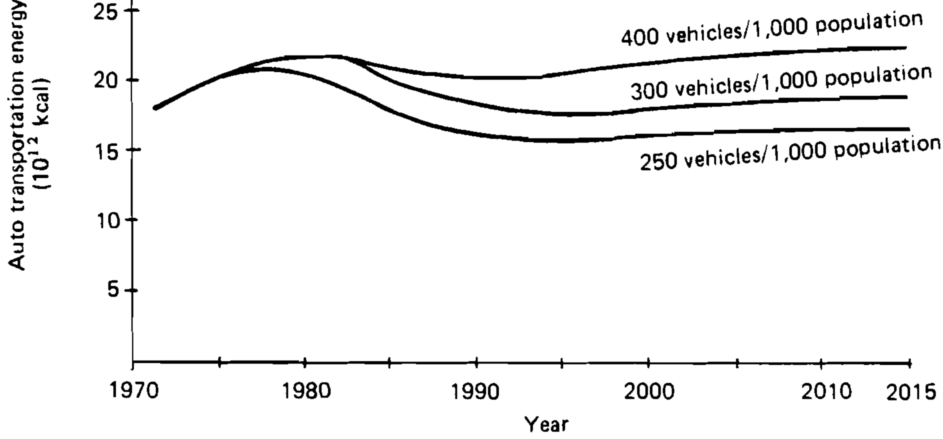

FIGURE 18 Private transportation energy: ownership sensitivity.

Figure 17 indicates the sensitivity of transportation energy use to varying fuel consumption for a given amount of vehicle kilometers. For a base case ownership of 300 vehicles per 1,000 population, moving from present average vehicle efficiencies of 12.3 liters/100 km to 8.9 liters/100 km as in S1 reduces energy consumption by 28% in 2015 from 26.3×10^{12} kcal to 19.0×10^{12} kcal. A higher efficiency of 7.0 liters/100 km reduces gasoline consumption by 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.

As shown in Figure 17, the level of energy use responds rapidly to the change in fuel economy characteristics of the automobile fleet. A policy shifting fuel economy in the period 1980–1985 to 8.9 liters/100 km has had its full effect by 1995 and the greater part of the effect by 1990.

Levels of vehicle ownership have lesser but still important effects on energy consumption, as shown in Figure 18, based on scenario S1 fuel economies. The figure indicates the sensitivity of energy use to vehicle ownership. As is evident in this figure, energy use does not rise proportionately with vehicle ownership because of the decrease in use per vehicle as ownership levels increase. An example is the decrease in the use of the second automobile or of both vehicles in families with two automobiles.

6 ENERGY SUPPLY

In all scenarios, *energy supply was defined as the amounts of primary energy by source required to meet end-use energy demands.* In the Austrian case study, two approaches were used to study energy supply questions. First, a demand/supply balance technique was employed, in which energy supply was matched to energy demand; however, it was necessary to determine supply options for electricity and district heat generation. Although no formal, computer-implemented model was used in this analysis, Austria's historical experience and future plans were considered.

A formal resource allocation model was also applied to the 1990 end-use demands for scenarios S1, S2, and S3. The model, which examines interfuel substitution strategies, was used to calculate an optimal supply strategy based on economic and resource availability criteria.

A brief methodological description of the energy demand/supply balance approach is presented in section 6.1. This is followed by a description of the assumptions used for determining electricity supply options and by the detailed presentation of the results. The magnitude of supply requirements associated with each demand scenario is assessed in total and disaggregated by energy source. Next, supply scenarios for electricity and for district heat generation are presented with reference to the size of demands and policy choices. Finally, supply requirements are compared with data on fuel availability in order to identify gaps that could occur between supply and demand and to assess fuel shifts that could close such gaps. In section 6.2 assumptions, including constraints and costs, are outlined for the resource supply optimization technique. This is followed by a presentation of results for the year 1990, with emphasis upon the structure of the electricity sector.

6.1 SUPPLY SCENARIOS: THE ENERGY DEMAND/SUPPLY BALANCE APPROACH

A demand/supply balance approach was used to calculate supply requirements associated with sectoral end-use demands in all four scenarios. Energy demands were divided into three categories: electric, district heat, and other nonelectric. Supply options were determined for the production of electricity and district heat based on Austria's historical experience, future plans, and policy choices. Primary energy for these conversion processes was then added to primary energy requirements for fuels burned at the point of end use in order to determine total supply requirements. Figure 19 depicts the flow of calculations used in the approach. As shown, the amounts of primary energy requirements to meet end-use demands are determined by accounting for transportation, refining, conversion, and distribution losses, as well as for plant thermal efficiencies in the electric and the district heat subsectors.

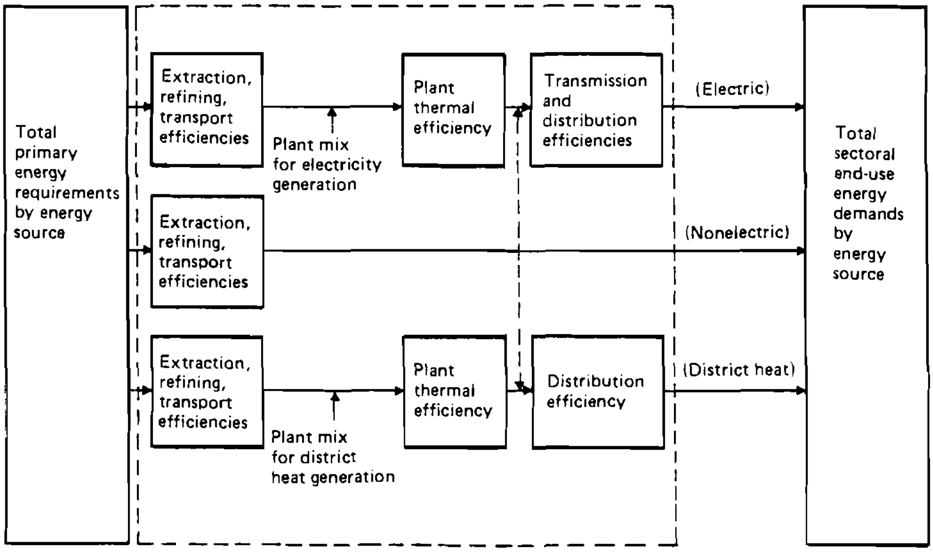

FIGURE 19 Calculation of primary energy requirements: energy demand/supply balance approach.

The output of the demand/supply balance approach was used to assess whether supply requirements can be met by domestic resources and imports in the future. The petroleum demands associated with the Conservation Case (S4) were compared with estimates of Austria's future petroleum imports (based on forecasts of world petroleum reserves and production rates) in order to elucidate possible petroleum shortfalls in Austria. Fuel shifts that could be used to close the petroleum gap were analyzed.

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

6.1.1 Electricity Assumptions

The principal policy issues underlying the alternative electricity futures examined in these scenarios were: the acceptability of nuclear power; the rate of hydropower expansion; the levels of electricity imports and exports; and the expansion of the fossil-fuel generation base. These four key policy issues led to the following set of scenario assumptions.*

> *Scenario S1.* There is restrained acceptance of nuclear power; one 730 MWe plant is operating in 1990 and two 1,300 MWe plants are operational by 2015. There is a steady development of hydropower to a saturation limit of 44.1×10^9 kWh in 2015 (10% of which is exported). Imports of electricity increase from 2.2×10^9 kWh in 1971 to 6.9×10^9 kWh in 1990; and are constant thereafter. Fossil fuel generation is relatively stable through 2015.
>
> *Scenario S2.* There is large nuclear penetration; one 730 MWe plant is operating in 1990 and five 1,300 MWe plants are operational by 2015. Hydropower is fully exploited by 2000, and there is a gradual reduction in exports from 10% of production in 2000 to zero in 2015.

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*In scenarios S1, S2, and S3, nuclear power was considered an option for producing electricity, while scenario S4 described a nonnuclear future. The outcome of the November 1978 referendum on nuclear power in Austria made it imperative that other electricity supply strategies be examined in S2, the high growth scenario.

Imports of electricity increase from the 1971 level to 11.7 × 10^9 kWh by 1990; and are constant thereafter. The fossil-fuel generation base expands from 12.6 × 10^9 kWh in 1971 to 21.3 × 10^9 kWh in 2015.

Scenario S3. Nuclear capacity is restricted to one 730 MWe plant which is retired by 2015. The situation with respect to hydropower development and to imports and exports is the same as in S1. The fossil-fuel generation base expands from the 1971 level of 12.6 × 10^9 kWh to 17.3 × 10^9 kWh in 2015.

Scenario S4. No nuclear permitted. The situation with respect to hydropower development and to imports and exports is the same as in S1. The use of petroleum for electricity is phased out between 1990 and 2000; after 1990, the level of electricity generated from lignite and gas is constant.

6.1.2 Results and Conclusions

Figure 20 shows *total primary energy* requirements for scenarios S1 to S4, comparing the scenario years 1990 and 2015 with historical data for 1971. 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 × 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 0.70%.

The growth of the Austrian economy in terms of GNP is greater than that for primary energy. As is shown in Table 15, the elasticities between primary energy requirements and GNP remain less than 1 throughout the time frame of the study in all scenarios except in S2, the High Case. The most marked decrease in energy input relative to economic output occurs in the 1980s. This results from assumptions of increased energy efficiency tied to technological advances. After 1990, further structural changes resulting in energy savings are not assumed; thus the elasticities increase. Figure 21 shows historical data and scenario results for GNP and primary energy use.

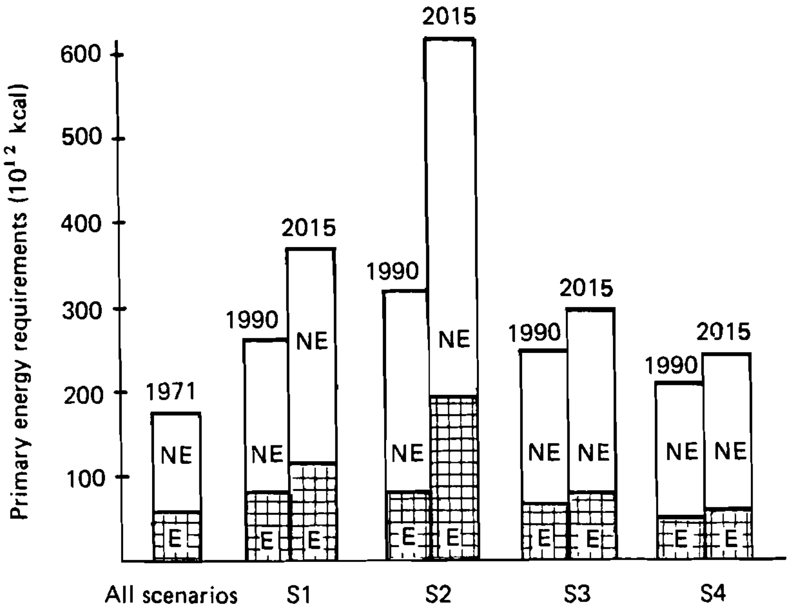


FIGURE 20 Total primary energy requirements, by scenario. E is electricity; NE is nonelectric energy.

TABLE 15 Elasticity between primary energy requirements and gross national product (GNP), Austria, 1971–2015 [(Δ Primary energy/Primary energy)/(ΔGNP/GNP)].

	Scenario			
Time period	S1	S2	S3	S4
1971–1980	0.75	1.10	0.70	0.37
1980–1990	0.59	0.83	0.54	0.19
1990–2000	0.87	1.03	0.48	0.44
2000–2015	0.83	0.95	0.88	0.62

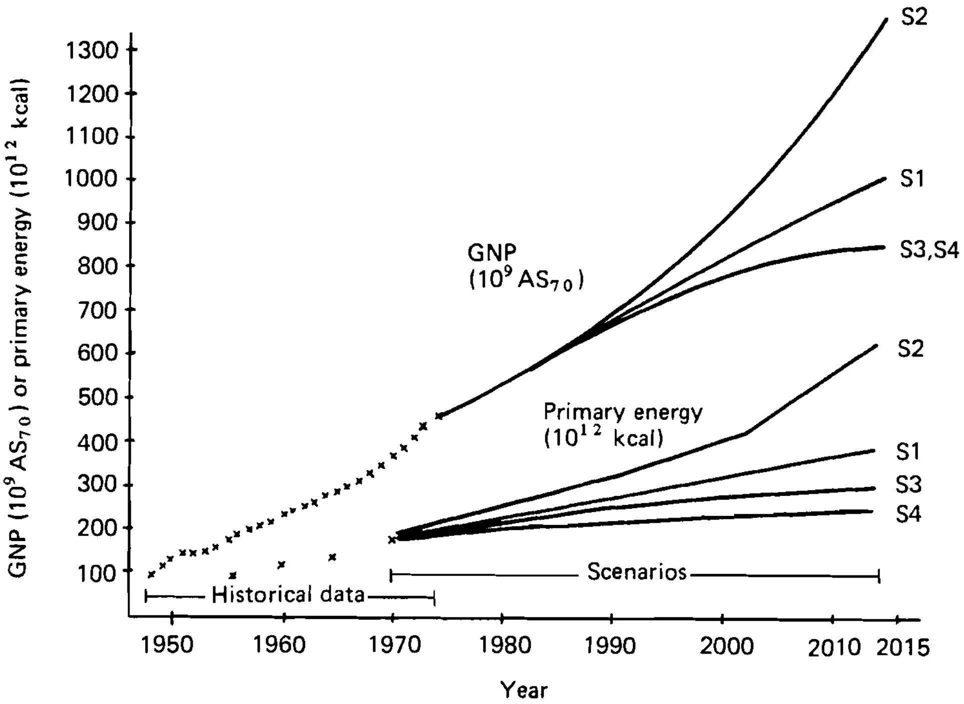


FIGURE 21 Austrian gross national product (GNP) and primary energy requirements. AS_{70} means Austrian schillings at 1970 values.

6.1.2.1 TOTAL PRIMARY ENERGY REQUIREMENTS: SCENARIO RESULTS COMPARED TO AUSTRIAN PROGNOSES

The primary energy requirements associated with the Base Case (S1), the Low Case (S3), and the Conservation Case (S4) for 1990 are lower than the results of published Austrian energy prognoses (Musil, 1975; Joint Marketing Research Team, 1977). As Figure 22 indicates, the prognosis of the Austrian Institute for Economic Research (WIFO) of total primary energy requirements in 1990 is 26% higher than those of scenario S1. The petroleum companies' prognosis for the year 1990 is 11% higher. Only the results of the S2 scenario provide an exception to the consistently lower results of the other three scenarios.

A comparison between the two prognoses and the three scenarios is shown in Table 16. These figures indicate that major economic driving functions are assumed to be lower in the scenarios than in the Austrian

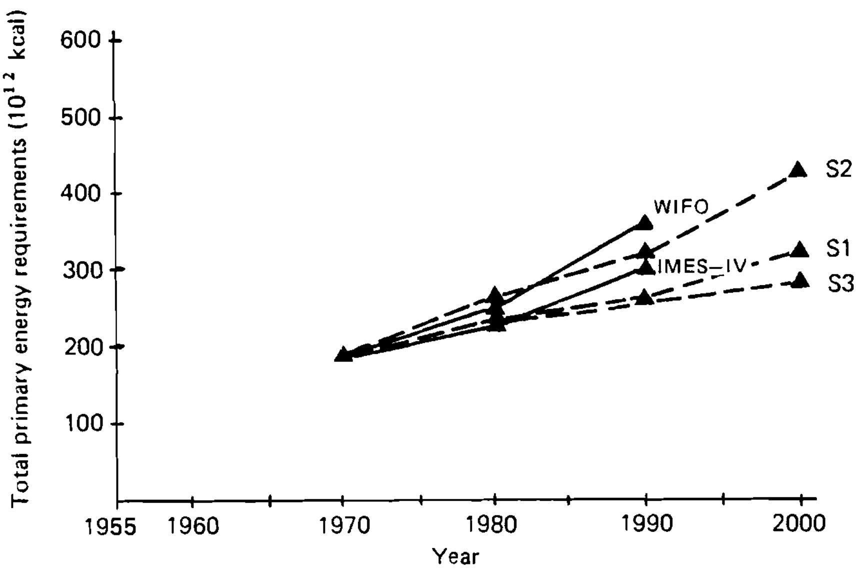


FIGURE 22 Total primary energy requirements: comparison of scenario results with Austrian prognoses from the Austrian Institute of Economic Research (WIFO) and IMES-IV.

prognoses. However, the scenario results for total primary energy requirements result from the analysis of a large quantity of variables affecting energy use in the residential and the commercial and service sectors as well as in the industrial and the transportation sectors.

Total primary energy requirements have been disaggregated by fuel types in Figure 23. The relative importance of fuels and long-range fuel demand trends are graphically illustrated. Both hard coal and lignite, which together represent 11% of primary energy in 1971, decline in significance by 2015 in all scenarios. The two energy sources that show a definite increase in importance over time are hydropower in scenarios S3 and S4, and nuclear power in scenarios S1 and S2.

Total electricity generation requirements for the four scenarios are illustrated in Figure 24, along with historical data for the period 1945–1971. A comparison between S2 and S4 shows that S2 requires more than twice as much electricity in 2015, a level that would lead to

TABLE 16 Selected assumptions underlying Austrian prognoses and the study scenarios.

Time period	WIFO, 1976	IMES-IV, 1977	Scenario S1	S2	S3
Average annual GNP growth rates (%)					
1975–1980	4.0	4.0	2.87	3.02	2.83
1980–1985	4.0	4.0	2.50	2.67	2.48
1985–1990	3.5	3.5	2.26	2.65	2.09
Average annual industrial production growth rates[a] *(%)*					
1975–1980	4.0	5.0	2.11	2.99	2.77
1980–1985	4.0	5.0	3.11	2.87	2.64
1985–1990	3.5	4.3	2.08	2.93	2.22
Number of gasoline-fueled automobiles (10^6)					
1980	2.0	2.03	2.05	2.20	1.76
1985	2.4	2.35	2.21	2.66	1.85
1990	2.54	2.51	2.23	2.97	1.86

[a] The average annual industrial production growth rates for the study scenarios refer to manufacturing as a whole, i.e. industry in the strict sense plus the handicraft industries. The rates from the other studies refer only to industry in the strict sense.

extremely high levels for fuel imports. In all scenarios, with the exception of S2, the growth in electricity is less than historical trends.

The mix of fuels used in the generation of electricity varies greatly among the four scenarios, as shown in Figure 25. This variation is a result of the wide range of electricity demands and the fuel use trends that resulted from specific policy assumptions. In the S1 scenario, the electricity demand in 2015 was met through full exploitation of hydropower (increasing from 45% of requirements in 1971 to 53% in 2015); the operation of two 1,300 MWe nuclear plants (21%); imports of 6.9×10^9 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 1,300 MWe nuclear plants (34% of total), through the full exploitation of hydropower (38%), through high levels of electricity imports (10%), and through the expansion of the fossil-fuel generation base (18%). This "high" nuclear future could have a number of major environmental and policy implications.

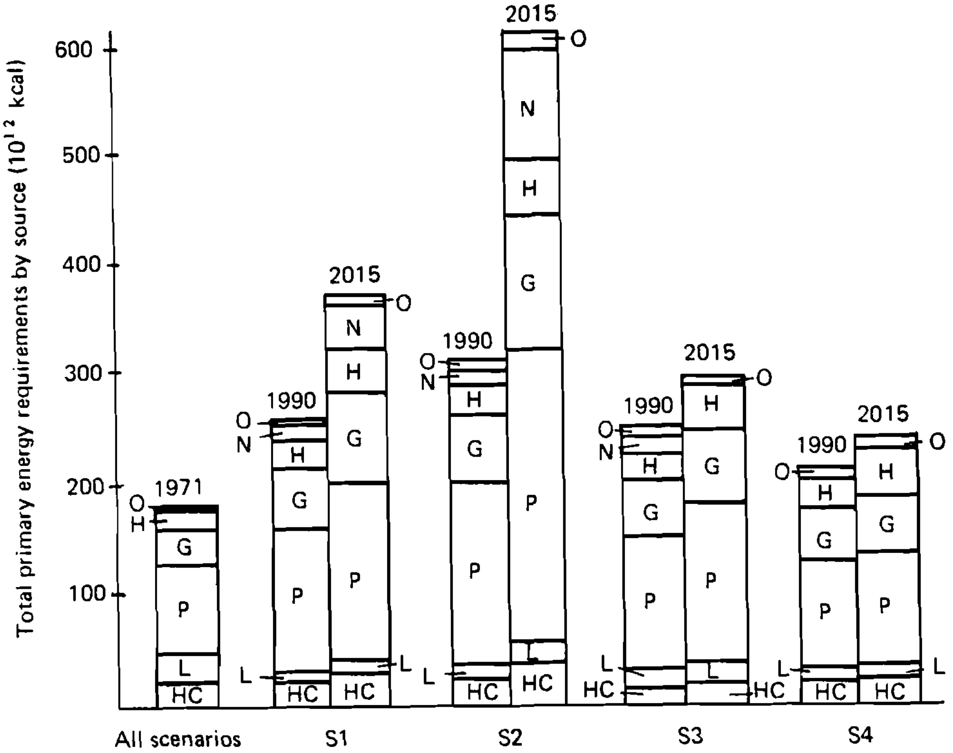


FIGURE 23 Total primary energy requirements by source, by scenario. HC is hard coal; L is lignite; P is petroleum; G is gases; H is hydro; N is nuclear; and O is other.

In contrast to these high demand scenarios, the low electricity requirements of S3 could be met with no major commitment to nuclear power (only one nuclear plant is assumed to be put into operation during the early period of S3). 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 requirements of S4 in 2015, only a factor of two greater than the 1971 level, could be met with no nuclear power and no petroleum-fired generation. This could be accomplished in a manner

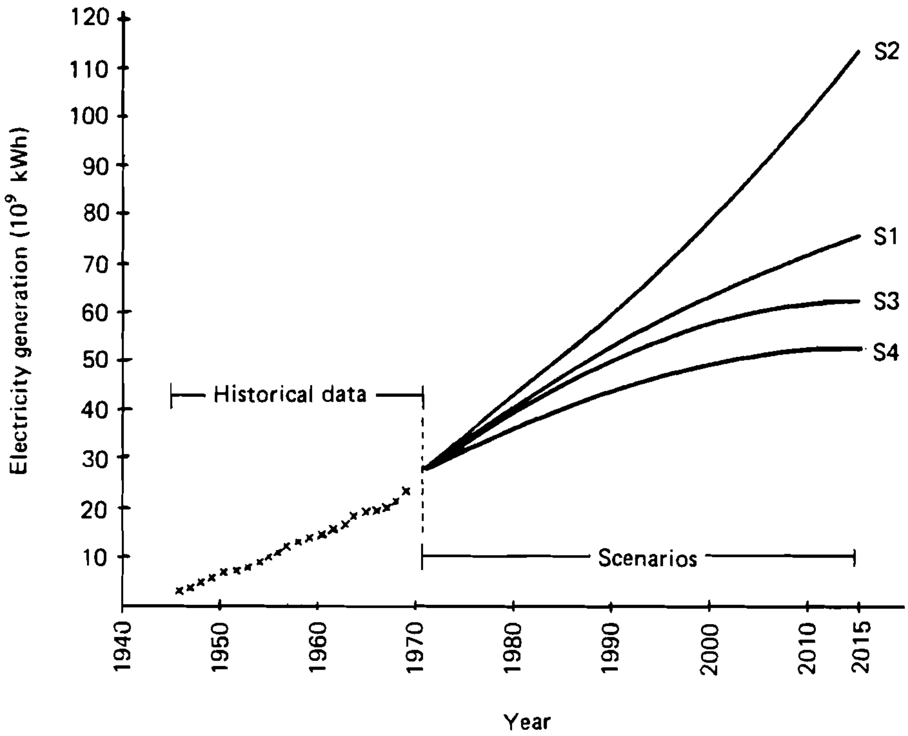


FIGURE 24 Electricity generation: historical data and scenarios S1–S4, 1940–2015.

similar to scenario S3, with the exception that coal- and gas-fired generation could be maintained at 1971 levels.

6.1.3 Availability of Fuels for Austria's Primary Energy Supply

Total requirements for *lignite* in Austria in 1990 range from 3.1 million tons in scenario S4 to 4.5 million tons in scenario S2 (5% of the total primary energy requirements). Scenario results show annual requirements remaining relatively constant through 2015. Historically, Austria has been able to meet most of its lignite requirements through domestic mining enterprises; only 14% of Austria's lignite was imported in 1974. Currently Austria is thought to have 152 million tons of "sure and probable" reserves of lignite, of which about 73 million tons are considered economical to mine (Bundesministerium fuer Handel, Gewerbe und

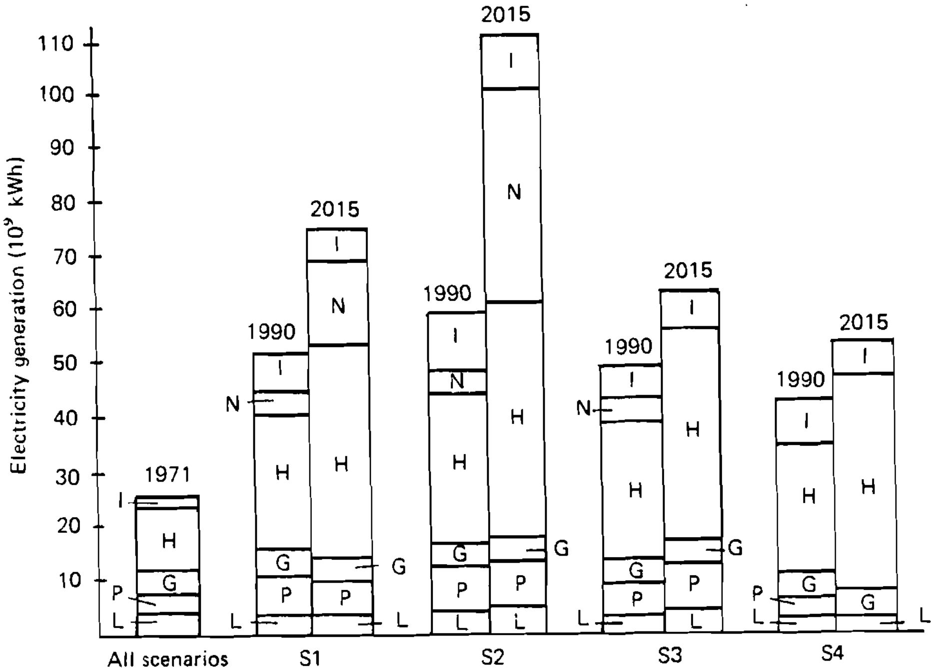


FIGURE 25 Electricity generation by source, by scenario. L is lignite; P is petroleum; G is gases; H is hydro; N is nuclear; I is imports.

Industrie, 1976). If mining continues at its current rate of approximately 3 million t/yr, and if no new reserves are found, then the lignite that could be economically extracted will be exhausted by the end of the century. However, the future of lignite mining in Austria is currently clouded by the fact that mining operations are suffering serious financial losses. Substantial government subsidies may be required to keep mining operations from closing down in the near future. Alternatively, more emphasis may be placed on lignite imports.

Annual requirements for *hard coal* are on the order of 3 million tons in all four scenarios in 1990, and as high as 5 million tons in S2 in 2015

(6.9 to 9.0% of the total primary energy requirements). Since domestic mining of hard coal in Austria ceased completely in 1967, the country depends entirely on imports. Trading partners have traditionally been Czechoslovakia, Poland, and the Soviet Union. Available statistics on hard coal reserves in these countries indicate that there is little likelihood of shortages occurring within the time horizon of the scenarios (WEC, 1977). If in the next two decades there are serious shortages of petroleum and gas – currently Austria's most important energy sources – the country's dependence upon coal exporting nations may increase greatly. The construction of a coal slurry pipeline between Poland and Austria, a project which has been discussed, could facilitate such imports. The opening of the Rhein/Main/Donau canal could also provide an economical route for importing hard coal and coke.

The scenario results indicate that by 1990 between 5,000 × 10^6 m^3 and 7,500 × 10^6 m^3 of *gases* will be needed to meet Austria's energy requirements (about 20% of the total primary energy needs). In the unlikely event that the high growth of S2 is realized, this could increase to as much as 14,000 × 10^6 m^3 by 2015. Currently, about 33% (1,730 × 10^6 m^3) of the annual requirements for gases are met through domestic reserves. However, if the current rate of extraction continues and no new reserves are identified, the reserves that are currently economically worthy of exploitation will be exhausted in about 10 years (Bundesministerium fuer Handel, Gewerbe und Industrie, 1976).

Because its known domestic reserves are small, Austria must rely heavily on imported gas. Currently, Austria has contracts until 1990 with the Soviet Union for annual imports of 3,300 × 10^6 m^3 of natural gas, and with Iran for imports of 1,800 × 10^6 m^3. Nevertheless, if requirements for natural gas in 1990 prove to be as large as are suggested in scenario S1, gaps between supply and demand could begin occurring by that year. Because the terms of the existing contracts end about the year 2000, the issue of contract renewals is very important. The potential gaps in supply, coupled with the uncertainty of access to imports, indicates that shifts from gas to other fuels may be necessary in the coming decades.

Petroleum is the most important primary fuel used in Austria, currently providing over 50% of the total primary energy requirements. This dominance is expected to continue throughout the next several decades. Because Austria's own petroleum reserves are thought to be limited, import dependence could increase to 90% by 1990 and to 100% thereafter. Therefore the current uncertainty about world petroleum reserves and production rates, and its impact on future supply availability, is an important concern for Austria. Results of recent studies forecast potential worldwide petroleum shortfalls developing in the late 1980s or early 1990s. For the Austrian case study, estimates were made of Austria's future petroleum supplies, using a world scenario developed by the Workshop on Alternative Energy Strategies (WAES) (Wilson, 1977). The petroleum supply curve was based on the 33 million barrels of oil per day (MBOD) production limit (noncommunist 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 potential 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 petroleum per year (about 0.05 MBOD) by 2015 in scenario S4, as illustrated in Figure 26. This sizeable shortfall develops despite the low growth in energy demand resulting from conservation measures, from lower economic growth, and from the phasing out of petroleum for electrical generation.

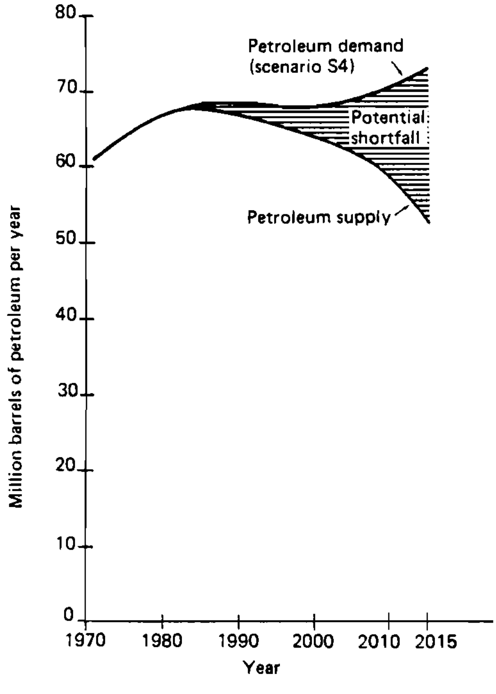


FIGURE 26 Divergence between demand and estimated petroleum supply in scenario S4.

6.1.3.1 CLOSING THE PETROLEUM GAP

A sensitivity study was developed for scenario S4 in the year 2015, in order to study the feasibility of relieving the petroleum shortfall through shifts to other fuels.

In the sensitivity study, fuel shifts were assumed to occur in the industrial, the commercial and service, and the residential sectors. The rationale for shifts in the industrial sector was taken from a 1975 Viennese investigation of fuel substitutability in major industries (Bundeskammer der Gewerblichen Wirtschaft, 1976). This study took into consideration technical changes that must accompany fuel shifts such as the replacement of boilers, the storage of solid fuels, and the construction of gas pipelines. The investigators found that large-scale Austrian industries, which consume over 80% of the nation's heavy fuel oil, would be capable of reducing their reliance on petroleum by 40% through shifts to coal, natural gas, and coke. In the S4 sensitivity study, similar substitutions were assumed for the industrial sector (with the exception of natural gas, because of uncertainty about the availability of this fuel in 2015).

In the sensitivity study, the potential for reductions in petroleum consumption through shifts to other fuels was also found in the commercial and service and the residential sectors. It was assumed that a decrease in petroleum consumption could be achieved by 2015 through stepped-up construction of waste- and coal-fired district heating plants in heavily settled areas, as well as through a slowing of the shift away from coal-burning ovens in urban apartments. In rural areas greater use of coal and wood for space heating was judged the most likely type of substitution. It was also assumed that new technologies, such as solar heating, could replace as much as 20% of petroleum requirements in the residential sector by 2015.

Figure 27 shows the results of the sensitivity study in terms of an alternative primary energy fuel mix. Because of the need to decrease the absolute quantity of petroleum by 30% in order to relieve the petroleum shortfall, the importance of this fuel dropped from 43% of primary energy requirements in the regular S4 scenario in 2015 to 31% in the sensitivity study. At the same time, the percentage of total primary energy requirements met by hard coal and lignite increased from 13% in the regular S4 scenario in the year 2015 to 24% in the sensitivity study in that year. The sensitivity study also showed a possibility for greater utilization of waste and wood as energy sources. The role of gas as a replacement fuel for petroleum was constrained, as it was deemed likely that supplies of gas would become limited by 2015.

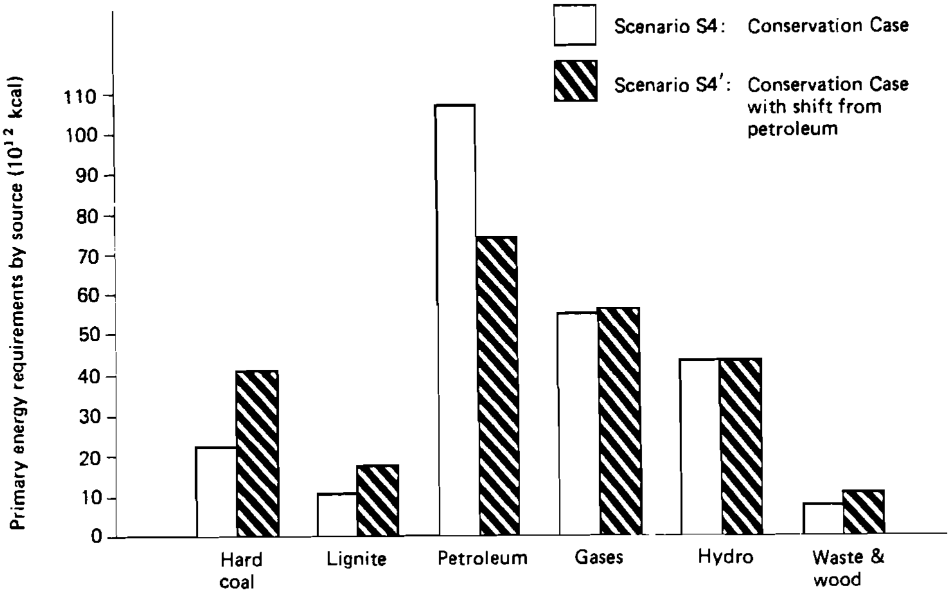


FIGURE 27 Alternative primary energy fuel mix for closing the petroleum gap: Conservation Case (S4) for the year 2015.

Table 17 presents the results of the sensitivity study on a sectoral basis. Of the total end-use demand for petroleum that was shifted to other energy sources (31.0×10^{12} kcal or 14% of the total end-use demand for energy), 49% was shifted within the industrial sector, 19% within the commercial and service sector, and 32% within the residential sector. In the industrial sector, hard coal was the most important replacement fuel for petroleum. In the commercial and service sector, 18% of the end-use demand for petroleum was shifted to coal-fired district heat, 11% to coke, 8% to wood, 5% to hard coal, and 3% to gases. In the residential sector, 18% of the end-use demand for petroleum was shifted to alternative fuels (using small-scale technologies for single homes such as solar/heat pump combinations), 11% to wood, 9% to coke, 9% to lignite, 7% to district heat, 4% to hard coal, and 4% to gases. If the industrial, the commercial and service, and the residential sectors are considered together, 42% of the total end-use demand for fuel oil was shifted to coal (hard coal, coke, and lignite).

The sensitivity study was based on the Conservation Case (S4) – the scenario with the lowest energy requirements in 2015. If the WAES-based assumptions about petroleum supply hold, then petroleum shortfalls in scenarios S1 to S3 would be much greater than those in S4 and correspondingly more difficult to close. For instance, in S1 petroleum shortfalls

TABLE 17 Fuel shifts in end-use energy demands for closing the petroleum gap, S4, 2015 (10^{12} kcal).

	Industrial sector		Commercial and service sector		Residential sector	
Energy source	S4	After shifts	S4	After shifts	S4	After shifts
Electricity	20.2	20.2	5.7	5.7	11.9	11.9
Hard coal	0.4	14.8	0.4	1.0	0.5	1.2
Coke	16.9	16.9	1.5	3.0	1.0	2.4
Lignite	1.5	2.3	0.8	0.8	1.0	2.4
Fuel oil	20.5	5.3	13.1	7.3	16.4	6.4
Gasoline	0.9	0.9	2.7	2.7	0.0	0.0
Diesel	2.1	2.1	6.1	6.1	0.0	0.0
Gases	31.7	31.7	2.6	3.0	6.7	7.3
Wood	2.0	2.0	0.0	1.0	4.8	6.6
District heat	0.0	0.0	0.6	2.9	3.5	4.6
Alternative energy	0.0	0.0	0.0	0.0	0.0	3.0
TOTAL	96.2	96.2	33.5	33.5	45.8	45.8

would be on the order of 20 million barrels/year in 1990, 34 million barrels/year in 2000, and 62.7 million barrels/year in 2015. This is equivalent to 23% of total S1 primary energy requirements for petroleum in 1990, 35% of total petroleum requirements in 2000, and 35% of total petroleum requirements in 2015. The petroleum shortfall calculated for S1 in 2015 is three times higher than the shortfall calculated for S4 in that year.

In order to close the petroleum gap in S1, in 2015, it would be necessary to have large-scale improvements in energy intensiveness as well as major shifts to other energy sources in the electricity and end-use sectors. By shifting petroleum out of the electricity and the district heat sectors in S1, 63% of the petroleum shortfall would be relieved in 1990, 34% of the petroleum shortfall would be relieved in 2000, and 21% in 2015. If petroleum were no longer available for electricity generation in S1, 7.2×10^9 kWh (14% of total generation) would have to be produced by alternative energy sources in order to meet domestic requirements in 1990, 5.9×10^9 kWh (9% of total generation) in 2000, and 6.4×10^9 kWh (8% of total generation) in 2015. One possible shift in the electricity sector would entail faster expansion of hydropower capacity, and greater reliance on coal-based generation.

If in S1, as in the S4 sensitivity study, hard coal and lignite were used as the principal replacement fuels for petroleum in the industrial, the commercial and service, and the residential sectors, then an additional 6 million tons of hard coal and coke and 4 million tons of lignite would be required in 2015. These quantities are more than twice as high as the 1975 level of hard coal and coke imports and four times higher than the 1975 level of lignite imports. Thus in order to relieve the large petroleum shortfalls which could arise in S1, Austria might have to greatly increase its dependence on other fossil fuel imports.

In order to bring about fuel shifts of the magnitude shown in Table 17, government policies and actions may be required. Although the Austrian case study has not addressed these in depth, a few courses of action are mentioned for consideration and more detailed evaluation by the Austrian government. These reflect a mix of regulating and pricing policies. For example, industry might be prohibited from burning petroleum in new boilers and in other types of new major fuel burning installations unless there are critical environmental and economic considerations. Investment tax credit for conversion expenditures or rebate of fuel taxes are possible tools for encouraging shifts to coal in existing facilities. Likewise, a program of public education and financial incentives, e.g., tax credits, could be used to stimulate the development of a larger market for alternative energy sources such as solar energy. Such a program should help launch the solar heating industry and eventually lead to reduced prices for solar technology. In addition, the constraints on petroleum supplies, as depicted in Figure 26, could lead to a greatly increased world petroleum price, causing the market to induce some of the shifts shown in Table 17. However, adequate long-term planning will be necessary to avoid severe dislocations and disruptions from unanticipated supply constraints.

6.2 BROOKHAVEN ENERGY SYSTEM OPTIMIZATION MODEL (BESOM)

6.2.1 Resource Supply Optimization

A 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) (Hoffman, 1973). BESOM is a resource allocation model developed at Brookhaven National Laboratory in the U.S. in order to examine interfuel substitution within a framework of constraints on the availability of competing resources and technologies and their associated costs. For the Austrian case study, a version of the Brookhaven model was modified to reflect the characteristics and structure of the Austrian energy system, including appropriate technologies, coefficients, and costs. Three alternative reference energy systems were developed for scenarios S1, S2, and S3, for the year 1990. These reference energy systems were based on a minimization of total system costs in that year.

6.2.2 Assumptions

Adequate fuel supply levels were assumed for lignite, petroleum, and natural gas, and these fuels were allowed to compete for the end-use demands in each scenario. In addition, hydropower was allowed to actively compete with the fossil fuels for meeting electrical sector demands. However, upper fuel use bounds were specified for some fuels and a maximum hydro generation constraint was imposed (34.5×10^9 kWh). This upper limit represented the level of hydroelectric generation in 1990 projected in the revised *Energieplan* (Musil, 1975). The direct end-use demands for hard coal, lignite, petroleum, natural gas, and wood and waste products were constrained to the usage levels specified in the three 1990 demand scenarios. Nuclear generation was held fixed in each of the scenarios, the levels corresponding to those used in the supply scenarios (see section 6.1).

Power plant capital costs for thermal electric generating stations were such that nuclear had the highest cost per kWe installed, followed by coal, petroleum, 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 to 4% of the plant capital costs. Fuel prices were set based on a crude oil price of $13/barrel and a uranium price of $35/pound 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.

6.2.3 Results and Conclusions

In each of the three scenarios, the 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, petroleum- 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 (section 6.1) showed lignite meeting only about 6% of the electricity requirements in 1990, while petroleum- and gas-fired generation supplied between 18 and 25% of the total electrical sector needs. In effect, the importance of electrical energy supplied by petroleum- and gas-fired generation and by lignite-fired generation was reversed compared to the results of the regular scenario analysis.

The principal result of the economic optimization procedure was the noticeable fuel shift in the electrical sector away from petroleum and gas toward the greater use of lignite. This shift is dependent upon several constraints, including adequate future supply levels of lignite and a competitive pricing structure relative to gas and petroleum. Further, environmental constraints (not used in this analysis) may play a role in deciding the future levels of lignite used 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 petroleum supply shortages over the next 10 to 20 years. The potential curtailment of petroleum supplies could necessitate a shift in the electrical sector toward greater reliance on lignite, a reversal from current trends. It is noteworthy that both the results of the BESOM cost optimization procedures and those produced by the S4 sensitivity analysis of fuel shifts to relieve petroleum shortfalls emphasized reliance upon coal. Thus from the viewpoint of possible scarcity of other fossil fuels, technological suitability, and economic considerations, coal seems to be an important future energy option in Austria.

Although the market penetration levels of nuclear power were held fixed in each of the three BESOM scenarios, the analysis of the marginal values for uranium indicated that nuclear fuel would be competitive with \$13/barrel petroleum at a U_3O_8 price of up to roughly \$40/pound. Results also tended to show a lower level of hydroelectric capacity than was forecasted in either the *Energieplan* of Austria or the "IMES-IV" Study (Musil, 1975; IMES-IV, 1977). This trend was attributable probably to the high capital cost estimates used for new hydroelectric plants relative to those used for other central stations. However, the hydro capital costs were offset to some extent by the high conversion efficiency (0.796) assumed in the calculations. Total system costs calculated by BESOM for the Austrian energy sector equalled \$8.83 × 10^9 in 1990 for S1, \$11.05 × 10^9 in 1990 for S2, and \$8.64 × 10^9 in 1990 for S3.

Simplified reference energy system diagrams for the three 1990 BESOM scenarios, S1, S2, and S3, are shown in Figures 28, 29, and 30, respectively.

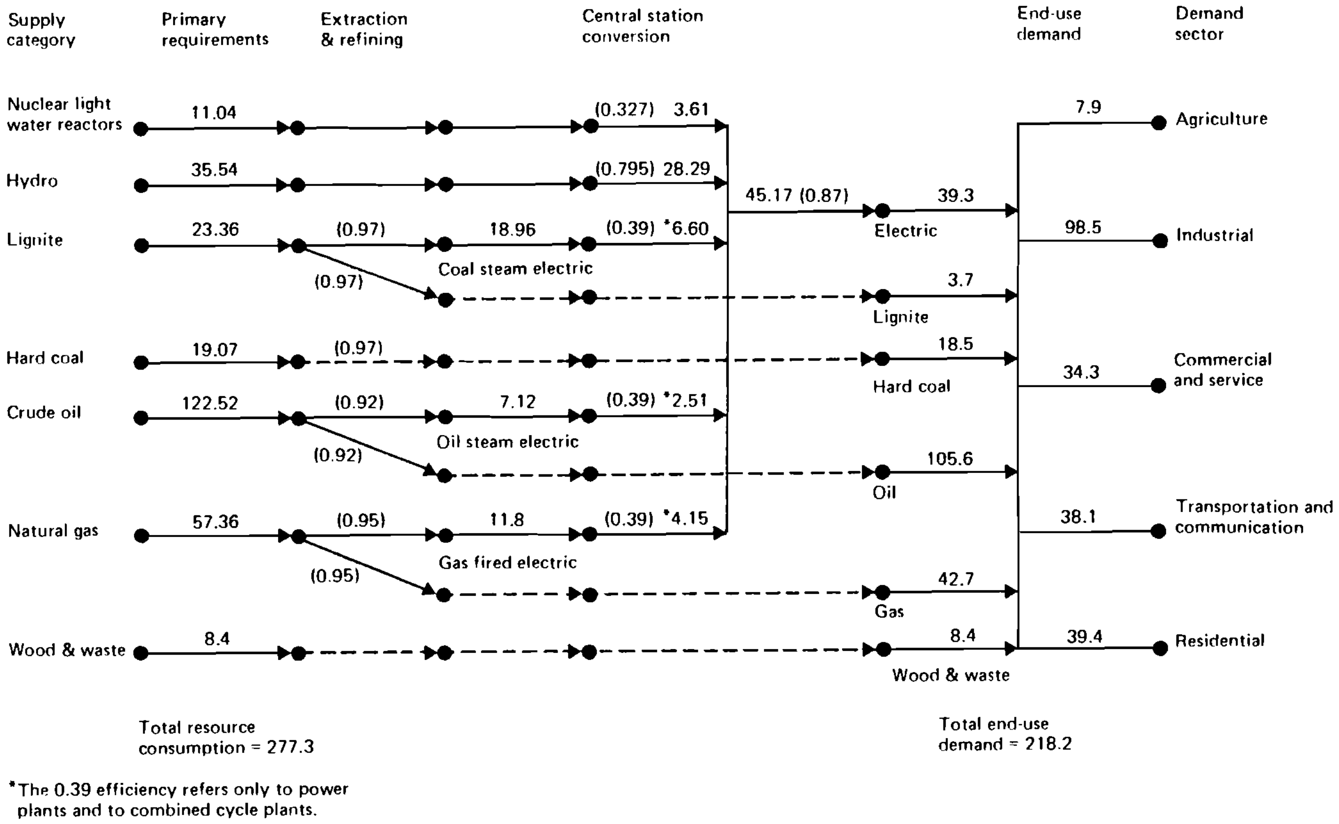


FIGURE 28 Austrian reference energy system: scenario S1, 1990. The flow diagram is simplified; a solid element denotes a real activity; energy flows are given in 10^{12} kcal; and conversion efficiencies are in parentheses.

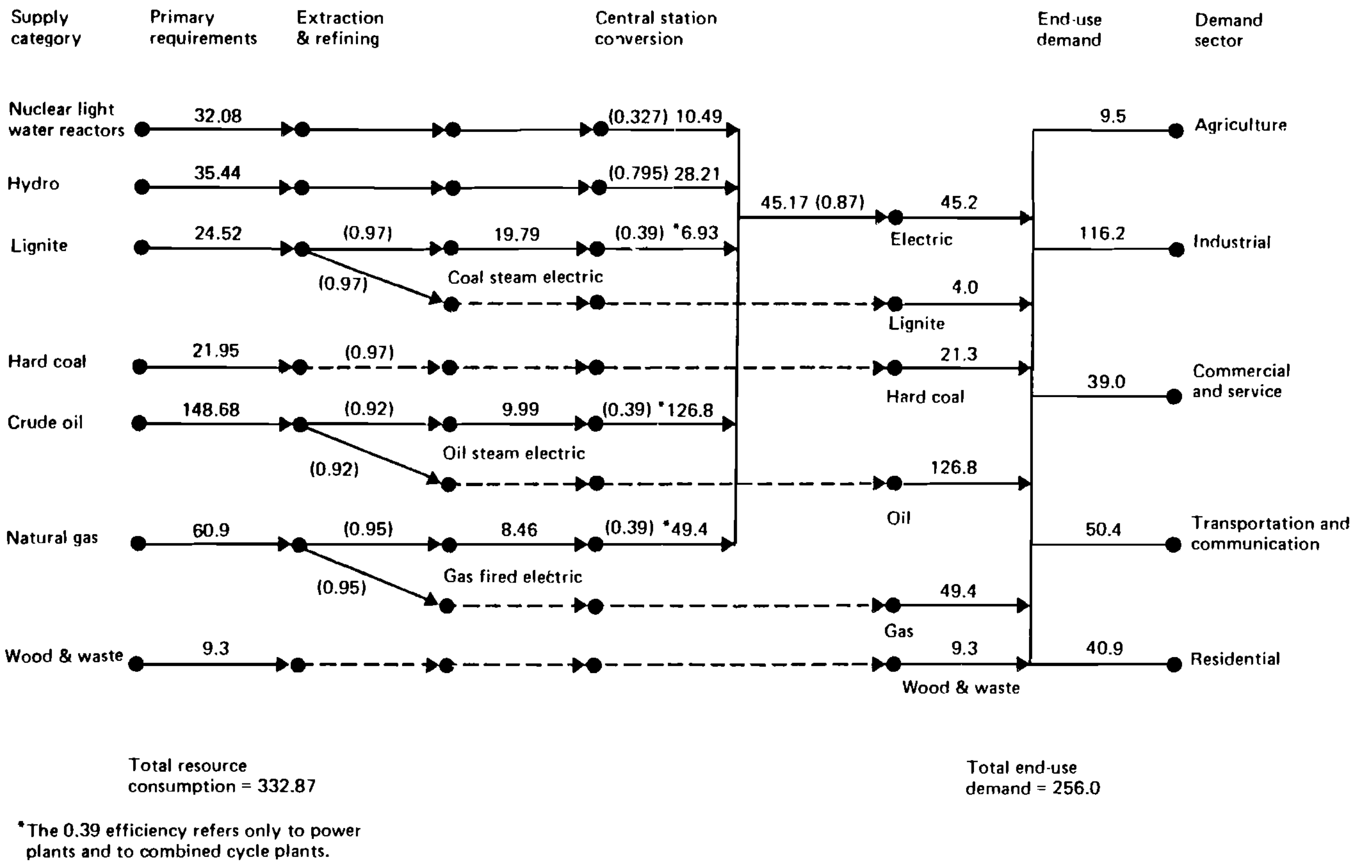
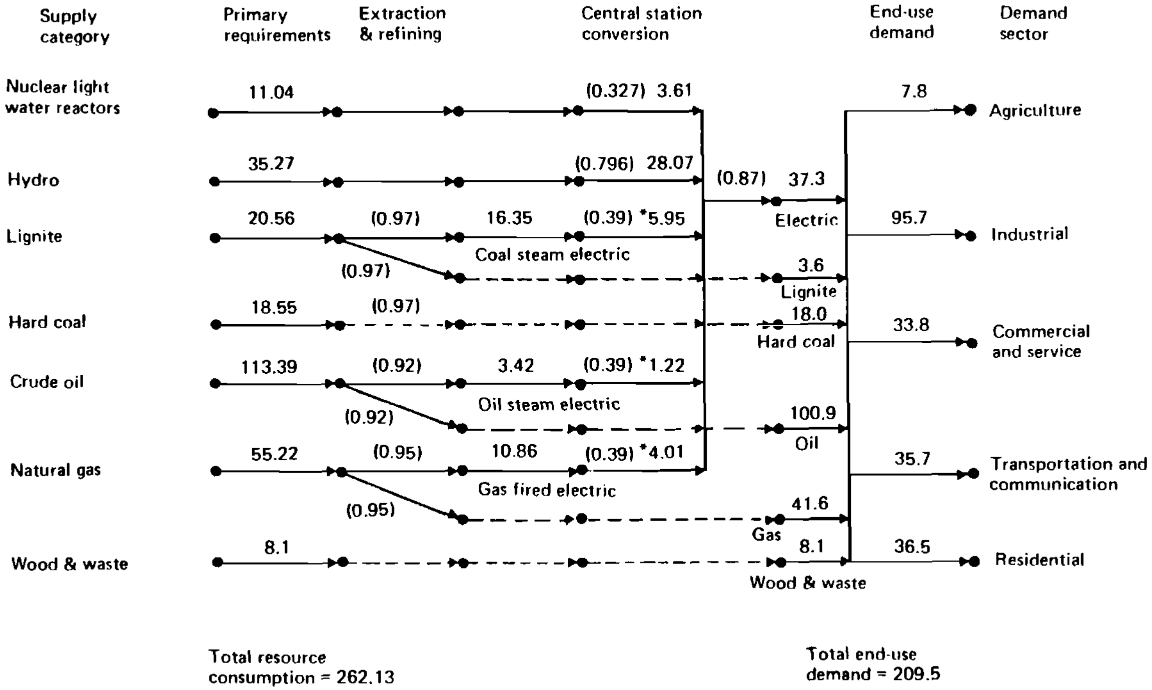


FIGURE 29 Austrian reference energy system: scenario S2, 1990. The flow diagram is simplified; a solid element denotes a real activity; energy flows are given in 10^{12} kcal; and conversion efficiencies are in parentheses.



*The 0.39 efficiency refers only to power plants and to combined cycle plants.

FIGURE 30 Austrian reference energy system: scenario S3, 1990. The flow diagram is simplified; a solid element denotes a real activity; energy flows are given in 10^{12} kcal; and conversion efficiencies are in parentheses.

7 ENVIRONMENTAL CONSEQUENCES

7.1 INTRODUCTION

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 at IIASA for regional studies, have been reparameterized and adapted to Austrian conditions.

Both end-use energy demand and primary energy requirements are inputs to the environmental models. Impacts at each point in the fuel chain are calculated – i.e., extraction, transportation, processing, conversion, and direct use. Impacts occurring both inside and outside Austria are tabulated.

These fuel chain impacts are calculated for reference coal, nuclear, oil and gas systems, including impacts associated with electricity generation. A reference energy system represents the average characteristics of the fuel chain for the entire region; these so-called system impacts are not site specific (Buehring, 1975; Buehring and Foell, 1976; Buehring *et al.*, 1976; Dennis, 1978). In contrast, site-specific impacts are calculated for air pollution resulting from end-use combustion of fuels, taking into account the spatial characteristics of the region. The air pollution impacts are concerned primarily with human health at the urban level (Dennis, 1976; 1978).

The impacts calculated by the environmental models are called quantified impacts. These do not represent all the impacts known to occur; the quantified environmental impacts are the impacts which the study team judges to have an adequate scientific basis for their evaluation and inclusion in the model. Not all quantified impacts are calculated; rather these models present one perspective on the system of impacts. The impacts are calculated in a systematic and systemwide manner. We believe this provides insight for analysis and evaluation. Only those impacts resulting directly from the use of energy are calculated. Impacts are given for each simulation year; time-dependent changes stemming from regulations or from technological advances are taken into account.

For manageability, only a subset of the quantified impacts calculated was chosen for presentation. Table 18 presents a representative set of impact categories and their measures. The evaluation of this set of impacts presents only one picture of the environmental state of the system; we attempt to put this picture into perspective in analyzing environmental issues in Austria. The representative set of impacts is discussed below.

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, death, and health hazards represent the "involuntary" risks that society is exposed to from the energy system. The units of measurements are deaths and person-days-lost (PDL) (ANSI, 1976). 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 activity per individual that is 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 disaggregated into PDL occurring inside and outside Austria, because there is usually more concern with PDL occurring within Austria.

Land-use impacts are included in Table 18 because of the quantities of land devoted to sites of energy facilities. In Austria, hydropower facilities cause the largest impact on land use. Land use also serves as an indicator of many aesthetic impacts of the energy system – e.g., 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 needed to be 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. These emissions are one indication of the issues and problems involved in pollution abatement strategies,

TABLE 18 Selected quantified environmental impacts. PDL means person-days-lost.

Human health and safety	
Fatalities	Annual deaths
Occupational accidents	Annual PDL
Public accidents	Annual PDL
Occupational health	Annual PDL
Public health	Annual PDL
Land-use for resource extraction	Km^2/year
Land-use for facilities	Km^2
Radioactive waste produced	Tons/year
SO_2 emissions	Tons/year
CO_2 emissions	Tons/year

including standard setting, where human health is an important consideration.

CO_2 emissions are included in response to concern with long-term global effects of energy use. This impact indicator concerns the use of fossil fuels.

The results and conclusions of the environmental analysis are presented in several sections. Section 7.2 provides an overview of the environmental impacts for scenario S1, and presents a discussion of the general issues that the impact indicators represent with respect to human health and safety, primary energy supply choices, and air pollution emissions.

Section 7.3 presents more details with respect to different species of air pollution emissions for all scenarios. Section 7.4 discusses the impacts calculated for human health and safety; this section concentrates on details of scenario S1 and on a general four-scenario overview in order to state clearly the conclusions about the importance of coal mining and air pollution. Following these conclusions, section 7.5 discusses the air pollution health impact, describing its geographic concentration in the largest urban centers. Section 7.6 addresses a specific set of strategies for control of SO_2 emissions. It then examines the effectiveness of these strategies relative to the health impact due to SO_2 air pollution. Section 7.7 compares the environmental impacts that are calculated for scenario S1 in 1990, and for the BESOM system cost minimization for 1990. The final section, section 7.8, makes summary comments concerning the environmental impact implications.

7.2 OVERVIEW OF THE ENVIRONMENTAL IMPACTS FOR SCENARIO S1

Table 19 presents selected environmental impacts calculated for scenario S1 for the years 1971, 1990, and 2015. This table does not represent all of the impacts; rather it gives an overview of the temporal changes in the impact indicators.

In Table 19, the total fatalities and nonfatal impacts on human health and safety do not change significantly over time. There are two main reasons for this degree of temporal constancy, both relating to coal. First, the quantity of coal demand does not change significantly in scenario S1; despite the increase in total energy demand, there is a shift away from coal to other fuels in all sectors. Second, no mining health and safety improvement is assumed in the scenarios, and this keeps the impact factors constant over time relative to coal demand. Since coal has by far the largest human health and safety impact of all the fuels, the total impacts remain relatively constant.

The total human health and safety impacts in Table 19 can be given perspective by comparing them with accident statistics for Austria. For example, in Austria in 1974, some 2,860 pedestrians were severely injured in street accidents; if 6 months of lost time are associated with each accident, the person-days-lost equals 510,000. In comparison, the energy-related human health and safety impacts occurring annually in Austria during the time frame of the scenario have an almost equivalent impact. Thus, although these impact estimates are not meant to serve as forecasts,

TABLE 19 Selected environmental impacts: scenario S1. PDL means person-days-lost.

	1971	1990	2015
Fatalities (annual deaths)	41	39	42
Nonfatal human health and safety (10^3 PDL/year)	530	470	540
Facility land use (Km^2)	96	200	320
Radioactive waste (tons/year)	0	1.0	6.9
CO_2 emissions (10^6 tons/year)	57	76	95
SO_2 emissions (10^3 tons/year)	320	260	180

we must conclude that energy-related impacts on human health and safety are significant and may require even stricter environmental control measures than are currently anticipated.

In addition, three of the impact indicators – facility land use, radioactive waste, and CO_2 emissions – are linked respectively to the three major choices that Austria has for supplying its primary energy: hydro, nuclear, and fossil fuels. Each has different types of consequences. CO_2 and radioactive waste impacts are more global and longer term in nature than the land-use impacts of hydro.

7.2.1 Land Use for Hydropower

Land required for hydropower facilities, which is shown in Figure 31, is the fastest growing impact of any category, nearly tripling by 2015 and growing faster than energy demand. Hydro facility land use is a poor proxy for total hydro impacts because it does not reflect two facts: that alpine ecosystems are affected differently from farmland or swampland ecosystems, and that there may be variability of response between alpine ecosystems. Because of the transportation infrastructure developed during the hydrofacility construction phase, there will also be indirect impacts such as opening a region to tourism. Despite the weakness of the impact evaluation, we conclude that impacts of hydropower facilities should be given increasing attention for decisions determining future Austrian energy policy.

7.2.2 Radioactive Wastes

Radioactive waste production is an important impact that cannot be ignored because of the Austrian government's decision not to operate a nuclear power plant until the waste storage questions in Austria have been resolved (Wiener Zeitung, 1977). The question of nuclear proliferation and fuel reprocessing is being actively discussed at the international level (Bundespressedienst, 1977); many questions about future plans for nuclear power are being discussed in terms of risks occurring in the fuel cycle. Among the four scenarios developed in this study, there are large differences in the annual waste production. Although the annual quantities of radioactive waste produced in Austria appear small, cumulative effects must be considered. The international effects will have to be addressed as well, as Austria may be one part of a larger nuclear fuel handling system.

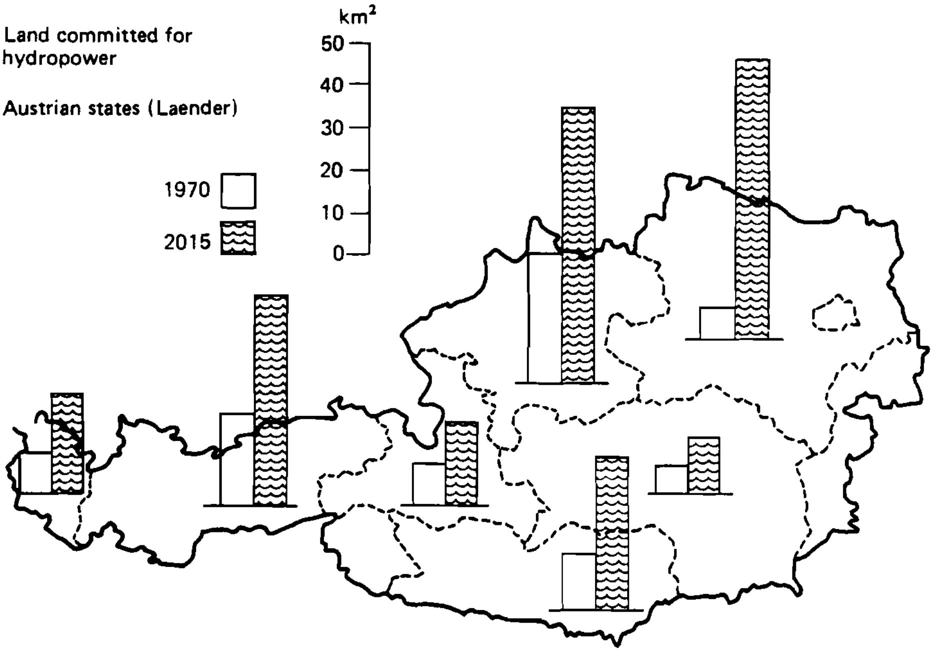


FIGURE 31 Regional distribution of facility land use.

7.2.3 Carbon Dioxide

CO_2 emissions are expected to grow more slowly than energy use (by a factor of 1.6 compared to energy's 2.2 by 2015). This is a result of the shift away from coal as a fuel. Shifts from coal to oil or from coal to gas produce 43% and 56% decreases, respectively, in the CO_2 emissions per unit of energy. Thus the supply mix may determine the future CO_2 emission growth rate; with a rapid shift back to coal, the CO_2 emissions could grow faster than energy demand. Austria is currently below the European average for CO_2 production per capita (Geophysics Study Committee, 1977).

7.2.4 Sulfur Dioxide

SO_2 emissions represent the most strictly controlled of the air pollutants. The SO_2 emissions in S1 decrease by 37% between 1971 and 2015, because of the extreme regulations assumed in the scenarios. SO_2 emissions as well as emissions of particulates (PM) and NO_x are discussed in more detail in other sections of this report. Public health impacts produced by SO_2 in our model calculations decrease during the time frame of the scenarios only by 16% relative to 1971. This will be discussed more fully in the section on SO_2 emissions regulations and their effectiveness.

7.3 AIR POLLUTANT EMISSIONS

The emissions of three air pollutants – SO_2, PM, and NO_x – are presented in Table 20 for scenario S1, for 5 different years.

Both SO_2 and PM emissions per unit of energy are reduced in the scenarios by assumed emission standards; see Appendix L for details of the emission standards assumed. NO_x emissions are uncontrolled. A significant reduction of SO_2 emissions is achieved; without SO_2 controls, the SO_2 emissions would have been a factor of 2.55 higher in 2015 than those in S1 in that year. The SO_2 emissions with and without controls will be discussed more fully in section 7.6.

The PM emissions are only moderately reduced over time. The PM emission controls are applied only to industrial and electricity power plant sources; they are not as stringent as those for SO_2 emissions. Without controls, the PM emissions in 2015 would have been a factor of 1.14 higher than those in S1. For PM emissions, the shift away from coal has the largest influence. The increase in NO_x emissions is also slower than the increase in energy demand. The shift away from coal and oil to gas is largely responsible for the effect on NO_x emissions.

The BESOM analysis (section 6.2) implied that a shift to coal would be economical. The effect on the air pollution emissions of a total shift to coal in fossil-fired power plants was therefore examined. The same level of controls was assumed as that of S1. For the same energy produced, there would be an increase in total emissions for all three pollutants. These are: SO_2 – a 23% increase in total emissions; PM – a 17% increase in total emissions; and NO_x – an 18% increase in total emissions. The principal factor responsible for the increases is the change from gas to coal. This switch from gas also implies a required increase in pollution control equipment, i.e., additional capital investment.

Further insight can be gained by looking at the air pollutant emissions by sector given in Table 21. Note that for the different pollutants, different economic sectors are dominant sources. For NO_x, industry, transportation, and electricity production are the major sources in 1971. By the end of the scenario period, the electricity share has dropped

TABLE 20 Air pollutant emissions of SO_2, PM, and NO_x for scenario S1.

	1971	1980	1990	2000	2015
SO_2 (10^3 tons)	320	303	260	223	180
PM (10^3 tons)	87	73	72	72	76
NO_x (10^3 tons)	106	118	138	148	174

TABLE 21 Distribution of SO_2, PM, and NO_x emissions by economic sector, 1971 and 2015.

	1971			2015		
Sector	SO_2	PM	NO_x	SO_2	PM	NO_x
Industrial	47	15	35	32	22	47
Commercial and service	9	13	3	18	16	4
Residential	12	55	8	23	42	7
Transportation and communication	1	7	22	5	15	25
Electricity	31	10	32	22	5	17
TOTAL	100	100	100	100	100	100

considerably, transportation maintains about the same share, and industry becomes the dominant source. Interestingly, the residential and the commercial and service sector emissions would have a greater health impact than the industrial emissions of NO_x. This is a result of the difference in the air pollution dispersion character between medium- and low-level sources. Furthermore, several global effects of NO_x are strongly suspected. Thus all sources of NO_x should be examined.

Because a first level of control exists in industry, the dominant source of PM is the residential sector. Even with the reduction of coal use in the residential sector, this sector's share of PM emissions remains the largest because of the controls assumed for the industrial sector PM emissions. The transportation PM emissions grow rapidly, because of the increase in diesel truck freight transport. The most health-impacting source of PM is still the residential sector. Means for reducing the PM emissions of this sector should be studied.

Although industry and electricity production are major sources of SO_2 emissions, they are not major sources of human health impact. With the vigorous controls of SO_2 emissions assumed in the scenarios, both the industry and the electricity production shares of the SO_2 emissions decrease while the residential and the commercial and service shares increase. These latter emissions are important contributors to human health impacts. Before further stringent controls are contemplated for industry and fossil-fueled power plants, SO_2 emissions from the residential and the commercial and service sectors should be controlled more vigorously.

7.4 HUMAN HEALTH AND SAFETY IMPACTS

The human health and safety category is composed of many impacts that are related to the common denominator of PDL. Deaths from all causes except from air pollution health impacts are counted as 6×10^3 PDL per death; air pollution-caused excess deaths are associated with considerably fewer PDL per death because elderly people are most affected. (Information based on personal communication with S.C. Morris of Brookhaven National Laboratory, U.S., and with L.J. Hoover, Argonne National Laboratory, U.S.) Figure 32 shows the total quantified human health and safety PDL (fatal plus nonfatal) in detail, through time, for scenario S1. The total is divided into the PDL occurring *inside* Austria and the PDL occurring *outside* Austria caused by Austria's energy use. The total does not change greatly, although there is structure in the graph. The fraction of the PDL occurring outside Austria increased considerably between 1990 and 2000. Austria is assumed to exhaust its economically recoverable coal reserves by 2000, and thereafter all its coal must be imported. Since coal has by far the largest human health and safety risk per unit of energy of all fuels, there is a marked switch of impact location from inside to outside the country.

The major source of human health and safety impacts as calculated by our models is coal mining; the next source of importance is air pollution. This can be deduced from Figure 32. The decline in total PDL between 1971 and 1980 is because of the shift in industry away from imported coal to oil and gas; this shift saturates shortly after 1980. The small, sharp drop in the PDL between 1978 and 1981 is because of reductions in SO_2 emissions stemming from fuel oil desulfurization. The quick rise again in total PDL between 1980 and 1990 is a result of increases in the amount of imported electricity, which is assumed to be produced by coal-fired power plants. The growth in total PDL between 1990 and 2015 is much slower than the economic growth because of the decreasing fraction of coal in the total primary energy demand for Austria. The level to which the *inside* Austria PDL drops in 2000 is related principally to air pollution.

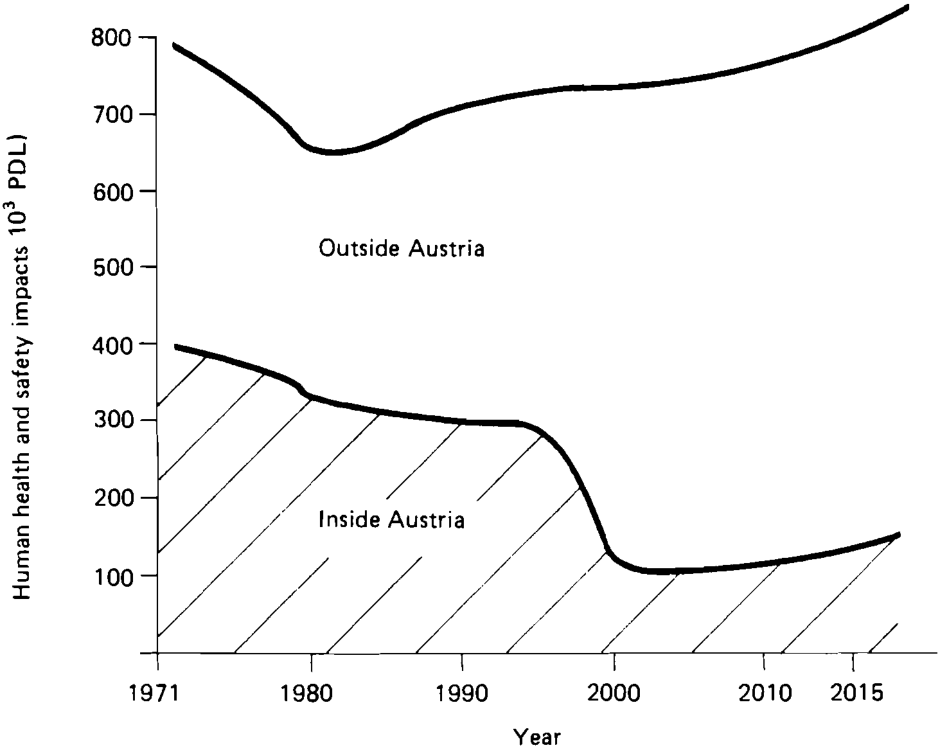


FIGURE 32 Total quantified human health and safety impacts for scenario S1. PDL means person-days-lost.

Further evidence of the importance of coal is obtained by calculating the change in total PDL which would result from the firing of all fossil-fueled power plants with coal in 2015, as shown earlier in section 7.3. Although the changeover of oil- and gas-fired power plants to coal represents 6% of the total primary energy demand for Austria, the switch produces a 40% increase in total PDL.

Since coal mining is an important contributor to the total quantified PDL, a sensitivity study was carried out that introduced improvements in mining safety standards and mining dust standards. The mining safety standard introduced would reduce fatal accidents to 30% of their 1971 level by 2000. This standard was assumed to begin in 1977. The dust standard introduced would reduce black lung (pneumoconiosis) deaths and nonfatal disability to 20% of the 1971 levels. The effect would not be apparent until some time between 1985 and 1990, and would saturate in 2015. These health and safety standards are based on U.S. experience

(Buehring, 1975). The results of the sensitivity study, as shown in Figure 33, demonstrate the importance of coal in the calculation of total PDL. The coal PDL accounts for most of the PDL occurring outside Austria, while the air pollution PDL accounts for most of the PDL occurring inside Austria. The calculation of air pollution related PDL considers only SO_2; it does not include other air pollutants such as CO, NO_x, and PM. Even within the SO_2 calculation, only a small number of effects are quantified. There are chronic effects that are expected to be large and are not included in our model (Morgan *et al.*, 1979; personal communication with S.C. Morris of the Brookhaven National Laboratory, U.S., and with L.J. Hoover of the Argonne National Laboratory, U.S.). Thus it is expected that the PDL which could occur inside Austria is much larger than that calculated here.

With the caution that the air pollution related PDL is likely to be larger than that calculated here, Figure 34 shows total quantified human health and safety impacts inside Austria for scenario S1, with

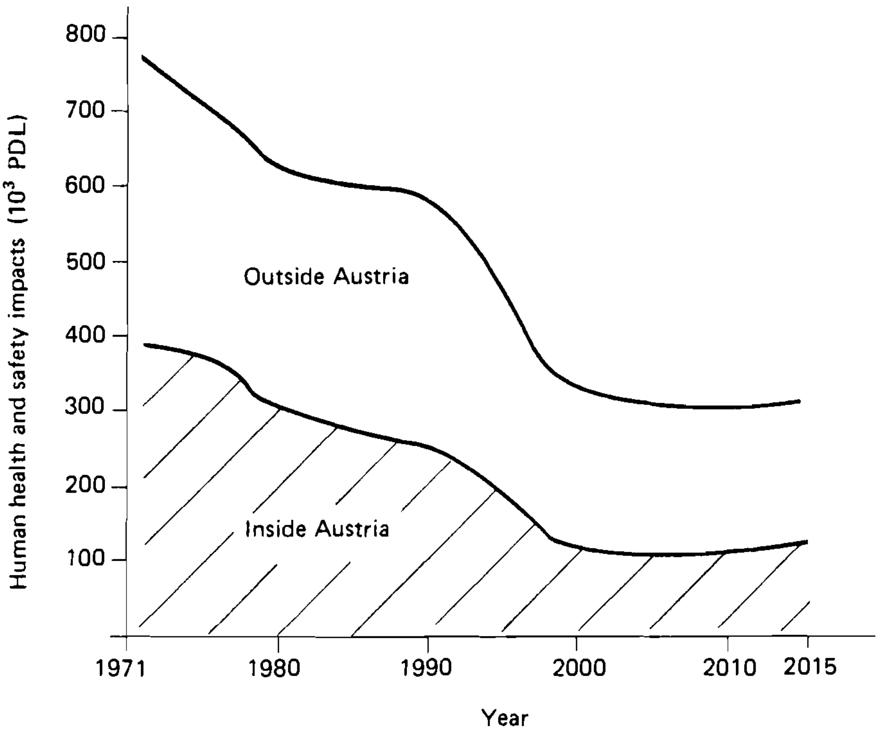


FIGURE 33 Total quantified human health and safety impacts with mining health and safety standards, S1. PDL means person-days-lost.

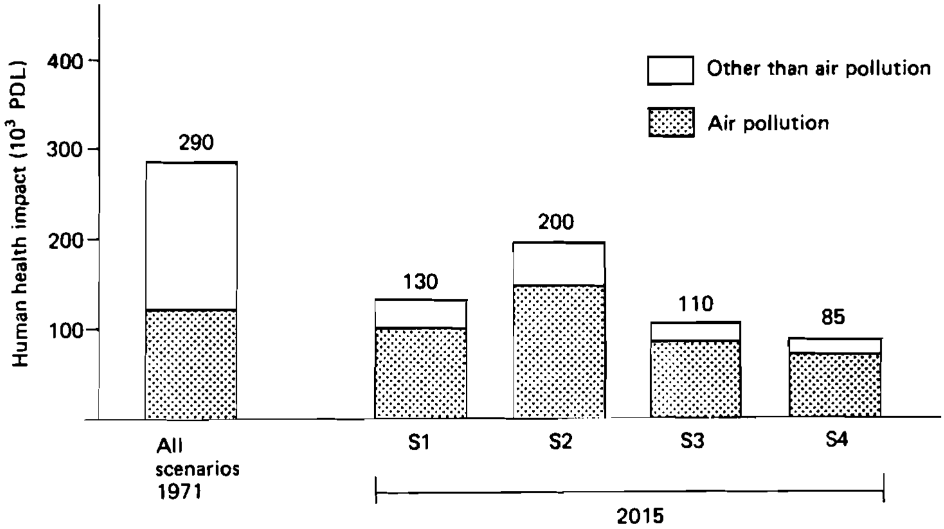


FIGURE 34 Person-days-lost (PDL) within Austria caused by air pollution and factors other than air pollution. Deaths are not included.

the component associated with pollution demarcated. In 1971, air pollution is responsible for 30% of the total PDL; in 2015, PDL caused by air pollution is 75% of the total. All of the scenarios show a similar pattern. Clearly, even with stringent standards on SO_2 emissions, air pollution becomes a dominant impact for Austria. Additionally, an important change occurs in the nature of the human health and safety impact within Austria. Currently, a major share of the PDL occurs in categories of "voluntary risk", i.e., they are occupationally related. In contrast, at the end of the scenario period a major share of the PDL within Austria is caused by air pollution, which is an "involuntary risk" category. The quantified human health and safety impacts calculated for the energy system become more societal in nature as opposed to the present occupational character.

7.5 AIR POLLUTION HUMAN HEALTH IMPACT

Since air pollution health impacts are not insignificant in Austria, it is important to locate the population groups that are most affected. Figure 35 shows the air pollution health PDL for all of the scenarios in 1971 and in 2015, aggregated into three groups based on where the PDL occurs: the five major cities, the rest of the towns, and rural areas. In 1971, the five

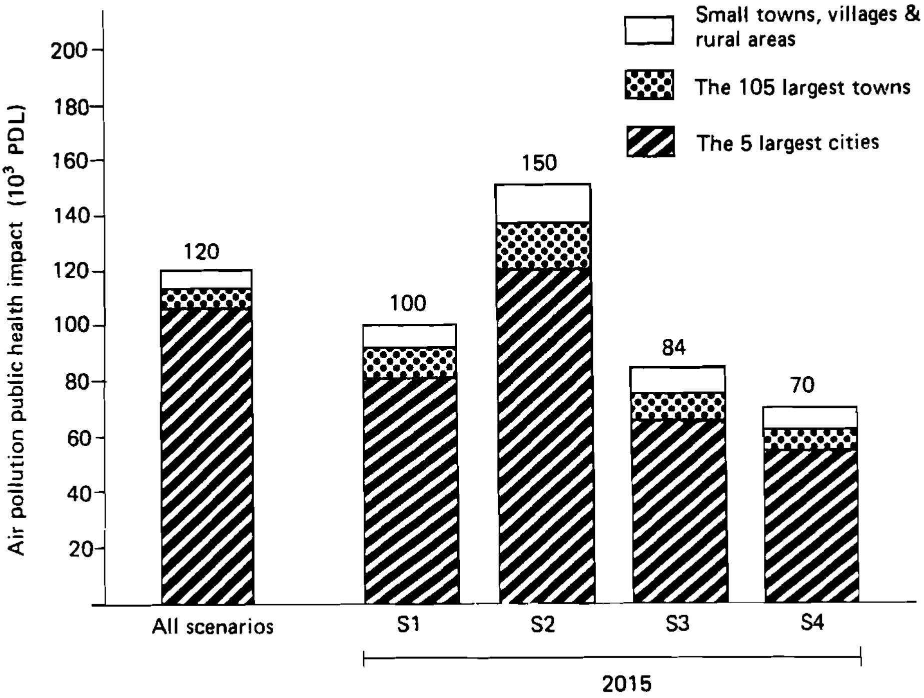


FIGURE 35 Air pollution public health person-days-lost (PDL) by city classification for Austria.

major cities of Austria (Vienna, Linz, Graz, Salzburg, and Innsbruck) accounted for 87% of the air pollution health impact. Vienna alone, with 22% of Austria's population, accounted for 75% of the total air pollution health impact for the country in 1971.

By 2015, the same five cities account for 80% of the air pollution impact on health in scenario S1. The principal factors responsible for the decline from the 1971 percentage are: the movement of inhabitants away from Vienna (despite the absence of a decrease in those working in the city), and a slight improvement in Vienna's air quality. The decline in residents, the move away from coal in all sectors, and the strict controls applied to industrial sources are the three most important influences responsible for the reduction of Vienna's air pollution concentrations. The commercial and service and the transportation and communication sectors would have increased Vienna's air pollution levels had it not been for the above three factors. In 2015, Vienna, with an estimated 16% of Austria's population, would have 63% of the total Austrian air pollution

PDL for scenario S1. Vienna's air pollution PDL for S2 declines 30% in 2015, relative to 1971. The only other city for which a change occurred in our calculations was Salzburg; the remaining three major cities showed no appreciable change. Because of the large in-migration of inhabitants and business that would be expected from the current trend, Salzburg is expected to have up to a 50% increase in air pollution health effects. In 1971, Salzburg's share of the air pollution PDL was 2% of the total PDL for scenario S1. By 2015, Salzburg's share of the total PDL would double to 4% of the total PDL in S1 for Austria.

For Vienna and Salzburg, the population out- and in-migration – i.e., population demography – can have a noticeable effect on the air pollution health impact. This is an effect on the health impact independent of changes in the energy use per capita. Clearly, changing energy use per capita will also have an effect on the air pollution health impact. It would be of interest to know whether a reduction in energy use would have an equivalent reduction in the air pollution health impact. The four scenarios in 2015 do not have greatly differing energy fuel mixes, nor do they have greatly differing structures of energy demand relative to the economic sectors (see Figures 6 and 8). Therefore, a comparison of health impacts among the scenarios for a given year should give some indication of the health impact response to overall changes in energy demand where no significant structural changes occur in the energy demand pattern. This comparison is shown in Figure 36.

In Figure 36, the percentage decline in the air pollution impact per capita between scenarios S1 and S3 is nearly equivalent to the percentage difference in end-use energy per capita. The percentage decline in health impact between S3 and S4 is somewhat larger than the percentage reduction in end-use energy per capita. This is because energy conservation has a proportionally larger effect on space heating energy use reduction (i.e., the reduction between S3 and S4) than a decline in economic growth would have (i.e., the reduction in energy use between S1 and S2). Conversely, the percentage increase in air pollution health impact between scenarios S1 and S2 is smaller than the percentage increase in end-use energy per capita. In this case, the industrial end-use energy demand grows more rapidly than that of any other sector and its air pollution emissions due to energy use have less of an impact on health than space heat emissions.

For comparative purposes, the increase in the air pollution health impact due to the removal of the SO_2 emission controls in scenario S1 is nearly equivalent to the difference in the per capita health impact between scenarios S2 and S4. The difference between S2 and S4 would have been larger if a fixed set of SO_2 emission controls had been prescribed in the

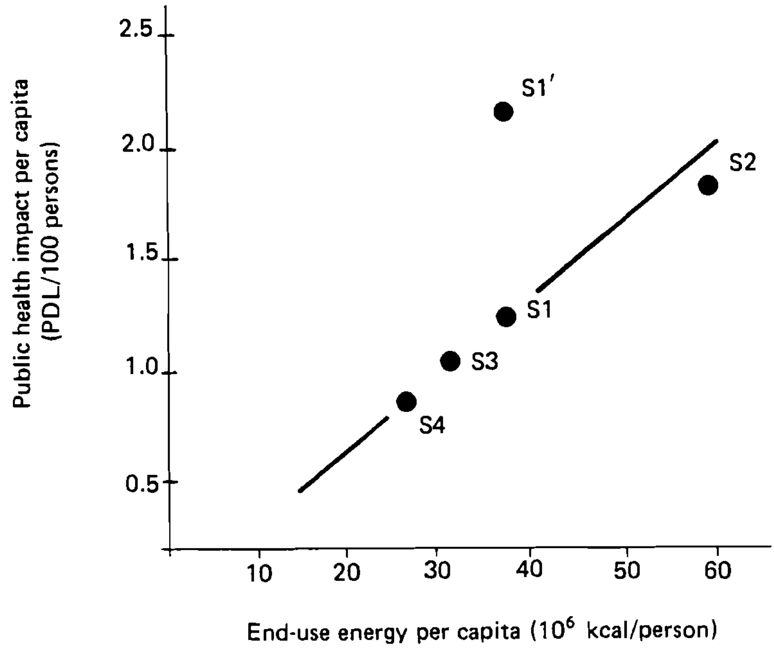


FIGURE 36 Air pollution person-days-lost (PDL) per capita versus end-use energy per capita in 2015. S1′ has no SO_2 emission controls.

scenarios; S2 had more stringent SO_2 emission controls than S4 because of economic reasons of capital availability.

For Austria as a whole, Figure 36 implies that reductions in end-use energy per capita can produce meaningful reductions in air pollution health impacts. Since the air pollution impact is localized (Figure 35), we should examine the health impact occurring in the five major Austrian cities. In this case, SO_2 emissions per capita provide the same measure as end-use energy per capita. The cross-scenario comparison of the air pollution health impact per capita and SO_2 emissions per capita for the year 2015 for Vienna, and the combined result for Graz, Innsbruck, Linz, and Salzburg is shown in Figure 37. Here, the sensitivity study of S1 with no SO_2 emission controls, S1′, is shown for reference.

For both Vienna and the four other Austrian cities, a given reduction in SO_2 emissions produced by reducing the average energy use is more effective in reducing the air pollution health impact than the same reduction via the assumed SO_2 emission controls. This is because the SO_2 controls are centered around the point sources (industry and electric

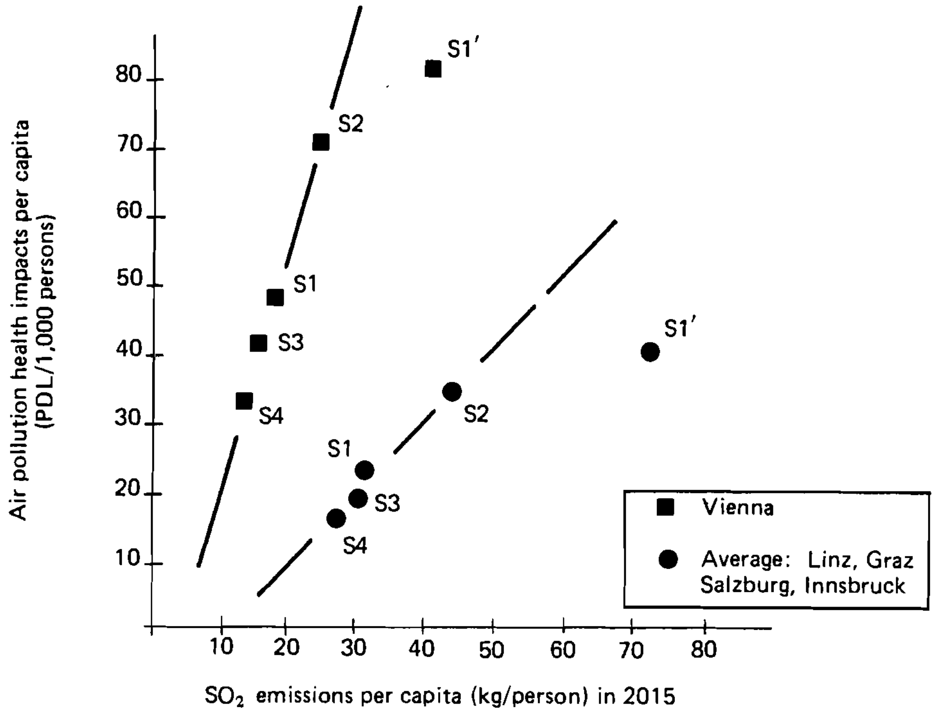


FIGURE 37 Air pollution health impact per capita versus SO_2 emissions per capita, all scenarios, 2015. S1′ has no SO_2 emission controls.

power). A reduction in energy use represented by going from S2 to S4 reduces the air pollution emissions from all sources. Since residential and commercial and service source emissions are more exposure producing than point sources, reducing all sources of emissions by reducing energy use is more effective than the prescribed SO_2 emission controls.

Vienna shows an especially strong response to a reduction in SO_2 emissions, whether by SO_2 controls or by reduced energy use. There are two reasons for this: Vienna has a smaller than average fraction of industry per capita (it is an office center), and Vienna's air pollution exposures are sufficiently high to activate two chronic health impact dose-response functions that have threshold values (Buehring *et al.*, 1976). Having a lower than average fraction of industry means that Vienna's SO_2 emissions are on the whole more health impact producing than the average; thus the health impact response to a reduction in the overall energy use will be larger than average. Also, the existence of "threshold" values means that changes in exposure will cause larger than equivalent changes in health impacts. These two factors combine to give Vienna a greater than average health impact response to a change in SO_2 emissions. Conversely, the slope between S2 and S4 that would occur for Linz and Graz combined would alone be flatter than the four-city combined average, because these cities have the most industry per capita. For Innsbruck and Salzburg, the combined slope would be steeper than the four-city average (because of less industry). A conclusion, therefore, is that in addition to direct standards on air pollution emissions, insulation standards for new and old buildings and more use of district heat would be effective ways to improve the air quality in Vienna.

7.6 SO_2 CONTROL: EFFECT AND EFFECTIVENESS

Because Austria is now considering the setting of air pollution standards, we have examined the effect and effectiveness of the SO_2 emission standards assumed in the scenarios. The overall effect of the SO_2 emission standards is presented in Figure 38 for all the scenarios. Except for scenario S2, all the air pollution PDLs calculated for the four scenarios in 2015 are below the 1971 level. Thus, the assumed standards for SO_2 emissions seem to be effective in maintaining air quality and even somewhat in reducing SO_2 health impacts over the time span of the scenarios. For S1, an upturn in SO_2 health impacts would be expected after 2015, unless more stringent standards are implemented.

Three stages of SO_2 emission control standards were defined.

> *Stage 1*: For fuel oil, the implementation (starting in 1978 and completed by 1981) of desulfurization of fuel oil according to new standards of sulfur content set by the Austrian Ministry of Health and Environment: extra light heating oil (0.3%); light heating oil (0.8%); medium heating oil (1.5%); and heavy heating oil (2.0%).
>
> *Stage 2*: For all emission sources, the implementation (starting in 1985 and completed by 2000) of the current U.S. emission standard of 2.16 kg of $SO_2/10^6$ kcal.
>
> *Stage 3*: For all point sources, the implementation (starting in 2000 and completed by 2015) of the more stringent U.S. emission standards anticipated for the year 2000 of 0.91–1.08 kg of $SO_2/10^6$ kcal, modified by economic growth: S1 (reduction to 1.08 kg of $SO_2/10^6$ kcal); S2 (reduction to 0.91 kg of $SO_2/10^6$ kcal); and S3, S4 (reduction to 1.53 kg of $SO_2/10^6$ kcal).

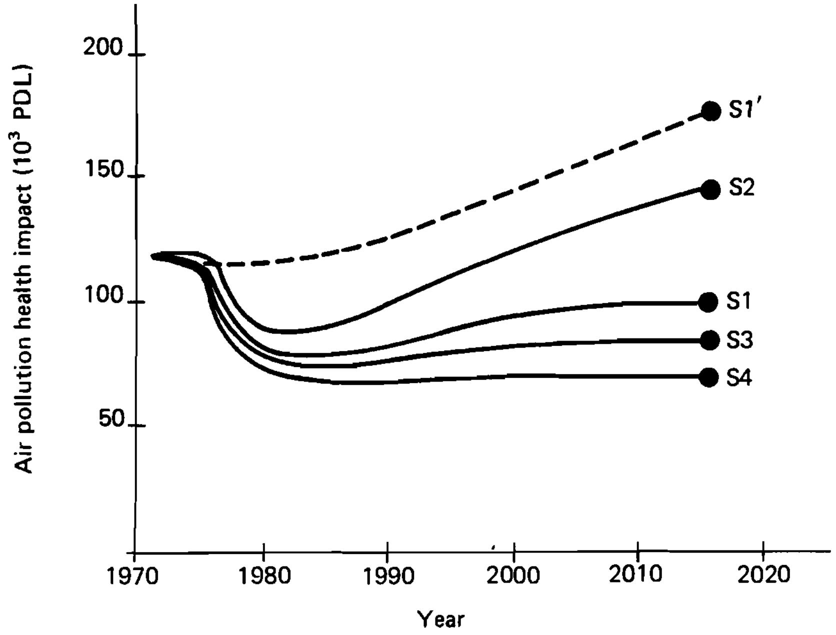


FIGURE 38 Air pollution health person-days-lost (PDL) as a function of time, S1–S4. S1' has no SO_2 emission controls.

The current U.S. standard, stage 2, would require a further 44% reduction of heavy oil sulfur content to 1.13%, a reduction of sulfur content of hard coal by 11%, and for brown coal a sulfur reduction of up to 23%.* For coal, this reduction could be achieved easily by present physical cleaning processes (Ferrell, 1977). This would mean that all of Austria's coal, domestic and imported, would need to be cleaned, or coal mixing would have to occur. The residential heating oil sulfur content produced by stage 1 meets the stage 2 requirements. Thus, stage 2 affects primarily coal and oil used by industry and electric power stations.

Stage 3 will require a halving of sulfur emissions from point sources. This means reductions of emissions (relative to 1971) of 72% for heavy oil and 61% for coal. These reductions in coal sulfur content could no longer be reasonably produced by the physical cleaning of coal, as more than half

*These and the following percentages for sulfur and sulfur emission reduction depend on the emission factors as given in the official Austrian energy plan of 1976. (Bundesministerium fuer Handel, Gewerbe und Industrie, 1976).

the energy content of the original coal would be lost. Coal costs would increase substantially. Such reductions of coal sulfur content can most economically be met with a mixture of stack-gas scrubbing and chemical coal cleaning for large capacity boilers (e.g., large electricity power plants) (Ferrell, 1977; Fossil Fuel and Advanced Systems Division, 1976). For medium-size boilers, the costs increase even more. Austria has only medium-size boilers in its largest electricity power plants.' Costs for stack-gas scrubbing become too large for plants with boiler sizes of less than 100 to 200 MW equivalent capacity (Rentz *et al.*, 1976). This eliminates many sulfur removal options for Austria which are widely discussed because these options are for large boilers and energy systems. Because of costs and economies of scale, Austria will most likely need to remove sulfur from coal at the national level rather than leaving the sulfur removal to individual plants to achieve at stage 3.

Studies from the U.S. suggest that stage 3 can be achieved by stack-gas removal from the very largest plants in Austria (with efficiencies of removal of 80 to 90%) and by the use of desulfurized oil and solvent-refined coal for the rest of the demand. Solvent-refined coal can have 60 to 90% of the sulfur removed, depending on the type of coal; in addition, it has better than 99% of the ash content removed (a bonus when considering more than one pollutant) (Ferrell, 1977; Fossil Fuel and Advanced Systems Division, 1976). In the U.S., solvent-refined coal is two to three times as expensive as untreated coal. Reducing emissions significantly beyond stage 3 would appear to require careful national planning and an examination of new technologies and their adaptation to Austria as these technologies become better known.

The three stages of emission standards seem reasonably attainable for Austria. A sensitivity study was designed to address the effectiveness of the SO_2 emission standards. Beginning with stage 3, each stage was sequentially removed and the new emissions and resulting health impacts were calculated. The results are presented graphically in Figures 39 and 40.

In Figure 39, the top curve (designated S''') shows the SO_2 emissions without controls. This curve is flat at the beginning because of large shifts in industry to natural gas between 1971 and 1980. The curve has a knee between 1980 and 1990. This is largely the result of three effects: the switch in old homes from single room heating to central heating, which doubles emissions for these homes; a further shift from coal to oil in industry, which also doubles SO_2 emissions per energy unit switched; and new fossil-fired electricity plants coming on-line.

Each of the three stages of the standards has a large impact on the total SO_2 emissions. Stage 1 reduces the emissions rapidly because it is

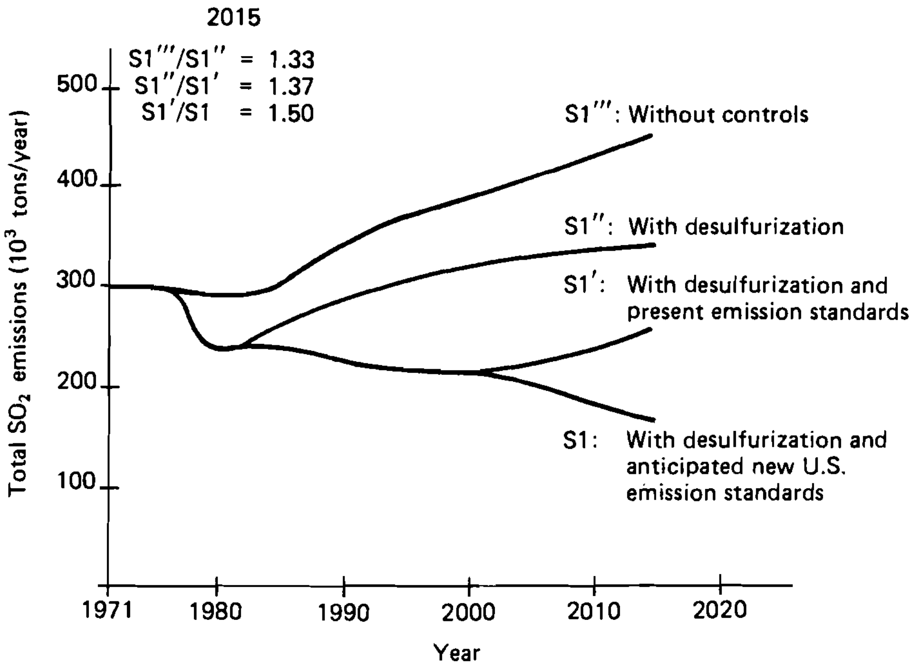


FIGURE 39 Sensitivity of the SO_2 emissions to SO_2 regulations, S1.

implemented quickly, but economic growth and fuel mix changes dominate again and emissions rise. Stage 2 flattens the emission curve over the implementation time, but economic growth increases the emissions after the year 2000. Stage 3 reduces total emissions even below that of stage 2; the emissions would be expected to grow after the year 2015. Each new stage reduces the emissions from the previous stage by more than one third.

Figure 40 shows the effectiveness of the three stages of controls with respect to health impacts. Each stage of the new regulations influences the health impact, but the influence is decreasing stage by stage. This is because the residential and the commercial and service sector emissions are affected only slightly by stage 2 and not at all by stage 3; these low-level emissions have a greater effect on health in urban areas per unit of emissions than do the industrial or the electric power plant sources of emissions. The share of the urban exposure that is being affected by stages 2 and 3 is small and declining; thus the reduction in health impact from each succeeding stage is diminishing.

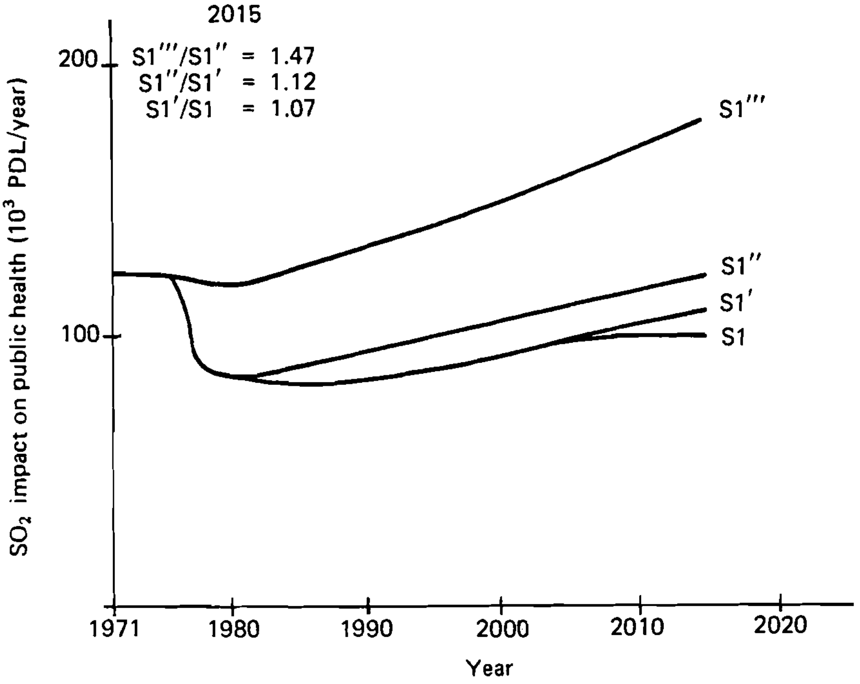


FIGURE 40 Sensitivity of air pollution public health impacts to SO_2 regulations, S1. PDL means person-days-lost.

Figure 40 implies that a further significant reduction in the human health impact is not possible through control of point sources alone. More stringent standards would need to be applied to the emissions from the commercial and service and the residential sectors. However, long-range transport of pollutants has been neglected in these calculations. Because a chemical reaction product, and not SO_2, is the causal agent of SO_2 health impacts, long-range transport effects are important (Private communication, R. Meyer, CONAES). Point sources are the major sources of long-range transport effects. Thus, it is important to reduce the point source emissions in stages 2 and 3.

Long-range transport is also important for determining environmental impacts on plants, and the point sources again become important. Because reliable damage functions for plants were not available at the time of the study, this impact was not included here. Effects from long-range transport cannot be ignored even though they are not yet well quantified. However, it is our opinion that for Austria, the urban health impacts comprise the majority of the human health impacts. In conclusion, we believe that the three stages of SO_2 standards would be an effective means for protecting human health in Austria.

7.7 BESOM SENSITIVITY STUDY

The BESOM analysis for 1990 (section 6.2) suggested a different mix of primary fuels for producing electricity than that assumed in scenario S1. A sensitivity study was defined to compare the human health impacts generated by S1 in 1990 and by the BESOM analysis in 1990. The results are shown in Figure 41.

With a switch of only 4% of the total primary energy from oil to coal, the total PDL increased by 29%. This increase was almost totally with respect to the occupational impacts; air pollution impacts were unchanged

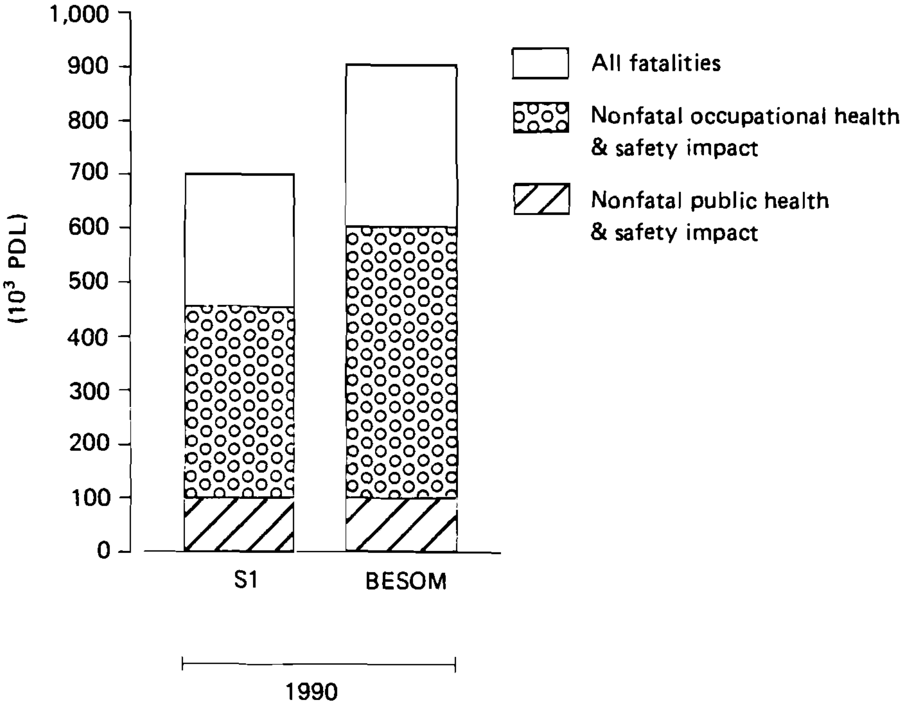


FIGURE 41 Total human health and safety, 1990: Base Case (S1) and BESOM Case. BESOM means BESOM electricity supply optimization results, i.e., a shift to coal-fired power plants compared to S1. PDL means person-days-lost.

because SO_2 controls were the same. This underscores the effect of the primary energy supply mix on these impacts.

The results shown in Figure 41 and the results discussed earlier for CO_2 and for air pollution emissions all point to increases (per unit of energy use) in many environmental impacts, because of shifts to coal from other fossil fuels. This environmental aspect must be taken into account when considering the coal option.

7.8 FINAL COMMENT

The results of the environmental impact models must be interpreted carefully; clearly not everything is included in the models. Some calculated impacts are well understood; other calculated impacts represent only a fraction of the impacts occurring, while yet other impacts are indicators of impacts that are occurring but not quantified. Further, many of the calculated impacts have different degrees of uncertainty associated with their quantifications. Many quantified impacts are not included, and the unquantified impacts are not included at all except by proxy. The calculations present several, but not all, facets of the energy/environment system; thus the calculations must be viewed in context. Results can be misleading if a broader perspective is not maintained; two examples are long-range transport and sulfates/SO_2. In this report we have attempted to point out many of the limitations of the method and have endeavored to put into perspective the environmental impact results.

8 CONCLUDING OBSERVATIONS

This report has presented the major results of the 15-month, Austrian case study, which examined alternative energy futures and strategies for Austria and some of their environmental implications. These results were also presented to Austrian planners and energy/environment specialists at a final workshop in July 1977.

We believe that this study, because of the systems perspective that it provides, has contributed to a better understanding of the overall energy and environmental problems facing Austria today. The cooperative arrangements with Austrian institutions aided immensely in disseminating the results to the energy/environment communities as well as to other individuals and groups in Austria.

The primary objective of this study was the examination of alternative energy/environment futures for Austria. A second objective was the development of appropriate concepts and methods for energy/environment management and policy design in Austria. We have concluded that the systems analytical approach used in this study has been an appropriate one, and that Austria could derive many benefits from incorporating some of these concepts and analytical tools into its existing set of policy design techniques. During the past several months, this transfer process has already begun; both the Oesterreichische Elektrizitaetswirtschaft AG (Electric Power Association) and the Wiener Stadtwerke (Vienna Municipal Utilities) have begun to integrate some of the models and data collections into their analyses. A more methodologically-oriented report summarizing the methods used in this study as well as in the three previous IIASA case studies is in preparation. More detailed descriptions of the models and user's guides are available upon request at IIASA and the University of Wisconsin-Madison.

In closing, we strongly recommend that the appropriate Austrian agencies and institutions consider developing their own capability for energy/environment analysis and policy design. We hope that the IIASA study has provided a first step in that direction.

APPENDIXES

Appendix A

CHARACTERISTICS OF SCENARIOS S1–S4

TABLE A.1 Characteristics of scenario S1.

Structure	
Population	Average growth rate of 0.22%/yr (7.456 million in 1971 to 8.26 in 2015). Regional differences: growth in Vorarlberg, Tyrol, Salzburg, Carinthia, and Styria; decline in Lower Austria, Burgenland, Vienna
Human settlements	Decline of rural population (i.e., population in communities with less than 3,000 people in 1971)
Economy	Average GNP growth rates: 1971–1980, 3.5%/yr; 1980–1990, 2.4%/yr; 1990–2000, 1.9%/yr; 2000–2015, 1.5%/yr (1971: 391 × 10^9 AS_{70}^{a}, 2015: 1,019 × 10^9 AS_{70}^{a})
Lifestyle	
Personal consumption	Total private consumption increasing from 200 × 10^9 AS_{70}^{a} in 1970 to 517 × 10^9 AS_{70}^{a} in 2015. Declining share of agriculture and food products; increasing shares of semidurables and durables and services
Transport	Moderate increase in use and ownership of automobiles reaching 280 vehicles/1,000 population by 1980 and 300 vehicles/1,000 population by 1990. Increasing emphasis on truck use for freight
Housing	General trends for all four scenarios: bigger new homes, convenient fuels and heating system appliances and thoroughly heated homes. The floorspace of new homes increases 0.8 m^2/yr until 2000. (1971 = 82 m^2). Floorspace per capita:

TABLE A.1 *Continued.*

	1971, 22.6 m^2; 2000, 30 m^2; 2015, 34 m^2. Heated floorspace per capita: 1971, 15 m^2; 2000, 29 m^2; 2015, 34 m^2. Household appliances: saturation level reached by about the year 2000
Technology	
Industry	Change of energy intensiveness until the year 2000. Increases of petroleum (20%) and mining (10%); no change in wood products, leather, and electrical equipment; decrease in primary metals (20%) and in other sectors (10%)
Transport	Automobile efficiency increases from 12.3 liters/100 km to 8.9 liters/100 km for new cars in the 1980s. Truck energy consumption per ton-km is reduced 20%
Housing	Fuel mix: coal decreases to insignificance by 2000; continuing trend to convenient fuels – electricity, gas, oil, and district heat. Insulation levels do not improve. Energy efficiency of appliances: no improvements. Alternative technologies: no significant use
Energy supply	Electricity demand grows more rapidly than total end-use demand, increasing from 14% to 19% of total end-use demand by 2015. Increases in required electricity provided by nuclear power (two 1,300 MWe plants by 2015), hydropower expansion, and electricity imports. Total primary energy requirements double between 1971 and 2015: 2015 requirements supplied by hard coal (7%), lignite (3%), petroleum (45%), gases (20%), hydropower (11%), nuclear (11%), and by waste and wood (3%); decreased emphasis on coal
Environment	
Environmental regulations	SO_2: proposed Austrian oil desulfurization by 1981. reduce all emission sources to present U.S. new source standard of SO_2 emission by 2000. Reduce point source emissions to 0.50 of present U.S. new source standard by 2015. Particulates (PM): reduce power plant emissions to 1.0 of U.S. new source PM emission standard by 2015. Reduce nonpower plant point source emissions to 1.18 of U.S. new source PM emission standard by 2015. CO_2: no controls. CO, NO_x, HC: only controlled in transportation and communications sector. Waste heat: no thermal regulations considered for cooling water for power plants

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[a] Austrian schillings at 1970 values.

TABLE A.2 Characteristics of scenario S2.

Structure	
Population	Same as in S1
Human settlements	Same as in S1
Economy	GNP growth rates: 1971–1980, 3.7%/yr; 1980–1990, 2.6%/yr; 1990–2000, 2.7%/yr; 2000–2015, 2.8%/yr (1971: 391 × 10^9 $AS_{70}{}^a$, 2015: 1,381 × 10^9 $AS_{70}{}^a$)
Lifestyle	
Personal consumption	Total private consumption increasing from 200 × 10^9 $AS_{70}{}^a$ in 1970 to 668 × 10^9 $AS_{70}{}^a$ in 2015. Similar trend in private consumption structure for all four scenarios, but stronger than that of scenario S1
Transport	Rapid increase in use and ownership of automobiles reaching 300 vehicles/1,000 population in 1980 and 400 vehicles/1,000 population by 1990. Reliance on trucks as in S1
Housing	Similar trends for all four scenarios (see S1). Floorspace of new constructions increases annually by 1.0 m^2 until 2000 (1971 = 82 m^2). Floorspace per capita: 1971, 22.6 m^2; 2000, 31 m^2; 2015, 36 m^2. Heated floorspace per capita: 1971 = 15 m^2; 2000 = 30 m^2; 2015 = 36 m^2. Household appliances: saturation level reached by about the year 1990. Higher saturation levels than in S1, and less restrained energy use; heating hours per year increase 40% until 2000
Technology	
Industry	Change of energy intensiveness until the year 2000. Increase of 30% for petroleum and mining; of 20% for wood products and leather; and of 10% for stone, cement, glass, chemicals, food, textiles, clothes, and electrical equipment; no change in paper, machinery, and metal products; decrease of 10% for primary metals
Transport	Automobile and truck technologies and efficiencies do not change
Housing	Same as in S1
Energy supply	Electricity demand grows more rapidly than total end-use demand, increasing to 18% of total end-use demand by 1990. In electrical sector, 69% expansion of fossil-fuel

TABLE A.2 *Continued.*

	generation during 1971–2015; nuclear power growing: five 1,300 MWe plants by 2015; increased hydro capacity and imports. Total primary energy requirements increase by factor of 3.5 between 1971–2015; 2015 requirements met by hard coal (6%), lignite (3%), petroleum (43%), gases (20%), hydro (8%), nuclear (17%), and wastes and wood (3%). Decreased emphasis on coal; increased on nuclear
Environment	
Environmental regulations	SO_2: same as in S1 except reduce point source emissions to 0.42 of U.S. new source standard by 2015. Particulates (PM): same as in S1, except reduce nonpower plant point source emissions to 1.0 of U.S. new source PM standard by 2015. CO_2, and waste heat: same as in S1

[a] Austrian schillings at 1970 values.

TABLE A.3 Characteristics of scenario S3.

Structure	
Population	Same as in S1
Human settlements	Same as in S1
Economy	Average GNP growth rates: 1971–1980, 3.4%/yr; 1980–1990, 2.3%/yr; 1990–2000, 1.6%/yr; 2000–2015, 0.7%/yr. (1971: 391 × 10^9 AS$_{70}$[a], 2015: 858 × 10^9 AS$_{70}$[a])
Lifestyle	
Personal consumption	Total private consumption increasing from 200 × 10^9 AS$_{70}$[a] in 1970 to 450 × 10^9 AS$_{70}$[a] in 2015. Same trend in private consumption structure for all four scenarios, but not as strong as that of S1
Transport	Significant slowing in the growth of automobile use and ownership. Ownership reaches 240 cars/1,000 population in 1980 and 250 cars/1,000 population by 1990
Housing	Similar trends for all four scenarios (see S1). Floorspace of new constructions increases annually by 0.4 m^2 until 2000 (1971 = 82 m^2). Floorspace per capita: 1971, 22.6 m^2;

	2000, 29 m^2; 2015, 32 m^2. Heated floorspace per capita: 1971, 15 m^2; 2000, 28 m^2; 2015, 32 m^2. Household appliances: saturation level reached by about the year 2015. Saturation levels are the same as in S1
Technology	
Industry	Change of energy intensiveness until the year 2000: similar to that of S1, but the changes occur earlier in the period. Few changes occur after 2000 because of assumed low economic growth
Transport	Same as in S1
Housing	Fuel mix: same as in S1. Insulation standards: heat losses for new homes lowered stepwise to 60% of 1971 levels by 2000. Retrofitting improves pre-1971 homes 15% by 2000. Energy efficiencies of appliances and alternative technologies: same as in S1
Energy supply	Electricity demand grows faster than total end-use demand, increasing to 19% of total end-use demand by 2000. In electricity sector additional generation requirements met by one 750 MWe nuclear plant, hydropower expansion and imports as in S1, and 37% increase in fossil-fuel-based generation. Total primary energy requirements increase 75% between 1971 and 2015; 2015 requirements met by hard coal (7%), lignite (4%), petroleum (50%), gases (22%), hydro (14%), and waste and wood (3%). Decreased emphasis on coal; increased importance of hydropower
Environment	
Environmental regulations	SO_2: same as in S1, except reduce point source emissions to 0.71 of present U.S. new source standards of SO_2 emissions by 2015. Particulates (PM): same as in S1 except reduce nonpower plant point source emissions to 1.6 of U.S. new source PM emission standard by 2015. CO_2 and waste heat: same as in S1

[a] Austrian schillings at 1970 values.

TABLE A.4 Characteristics of scenario S4.

Structure	
Population	Same as in S1
Human settlements	Same as in S1
Economy	Average GNP growth rates are the same as in S3, but value-added shares are different
Lifestyle	
Personal consumption	Total private consumption grows as in S3, but with lower share of petroleum sector and higher share of construction industry (because of insulation measures)
Transport	Same as in S1, except automobiles are lighter, less powerful and, on the average, smaller. Freight has a small shift back to rail
Housing	Similar trends for all four scenarios (see S1). Floorspace of new construction increases annually by 0.4 m^2 until 2000 (1971 = 82 m^2). Floorspace per capita: 1971, 22.6 m^2; 2000, 29 m^2; 2015, 32 m^2. Heated floorspace per capita: 1971, 15 m^2; 2000, 28 m^2; 2015, 32 m^2. Household appliances: saturation levels are reached by about the year 2015. Saturation levels same as in S1
Technology	
Industry	Change of energy intensiveness until the year 2000: general decrease of 10% for mining; of 20% for glass, paper, wood products, food, leather, machinery and metal products, and electrical equipment; of 25% for primary metals; and of 30% for petroleum, stone and cement, chemicals, textiles, clothes
Transport	Significant design improvements foreseen helping to reduce fuel use in automobiles and trucks. New automobiles reach fuel consumption level of 7 liter/100 km by 1990, while truck energy consumption per ton-km is reduced 35%
Housing	Fuel mix: same as in S1. Insulation standard: strict conservation policy; stepwise lowering of heat losses to 5% of 1971 levels by 2000; and 20% reduction of heat losses of old homes. Energy efficiency of appliances: improvements of about 10% between 1980 and 1990. Alternative technologies: for the sensitivity study, significant use of solar energy/heat pumps

Energy supply	Electricity demand grows more rapidly than total end-use demand, increasing to 19% of total end-use demand by 2000. In electricity sector, additions to generation requirements met by expansion of hydro capacity, imports, and increases in coal- and gas-based generation. Petroleum phased out as primary fuel for electrical generation. Total primary energy requirements increase 36% between 1971 and 2015; 2015 requirements met by hard coal (9%), lignite (4%), petroleum (43%), gases (22%), hydro (18%), and by waste and wood (3%). Despite lower demand due to constrained petroleum supply, possible shortfalls could cause shifts in fuel mix
Environment	
Environmental regulations	SO_2: same as in S1 except reduce point source emissions to 0.71 of present U.S. new source standards of SO_2 emission by 2015. Particulates (PM): same as in S1 except reduce nonpower plant point source emissions to 1.60 of U.S. new source PM emission standard by 2015. CO_2: no controls. Waste heat: same as in S1

Appendix B

DATA ON THE AUSTRIAN ECONOMY IN 1970 AND SCENARIO RESULTS FOR 2015

TABLE B.1 Austrian value added by sector in 1970 and scenario results for 2015 (10^9 Austrian schillings at 1970 values).[a]

		2015			
Sector	1970	S1	S2	S3	S4
Agriculture and forestry	26.2	46.3	59.1	39.7	39.7
Mining	2.2	5.1	5.7	2.8	1.7
Petroleum and natural gas	5.0	8.5	9.6	7.6	5.2
Stone, clay, cement	6.8	15.2	20.6	13.0	13.8
Glass	1.3	3.4	5.8	2.4	2.5
Food	14.9	36.1	47.0	31.6	32.1
Tobacco	4.4	9.3	10.4	8.6	8.6
Textiles	6.3	10.0	6.8	9.7	9.8
Clothes	5.2	6.5	7.0	6.2	6.2
Leather	2.2	6.4	10.3	4.9	4.9
Chemicals	10.0	38.1	63.2	28.8	30.5
Iron and steel	7.9	20.3	20.6	17.3	18.1
Machinery	10.1	35.7	60.0	27.4	27.4
Casting	1.6	5.5	8.9	4.1	4.2
Nonferrous metals	2.0	5.3	10.4	3.6	3.7
Iron and metal products	7.0	21.3	35.0	16.2	16.3
Electrical mach. and equip.	7.2	30.6	49.6	19.3	19.3
Vehicles	7.5	15.1	19.1	13.6	13.6
Saw mills	1.7	4.0	5.2	3.2	3.2
Wood products	6.8	22.6	33.0	18.3	18.6
Pulp, paper, plywood	2.2	6.1	9.4	4.7	5.4
Paper products	4.7	13.7	19.3	11.4	11.6

TABLE B.1 *Continued.*

Sector	1970	2015 S1	2015 S2	2015 S3	2015 S4
Construction industry	33.8	79.5	96.3	71.5	74.4
Electricity, gas, and water	10.6	29.8	40.9	24.9	22.4
Trade and leasing	51.4	140.4	186.6	120.0	119.6
Transportation and communication	23.4	70.1	88.0	62.1	62.0
Banking and insurance	14.8	46.6	63.3	39.2	39.0
Hotels and restaurants	10.4	25.5	26.7	25.1	25.4
Other services	20.6	59.6	75.9	52.5	52.4
Housing	5.5	12.1	15.6	10.6	10.6
Public administration	40.2	98.9	132.7	84.5	84.7
TOTAL	354.2	927.5	1,242.1	784.9	786.9

[a] Columns may not add to totals because of rounding.

TABLE B.2 Value-added structure of the Austrian economy in 1970 and scenario results for 2015 (percentage).[a]

Sector	1970	2015 S1	S2	S3	S4
Agriculture and forestry	7.39	4.99	4.76	5.06	5.04
Mining	0.63	0.55	0.46	0.36	0.21
Petroleum and natural gas	1.41	0.92	0.77	0.97	0.66
Stone, clay, cement	1.92	1.64	1.66	1.66	1.75
Glass	0.37	0.37	0.47	0.31	0.32
Food	4.21	3.89	3.78	4.02	4.08
Tobacco	1.25	1.00	0.84	1.10	1.10
Textiles	1.77	1.07	0.55	1.24	1.24
Clothes	1.48	0.70	0.57	0.79	0.79
Leather	0.63	0.69	0.83	0.63	0.63
Chemicals	2.83	4.11	5.09	3.67	3.88
Iron and steel	2.23	2.18	1.66	2.21	2.30
Machinery	2.85	3.85	4.83	3.49	3.48
Casting	0.47	0.59	0.72	0.52	0.53
Nonferrous metals	0.55	0.57	0.84	0.46	0.47
Iron and metal products	1.98	2.30	2.82	2.06	2.07
Electrical mach. and equip.	2.04	3.30	3.99	2.45	2.45
Vehicles	2.13	1.63	1.54	1.74	1.73
Saw mills	0.49	0.43	0.42	0.41	0.41
Wood products	1.93	2.44	2.65	2.33	2.36
Pulp, paper, plywood	0.63	0.66	0.76	0.60	0.69
Paper products	1.34	1.48	1.56	1.45	1.47
Construction industry	9.53	8.57	7.75	9.10	9.45
Electricity, gas, and water	2.99	3.21	3.29	3.17	2.85
Trade and leasing	14.51	15.14	15.02	15.29	15.20
Transportation and communication	6.61	7.55	7.08	7.92	7.88
Banking and insurance	4.18	5.02	5.09	5.00	4.96
Hotels and restaurants	2.93	2.75	2.15	3.19	3.23
Other services	5.81	6.43	6.11	6.69	6.66
Housing	1.54	1.31	1.25	1.35	1.35
Public administration	11.36	10.66	10.68	10.76	10.76
TOTAL	100.00	100.00	100.00	100.00	100.00

[a] Columns may not add to totals because of rounding.

TABLE B.3 Demand and supply of the Austrian economy in 1970 and scenario results for 2015 (10^9 Austrian schillings at 1970 prices).[a]

		2015			
Sector	1970	S1	S2	S3	S4
Private consumption	199.8	517.4	668.1	449.6	450.5
Public consumption	55.0	123.0	161.0	106.6	106.9
Investment in buildings	55.3	129.4	151.2	118.1	118.3
Investment in machinery	43.5	94.5	109.7	86.5	86.7
Inventory change	10.0	10.1	13.8	8.5	8.6
Tourism	25.3	76.1	76.1	76.1	76.1
Exports	81.9	610.9	1,047.7	448.7	448.7
. . .					
Final demand	470.7	1,561.4	2,227.8	1,294.2	1,295.7
Intermediate demand	306.3	906.6	1,288.7	736.6	727.2
TOTAL DEMAND	777.0	2,468.0	3,516.5	2,030.8	2,022.9
Value added	354.2	927.5	1,242.1	784.9	786.9
Import duties	17.0	91.1	138.9	73.3	73.6
Imports (excl. noncompetitive)	94.6	527.5	826.7	423.0	424.6
Noncompetitive imports	4.8	15.2	19.9	12.9	10.7
. . .					
Primary inputs	470.7	1,561.4	2,227.8	1,294.2	1,295.7
Secondary inputs	306.3	906.6	1,288.7	736.6	727.2
TOTAL INPUTS	777.0	2,468.0	3,516.5	2,030.8	2,022.9

[a] Columns may not add to totals because of rounding.

TABLE B.4 Demand and supply structure of the Austrian economy in 1970 and scenario results for 2015 (percentage of demand and supply).[a]

		2015			
Sector	1970	S1	S2	S3	S4
Private consumption	25.72	20.96	19.00	22.14	22.27
Public consumption	7.08	4.98	4.58	5.25	5.28
Investment in buildings	7.11	5.24	4.30	5.82	5.85
Investment in machinery	5.60	3.83	3.12	4.26	4.28
Inventory change	1.28	0.41	0.39	0.42	0.42
Tourism	3.25	3.09	2.17	3.75	3.76
Exports	10.54	24.76	29.79	22.09	22.18
. . .					
Final demand	60.58	63.27	63.35	63.73	64.05
Intermediate demand	39.42	36.73	36.65	36.27	35.95
TOTAL DEMAND	100.00	100.00	100.00	100.00	100.00
Value added	45.59	37.58	35.32	38.65	38.90
Import duties	2.19	3.69	3.95	3.61	3.64
Imports (excl. noncompetitive)	12.17	21.38	23.51	20.83	20.99
Noncompetitive imports	0.62	0.62	0.57	0.63	0.53
. . .					
Primary inputs	60.58	63.27	63.35	63.73	64.05
Secondary inputs	39.42	36.73	36.65	36.27	35.95
TOTAL SUPPLY	100.00	100.00	100.00	100.00	100.00

[a] Columns may not add to totals because of rounding.

TABLE B.5 Private consumption in Austria in 1970 and scenario results for 2015 (10^9 Austrian schillings at 1970 prices).[a]

		2015			
Sector	1970	S1	S2	S3	S4
Agriculture and forestry	12.0	13.3	13.9	13.0	13.0
Mining	0.8	0.2	0.1	0.2	0.2
Petroleum and natural gas	3.5	10.4	12.2	9.5	6.0
Stone, clay, cement	0.4	1.3	1.7	1.1	1.1
Glass	0.2	0.5	0.7	0.4	0.4
Food	37.2	86.2	111.2	75.1	75.3
Tobacco	4.9	10.0	11.4	9.2	9.2
Textiles	8.2	28.5	38.8	24.0	24.0
Clothes	10.3	32.8	44.2	27.8	27.9
Leather	4.0	10.1	13.2	8.8	8.8
Chemicals	5.5	18.8	25.9	15.7	15.7
Iron and steel	0.7	0.7	0.8	0.7	0.7
Machinery	0.2	0.9	1.3	0.8	0.8
Casting	0.1	0.2	0.2	0.2	0.2
Nonferrous metals	0.9	1.3	1.5	1.2	1.2
Iron and metal products	2.9	9.1	12.1	7.7	7.7
Electrical mach. and equip.	4.3	17.2	23.6	14.3	14.4
Vehicles	9.5	32.9	39.1	29.5	29.5
Saw mills	0.3	0.3	0.3	0.3	0.3
Wood products	6.1	25.1	34.7	20.8	20.9
Pulp, paper, plywood	0.0	0.0	0.0	0.0	0.0
Paper products	1.9	4.4	5.6	3.8	3.8
Construction industry	3.7	6.7	7.5	6.3	11.2
Electricity, gas, and water	3.7	15.3	21.1	12.7	12.7
Trade and leasing	35.8	90.4	116.3	78.7	77.3
Transportation and communication	7.0	13.1	14.7	12.2	12.2
Banking and insurance	2.0	9.6	13.4	7.9	7.9
Hotels and restaurants	7.0	7.3	7.3	7.3	7.3
Other services	11.4	30.2	39.8	25.9	25.9
Housing	10.9	22.9	29.4	20.2	20.2
Public administration	4.5	17.9	26.4	14.4	14.4
TOTAL	199.8	517.4	668.1	449.6	450.5

[a] The sum of the trade margins contained in private consumption is recorded as private consumption expenditure on trade; the individual figures contain no trade margins. Columns may not add to totals because of rounding.

TABLE B.6 Private consumption in Austria in 1970 and scenario results for 2015 (percentage of total).[a]

Sector	1970	2015 S1	S2	S3	S4
Agriculture and forestry	6.01	2.57	2.09	2.89	2.89
Mining	0.40	0.03	0.01	0.05	0.05
Petroleum and natural gas	1.77	2.02	1.82	2.10	1.34
Stone, clay, cement	0.21	0.24	0.25	0.24	0.24
Glass	0.09	0.10	0.10	0.10	0.10
Food	18.64	16.66	16.65	16.71	16.71
Tobacco	2.45	1.93	1.70	2.05	2.05
Textiles	4.09	5.51	5.81	5.33	5.33
Clothes	5.15	6.34	6.61	6.18	6.19
Leather	1.98	1.96	1.97	1.95	1.95
Chemicals	2.74	3.63	3.88	3.49	3.49
Iron and steel	0.37	0.14	0.12	0.16	0.16
Machinery	0.11	0.18	0.19	0.17	0.17
Casting	0.04	0.04	0.03	0.04	0.04
Nonferrous metals	0.43	0.26	0.23	0.28	0.28
Iron and metal products	1.45	1.75	1.82	1.71	1.72
Electrical mach. and equip.	2.14	3.32	3.53	3.19	3.19
Vehicles	4.77	6.36	5.85	6.56	6.55
Saw mills	0.13	0.05	0.04	0.06	0.06
Wood products	3.04	4.85	5.19	4.63	4.64
Pulp, paper, plywood	0.01	0.00	0.00	0.00	0.00
Paper products	0.95	0.85	0.84	0.85	0.85
Construction industry	1.87	1.30	1.13	1.39	2.50
Electricity, gas, and water	1.83	2.95	3.16	2.82	2.82
Trade and leasing	17.91	17.46	17.41	17.50	17.15
Transportation and communication	3.48	2.54	2.21	2.72	2.71
Banking and insurance	1.02	1.86	2.01	1.76	1.76
Hotels and restaurants	3.52	1.41	1.09	1.62	1.62
Other services	5.71	5.83	5.96	5.76	5.76
Housing	5.44	4.42	4.34	4.48	4.48
Public administration	2.23	3.45	3.95	3.20	3.21
TOTAL	100.00	100.00	100.00	100.00	100.00

[a] The sum of the trade margins contained in private consumption is recorded as private consumption expenditure on trade; the individual figures contain no trade margins. Columns may not add to totals because of rounding.

TABLE B.7 Austrian exports by sector in 1970 and scenario results for 2015 (10^9 Austrian schillings at 1970 values).[a]

		2015			
Sector	1970	S1	S2	S3	S4
Agriculture and forestry	1.6	7.6	12.8	4.8	4.8
Mining	2.2	10.1	16.6	7.5	7.5
Petroleum and natural gas	0.2	4.0	7.5	2.9	2.9
Stone, clay, cement	1.1	8.8	16.1	6.3	6.3
Glass	1.0	5.5	9.3	4.0	4.0
Food	2.0	18.5	33.6	12.8	12.8
Tobacco	0.0	0.0	0.0	0.0	0.0
Textiles	6.4	52.5	95.1	37.1	37.1
Clothes	1.7	9.9	16.7	7.2	7.2
Leather	1.4	13.1	23.6	9.3	9.3
Chemicals	7.4	67.0	122.1	47.6	47.6
Iron and steel	8.5	56.0	100.0	39.8	39.8
Machinery	10.2	101.2	184.8	71.9	71.9
Casting	0.4	3.4	6.1	2.4	2.4
Nonferrous metals	2.4	6.3	8.7	5.2	5.2
Iron and metal products	4.6	40.5	72.1	28.8	28.8
Electrical mach. and equip.	6.7	66.9	121.7	46.2	46.2
Vehicles	2.2	25.7	47.3	18.0	18.0
Saw mills	4.6	11.3	14.4	9.0	9.0
Wood products	2.5	19.3	33.6	13.8	13.8
Pulp, paper, plywood	3.6	17.2	25.4	13.5	13.5
Paper products	1.4	10.6	17.7	7.9	7.9
Construction industry	0.1	0.7	0.7	0.7	0.7
Electricity, gas, and water	1.9	2.0	2.0	2.0	2.0
Trade and leasing	2.2	16.0	23.4	13.1	13.1
Transportation and communication	2.8	18.5	18.4	18.5	18.5
Banking and insurance	0.6	4.0	4.0	4.0	4.0
Hotels and restaurants	0.0	0.1	0.1	0.0	0.0
Other services	2.1	14.1	14.0	14.1	14.1
Housing	0.0	0.0	0.0	0.0	0.0
Public administration	0.0	0.0	0.0	0.0	0.0
TOTAL	81.9	610.9	1,047.8	448.7	448.7

[a] Columns may not add to totals because of rounding.

TABLE B.8 Austrian exports in 1970 and scenario results for 2015 (percentage of total).[a]

		2015			
Sector	1970	S1	S2	S3	S4
Agriculture and forestry	2.01	1.25	1.22	1.06	1.06
Mining	2.71	1.66	1.58	1.67	1.67
Petroleum and natural gas	0.28	0.65	0.72	0.65	0.65
Stone, clay, cement	1.31	1.44	1.54	1.40	1.40
Glass	1.17	0.90	0.89	0.89	0.89
Food	2.41	3.03	3.21	2.86	2.86
Tobacco	0.02	0.00	0.00	0.01	0.01
Textiles	7.87	8.60	9.08	8.27	8.27
Clothes	2.05	1.62	1.59	1.61	1.61
Leather	1.73	2.15	2.25	2.07	2.07
Chemicals	9.04	10.97	11.65	10.62	10.62
Iron and steel	10.44	9.17	9.54	8.88	8.88
Machinery	12.48	16.57	17.64	16.03	16.03
Casting	0.47	0.56	0.58	0.54	0.54
Nonferrous metals	2.90	1.03	0.83	1.16	1.16
Iron and metal products	5.58	6.63	6.88	6.43	6.43
Electrical mach. and equip.	8.16	10.95	11.62	10.29	10.29
Vehicles	2.73	4.20	4.51	4.02	4.02
Saw mills	5.56	1.85	1.37	2.01	2.01
Wood products	3.00	3.16	3.21	3.08	3.08
Pulp, paper, plywood	4.34	2.81	2.42	3.01	3.01
Paper products	1.77	1.74	1.69	1.76	1.76
Construction industry	0.13	0.11	0.07	0.15	0.15
Electricity, gas, and water	2.30	0.32	0.19	0.44	0.44
Trade and leasing	2.72	2.62	2.23	2.91	2.91
Transportation and communication	3.44	3.03	1.76	4.12	4.12
Banking and insurance	0.74	0.65	0.38	0.89	0.89
Hotels and restaurants	0.01	0.01	0.01	0.01	0.01
Other services	2.62	2.30	1.34	3.14	3.14
Housing	0.00	0.00	0.00	0.00	0.00
Public administration	0.00	0.00	0.00	0.00	0.00
TOTAL	100.00	100.00	100.00	100.00	100.00

[a] Columns may not add to totals because of rounding.

TABLE B.9 Austrian imports by type of product in 1970 and scenario results for 2015 (10^9 Austrian schillings at 1970 values).[a]

Sector	1970	2015 S1	S2	S3	S4
Agriculture and forestry	6.6	21.1	29.1	18.0	18.1
Mining	4.0	12.2	22.4	11.0	11.1
Petroleum and natural gas	7.1	24.2	33.9	20.1	20.1
Stone, clay, cement	1.6	10.0	14.6	8.0	8.0
Glass	0.8	5.7	7.6	4.9	4.8
Food	5.7	25.2	36.2	20.5	20.6
Tobacco	0.1	0.2	0.2	0.1	0.1
Textiles	8.5	67.7	126.3	48.3	48.6
Clothes	1.3	30.3	46.9	23.3	23.4
Leather	1.6	10.1	14.2	8.3	8.3
Chemicals	12.7	66.2	96.3	53.4	53.6
Iron and steel	5.1	53.3	114.9	35.1	35.4
Machinery	14.9	73.1	105.4	59.4	59.5
Casting	0.4	2.3	3.4	1.8	1.8
Nonferrous metals	4.4	13.2	16.1	12.1	12.1
Iron and metal products	6.6	39.6	57.0	32.2	32.3
Electrical mach. and equip.	8.5	51.7	81.6	47.4	47.5
Vehicles	11.6	59.1	85.4	47.9	48.1
Saw mills	0.5	3.2	4.6	2.5	2.5
Wood products	2.0	15.3	22.7	12.2	12.3
Pulp, paper, plywood	1.2	10.7	14.6	9.1	9.1
Paper products	1.9	11.3	16.5	9.1	9.1
Construction industry	0.2	0.4	0.5	0.3	0.3
Electricity, gas, and water	0.3	1.7	2.6	1.4	1.4
Trade and leasing	1.3	3.2	3.9	2.9	2.9
Transportation and communication	0.0	0.1	0.1	0.1	0.1
Banking and insurance	0.7	1.8	2.1	1.6	1.6
Hotels and restaurants	0.0	0,0	0.0	0.0	0.0
Other services	2.2	5.4	6.5	4.9	4.9
Housing	0.0	0.0	0.0	0.0	0.0
Public administration	0.1	0.2	0.2	0.2	0.2
TOTAL	111.6	618.7	965.7	496.4	498.2

[a] Columns may not add to totals because of rounding.

TABLE B.10 Austrian imports in 1970 and scenario results for 2015 (percentage of total).[a]

		2015			
Sector	1970	S1	S2	S3	S4
Agriculture and forestry	5.92	3.41	3.01	3.63	3.63
Mining	3.60	1.97	2.32	2.22	2.22
Petroleum and natural gas	6.33	3.91	3.51	4.04	4.03
Stone, clay, cement	1.44	1.61	1.51	1.61	1.61
Glass	0.70	0.92	0.79	0.98	0.97
Food	5.13	4.08	3.75	4.14	4.14
Tobacco	0.07	0.03	0.02	0.03	0.03
Textiles	7.58	10.95	13.08	9.74	9.76
Clothes	1.15	4.90	4.86	4.69	4.69
Leather	1.42	1.63	1.47	1.68	1.67
Chemicals	11.36	10.70	9.97	10.76	10.76
Iron and steel	4.57	8.61	11.90	7.08	7.10
Machinery	13.34	11.82	10.91	11.96	11.95
Casting	0.39	0.37	0.35	0.37	0.37
Nonferrous metals	3.90	2.13	1.67	2.44	2.43
Iron and metal products	5.88	6.40	5.90	6.49	6.49
Electrical mach. and equip.	7.65	8.35	8.45	9.54	9.54
Vehicles	10.36	9.56	8.84	9.66	9.65
Saw mills	0.42	0.51	0.48	0.51	0.51
Wood products	1.81	2.48	2.35	2.46	2.46
Pulp, paper, plywood	1.05	1.73	1.51	1.83	1.83
Paper products	1.70	1.83	1.71	1.83	1.83
Construction industry	0.14	0.06	0.05	0.07	0.07
Electricity, gas, and water	0.23	0.28	0.27	0.28	0.28
Trade and leasing	1.14	0.52	0.40	0.58	0.58
Transportation and communication	0.04	0.02	0.01	0.02	0.02
Banking and insurance	0.64	0.29	0.22	0.33	0.33
Hotels and restaurants	0.01	0.00	0.00	0.00	0.00
Other services	1.98	0.88	0.67	0.99	0.99
Housing	0.00	0.00	0.00	0.00	0.00
Public administration	0.07	0.03	0.02	0.04	0.04
TOTAL	100.00	100.00	100.00	100.00	100.00

[a] Columns may not add to totals because of rounding.

TABLE B.10 Austrian imports in 1970 and scenario results for 2015 (percentage of total).[a]

Sector	1970	2015			
		S1	S2	S3	S4
Agriculture and forestry	5.92	3.41	3.01	3.63	3.63
Mining	3.60	1.97	2.32	2.22	2.22
Petroleum and natural gas	6.33	3.91	3.51	4.04	4.03
Stone, clay, cement	1.44	1.61	1.51	1.61	1.61
Glass	0.70	0.92	0.79	0.98	0.97
Food	5.13	4.08	3.75	4.14	4.14
Tobacco	0.07	0.03	0.02	0.03	0.03
Textiles	7.58	10.95	13.08	9.74	9.76
Clothes	1.15	4.90	4.86	4.69	4.69
Leather	1.42	1.63	1.47	1.68	1.67
Chemicals	11.36	10.70	9.97	10.76	10.76
Iron and steel	4.57	8.61	11.90	7.08	7.10
Machinery	13.34	11.82	10.91	11.96	11.95
Casting	0.39	0.37	0.35	0.37	0.37
Nonferrous metals	3.90	2.13	1.67	2.44	2.43
Iron and metal products	5.88	6.40	5.90	6.49	6.49
Electrical mach. and equip.	7.65	8.35	8.45	9.54	9.54
Vehicles	10.36	9.56	8.84	9.66	9.65
Saw mills	0.42	0.51	0.48	0.51	0.51
Wood products	1.81	2.48	2.35	2.46	2.46
Pulp, paper, plywood	1.05	1.73	1.51	1.83	1.83
Paper products	1.70	1.83	1.71	1.83	1.83
Construction industry	0.14	0.06	0.05	0.07	0.07
Electricity, gas, and water	0.23	0.28	0.27	0.28	0.28
Trade and leasing	1.14	0.52	0.40	0.58	0.58
Transportation and communication	0.04	0.02	0.01	0.02	0.02
Banking and insurance	0.64	0.29	0.22	0.33	0.33
Hotels and restaurants	0.01	0.00	0.00	0.00	0.00
Other services	1.98	0.88	0.67	0.99	0.99
Housing	0.00	0.00	0.00	0.00	0.00
Public administration	0.07	0.03	0.02	0.04	0.04
TOTAL	100.00	100.00	100.00	100.00	100.00

[a] Columns may not add to totals because of rounding.

Appendix C

THE INTERMEDIATE SECTORS OF THE AUSTRIA II MODEL

An aggregation was made in order to find the correlation between the intermediate sectors of the AUSTRIA II model and the energy balance published annually by the Austrian Central Statistical Office. The energy balance has 43 production sectors which can, in general, be defined in terms of 2-digit sectors of the 1968 classification scheme of economic activities (Betriebssystematik 1968).

There were differences with respect to the following 3-digit and 4-digit sectors:

Products from coal and asphalt	462
Magnesium products	4722

and

Mining of gypsum	262
Mining of peat	268
Upholstery	382
Raw leather	3432

The first group of differences occurs also in the energy balance; the second group of differences are not important because their specific energy consumption as well as their activity levels are small.

TABLE C.1 Aggregation of the intermediate sectors of the AUSTRIA II model for the energy demand calculations.

		Austrian classification of economic activities (Betriebssystematik) 1968		
Sector	AUSTRIA II	2-digit	Minus	Plus
1 Agriculture and forestry	1	01,02		
2 Mining	2	21,22,24–26	262,268	4722
3 Petroleum and natural gas	3	23,46	462	
4 Primary metals	12,14,15	51		
5 Stone, clay, cement	4	27,47	4722	262
6 Glass	5	48		
7 Chemicals	11	44,45		268,462
8 Paper and paper products	21,22	41–43		
9 Wood products	19,20	37–39	382	
10 Food and tobacco	6,7	31,32		
11 Leather and leather products	10	35,36		3432
12 Textiles	8	33		
13 Clothes	9	34	3432	382
14 Machinery/metal products/ vehicles	13,16,18	52–55,58,59		
15 Electrical mach. and equip.	17	56,57		
16 Construction industry	23	61–63		
17 Electricity, gas, and water supply	24	11–14		
18 Trade	25	71–76		
19 Transportation and communication	26	81–85,88,77		
20 Banking and insurance	27	91,92		
21 Hotels and restaurants	28	78		
22 Other services	29–31	93–98		

TABLE C.2 Definition of the intermediate sectors of the AUSTRIA II model.

	Austrian classification of economic activities (Betriebssystematik) 1968		
AUSTRIA II sectors	2-digit	Minus	Plus
Agriculture and forestry	01,02		
Mining	21,22,24–26	262,268	4722
Petroleum and natural gas	23,46	462	
Stone, clay, cement	27,47	4722	262
Glass	48		
Food	31,32	328	
Tobacco			328
Textiles	33		
Clothes	34	3432	382
Leather	35,36		3432
Chemicals	44,45		268,462
Iron and steel	51	512,513	
Machinery	52,54,55	521	581,582
Casting			513
Nonferrous metals			512
Iron and metal products	53,59		521
Electrical machinery and equipment	56,57		
Vehicle construction and repair	58	581,582	
Saw mills			371
Wood products			
Pulp, paper, plywood			411
Paper products, printing, publishing	41–43	411	
Construction industry	61–63		
Electricity, gas, and water	11–14		
Trade and leasing	71–76		
Transportation and communication	81–85,88,77		
Banking and insurance	91,92		
Hotels and restaurants	78		
Other services	93–97,99		986,987
Housing[a]			
Public administration	98	986,987	

[a] Includes rented and privately owned buildings.

TABLE C.3 Assumptions about the evolution of energy intensiveness of the intermediate sectors of the AUSTRIA II model.

	Energy intensiveness		Change factor, 1974–2000			
Sector	1970 (kcal/AS$_{70}$[a])	1974 (kcal/AS$_{70}$[a])	S1	S2	S3	S4
1 Agriculture and forestry	370	366	1.0	1.2	1.0	0.8
2 Mining	1,187	1,249	1.1	1.3	1.1	0.9
3 Petroleum and natural gas	497	934	1.2	1.3	1.2	0.7
4 Primary metals	1,886	1,700	0.8	0.9	0.8	0.75
5 Stone, clay, cement	1,150	1,174	0.9	1.1	0.9	0.7
6 Glass	909	982	0.9	1.1	0.9	0.8
7 Chemicals	517	632	0.9	1.1	0.9	0.7
8 Paper and paper products	851	831	0.9	1.0	0.9	0.8
9 Wood products	156	193	1.0	1.2	1.0	0.8
10 Food and tobacco	220	205	0.9	1.1	0.9	0.8
11 Leather and leather products	79	80	1.0	1.2	1.0	0.8
12 Textiles	415	306	0.9	1.1	0.9	0.7
13 Clothes	92	88	0.9	1.1	0.9	0.7
14 Machinery/metal products/vehicles	139	144	0.9	1.0	0.9	0.8
15 Electrical machinery and equipment	84	110	1.0	1.1	1.0	0.8
16 Construction	111	108	0.9	1.1	0.9	0.8
17 Electricity, gas, and water supply	28	24	0.9	1.0	0.9	0.7
18 Trade	45	93	1.1	1.2	1.1	0.8
19 Transportation and communication	866	819	0.77	1.04	0.74	0.59
20 Banking and insurance	37	29	0.8	1.0	0.8	0.6
21 Hotels and restaurants	186	493	1.0	1.1	1.0	0.6
22 Other services	98	85	0.9	1.0	0.9	0.8
Fraction of potential change assumed to be exhausted by year 2000			0.8	0.9	0.85	0.95

[a] Austrian schillings at 1970 values.

Appendix D

FUNCTIONAL REGIONS IN AUSTRIA[a]

Core	Ring 1	Ring 2
Vienna	Bruck a.d. Leitha	Krems a.d. Donau (*St*)
	Gaenserndorf	Baden
	Korneuburg	Gmuend
	Moedling	Hollabrunn
	Tulln	Horn
	Vienna (*U*)	Krems a.d. Donau (*L*)
		Mistelbach a.d. Zaya
		Waidhofen a.d. Thaya
		Zwettl
		Eisenstadt (*St* & *U*) and Rust
		Neusiedel am See
Klagenfurt	Klagenfurt (*L*)	St. Veit a.d. Glan
		Voelkermarkt
		Wolfberg
Villach	Villach (*L*)	Hermagor
		Spittal a.d. Drau
		Lienz
St. Poelten	St. Poelten (*L*)	Lilienfeld
		Melk
		Scheibbs
Wiener Neustadt	Wiener Neustadt (*L*)	Neunkirchen
		Mattersburg
		Oberpullendorf

APPENDIX D *Continued.*

Core	Ring 1	Ring 2
Linz	Eferding Linz (*L*) Perf Urfahr (*U*)	Freistadt Rohrbach Schaerding
Steyr	Steyr (*L*)	Kirchdorf a.d. Krems Waidhofen a.d. Ybbs (*St*) Amstetten
Wels	Wels (*L*)	Gmunden Grieskirchen
Salzburg	Salzburg (*U*)	Hallein St. Johann i. Pg. Zell am See Braunau a. Inn Ried i. Innkreis Voecklabruck
Graz	Graz (*U*)	Deutschlandsberg Feldbach Fuerstenfeld Hartberg Leibnitz Radkersburg Voitsberg Weiz Guessing Jennersdorf Oberwart
Bruck	Leoben	Judenburg Knittelfeld Liezen Muerzzuschlag Murau Tamsweg

Core	Ring 1	Ring 2
Innsbruck	Innsbruck (*L*)	Imst Kitzbuehel Kufstein Landeck Reutte Schwaz
Bregenz	Bludenz	Dornbirn and Feldkirch

[a] *St* after a location means city proper (*Stadt*); *U* and *L* mean the environs of a city (*Umgebung* and *Land*).

Appendix E

AUSTRIAN POPULATION DATA FOR 1971–2015 USED FOR SCENARIOS S1–S4

These projections are based on data supplied by the Austrian Institute of Regional and Urban Planning and are used for additional demographic analysis.

TABLE E.1 Population projections, 1971–2015, growth case.

Region	Population (10^3)			Average change/ yr (%)	Rural population (%)			Average change/ yr (%)
	1971	1990	2015		1971	1990	2015	
Burgenland	272	260	250	-0.19	65	63	61	-0.14
Carinthia	526	551	605	0.32	42	39	34	-0.48
Lower Austria	1,414	1,388	1,398	-0.03	56	52	47	-0.40
Upper Austria	1,223	1,327	1,541	0.53	46	42	37	-0.49
Salzburg	402	475	601	0.92	43	36	29	-0.89
Styria	1,192	1,223	1,297	0.19	47	45	41	-0.31
Tyrol	541	636	817	0.94	53	45	35	-0.94
Vorarlberg	271	335	449	1.15	42	34	26	-1.08
Vienna	1,615	1,467	1,302	-0.49	0	0	0	
Austria	7,456	7,662	8,260	0.23	39	36	33	-0.38

TABLE E.2 Average household size in Austria, 1971–2015, growth case.

Region	No. of persons per household			Average change/ yr (%)	No. of persons per household in rural areas			Average change/ yr (%)
	1971	1990	2015		1971	1990	2015	
Burgenland	3.43	3.34	3.06	-0.26	3.52	3.26	3.04	-0.33
Carinthia	3.09	2.93	2.76	-0.26	3.91	3.75	3.45	-0.28
Lower Austria	2.86	2.71	3.53	-0.28	3.16	2.99	2.79	-0.28
Upper Austria	2.95	2.81	2.65	-0.24	3.55	3.37	3.12	-0.29
Salzburg	2.92	2.84	2.67	-0.20	3.64	3.42	3.17	-0.31
Styria	3.02	2.87	2.68	-0.27	3.62	3.43	3.19	-0.29
Tyrol	3.11	2.99	2.84	-0.21	3.75	3.57	3.32	-0.28
Vorarlberg	3.39	3.19	2.98	-0.29	3.48	3.29	3.03	-0.31
Vienna	2.20	2.07	1.92	-0.31	–	–	–	–
Austria	2.66	2.58	2.47	-0.17	3.49	3.31	3.08	-0.28

TABLE E.3 Population projections, 1971–2015, decline case.[a]

Region	Total population (10^3)			Average change/ yr (%)	Rural population (%)			Average change/ yr (%)
	1971	1990	2015		1971	1990	2015	
Burgenland	272	247	212	-0.56	65	61	54	-0.42
Carinthia	525	526	518	0.30	42	40	36	-0.35
Lower Austria	1,414	1,308	1,164	-0.44	56	52	47	-0.40
Upper Austria	1,223	1,266	1,335	0.20	46	44	41	-0.26
Salzburg	402	456	526	0.61	43	38	33	-0.60
Styria	1,192	1,170	1,133	-0.12	47	45	42	-0.26
Tyrol	541	613	718	0.65	53	47	40	-0.64
Vorarlberg	271	321	387	0.81	42	36	30	-0.76
Vienna	1,615	1,440	1,248	-0.58	0	0	0	
Austria	7,456	7,347	7,241	-0.07	39	37	34	-0.31

[a] Only the growth case projections were used in the scenarios; see p. 17.

TABLE E.4 Average household size in Austria, 1971–2015, decline case.[a]

Region	No. of persons per household			Average change/ yr (%)	No. of persons per household in rural areas			Average change/ yr (%)
	1971	1990	2015		1971	1990	2015	
Burgenland	3.43	3.43	3.03	-0.28	3.52	3.26	3.03	-0.34
Carinthia	3.09	2.94	2.72	-0.29	3.91	3.71	3.50	-0.25
Lower Austria	2.86	2.71	2.53	-0.28	3.16	2.99	2.78	-0.29
Upper Austria	2.95	2.65	2.62	-0.27	3.55	3.36	3.11	-0.30
Salzburg	2.92	2.82	2.65	-0.22	3.64	3.42	3.17	-0.31
Styria	3.02	2.86	2.67	-0.28	3.62	3.45	3.22	-0.27
Tyrol	3.11	2.97	2.82	-0.22	3.75	3.57	3.32	-0.28
Vorarlberg	3.39	3.22	2.99	-0.28	3.48	3.29	3.03	-0.31
Vienna	2.20	2.07	1.92	-0.31	–	–	–	–
Austria	2.66	2.56	2.43	-0.21	3.49	3.26	3.10	-0.27

[a] Only the growth case projections were used in the scenarios; see p. 17.

Appendix F

ENERGY DATA FOR AUSTRIA, 1971–2015

TABLE F.1 Total end-use energy demand by sector (10^{12} kcal)[a].

	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%)	9.5 (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%)	49.5 (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 and communication	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	259.3	187.0	217.8

[a] Columns may not add to totals because of rounding.

TABLE F.2 Primary energy demand by source (10^{12} kcal)[a].

	All four scenarios	S1		S2		S3		S4	
	1971	1990	2015	1990	2015	1990	2015	1990	2015
Hard coal[b]	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 (47.8%)	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[c]	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

[a] Columns may not add to totals because of rounding.
[b] Including coke.
[c] Conversion factor: 1 GWh = 1.08 Tcal.

Appendix G

ASSUMPTIONS FOR THE RESIDENTIAL SECTOR SCENARIOS

ASSUMPTIONS THAT REMAIN CONSTANT IN THE RESIDENTIAL SECTOR SCENARIOS

Projection of Number and Type of Inhabited Homes

Major determinants of residential energy consumption are the number of occupied housing units, the ratio of single-family houses to apartments, and the average size of housing units. Second units and unoccupied units have not been included in the calculations.

Population projections are based on projections made by the Austrian Institute of Regional and Urban Planning (Sauberer *et al.*, 1976). The average family size is assumed to decline by a factor of 0.997/yr from 2.94 in 1971 to 2.77 in 1990 and to 2.57 in 2015. Because of the decline in family size, the floor space per capita increases.

Over the time frame of the scenarios, both total population and the total number of housing units show relative stability. The latter increase from 2.43 million in 1971 to 3.20 million in 2015. Concurrently, the total population increases from 7.46 million in 1971 to 8.26 million in 2015. By 2015, 46% of the housing stock consists of post-1971 construction. Single-family units account for approximately 44% of the total housing stock in 1971, and for 41% by the year 2015.

Because of the relatively small number of housing units added to the existing housing stock each simulation year, changes in overall residential fuel mix and insulation levels proceed slowly. More rapid changes require retrofitting of old units – that is, housing constructed before 1971.

Choice of Fuel and Base Appliances

Other major determinants of residential energy consumption are the type of space and water heating appliance and the fuels chosen. It is assumed that the trend toward a more convenient lifestyle is a dominant consumer response in the residential sector in all four scenarios. Convenient, easily controlled space heating units are adopted as are hot water facilities, such as showers and baths.

The fuel mix for space heating has shown strong shifts in the recent past, according to Austrian Census data (OeStZ, 1969; 1971d; 1972; 1973; 1974; 1975d; 1977a). In 1969, about 83% of the Austrian housing units were heated with coal or wood (coal 61% and wood 22%) mostly in combination with single ovens. Oil was used by 10% of all units. By 1977, the fraction of units using solid fuels dropped to 46% (coal 29% and wood 17%). Concurrently, the use of oil increased to 26% of all units. On the basis of these trends, it is assumed that the use of coal will be nearly phased out by the year 2000; wood, however, will maintain its importance in rural areas, because of its availability and low cost. Convenient fuels – e.g., oil, gas, electricity and district heat – will continually gain in importance in the housing sector as a whole. The following figure shows the percent of housing units using each fuel for space heating in the scenarios. The historical values for 1969 to 1977, as given by the Microcensuses, are included in Figure G.1.

Interlinked with the shift toward convenient fuels during the scenario time frame is the trend toward convenient space heating appliances. In 1969, 90% of all housing

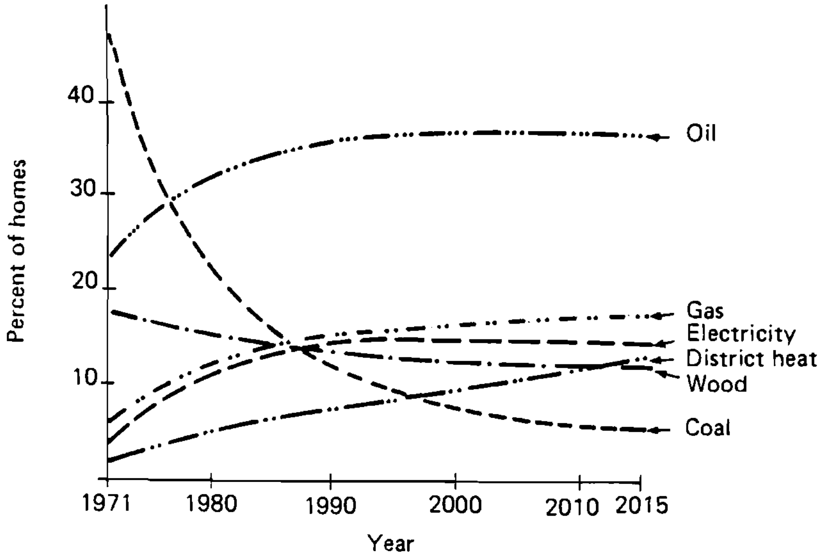


FIGURE G.1 Fuel mix: historical trends and model simulations in the residential sector, 1977–2015.

units were heated with single ovens and 10% were centrally heated. In the scenarios, 46% of all homes are assumed to be fitted with central heating by 2000, and by 2015, 62%. ("Etagenheizungen" are included in the category of single ovens.) These trends toward central heating systems differ for single-family homes and apartments, new construction and retrofitted units.

Just as a trend toward convenient fuels and space heating appliances was assumed to occur in the scenarios, it is foreseen that housing units will be rapidly fitted with baths or showers. According to census data of 1961, only 29% of Austrian dwellings had a bath or a shower (OeStZ, 1961); by 1971, this fraction increased to 53% (OeStZ, 1971a); and by 1977, to 72% (OeStZ, 1977b). The actual number of units fitted with a bath or a shower approximately doubled between 1961 and 1971 and tripled between 1961 and 1977. In the scenarios, it is assumed that by 1990, nearly all housing units will be fitted with a bath or a shower. This will be achieved by retrofitting pre-1971 units and fitting 100% of post-1971 units with baths or showers. Convenient fuels such as electricity, gas, and oil are used for these hot water appliances.

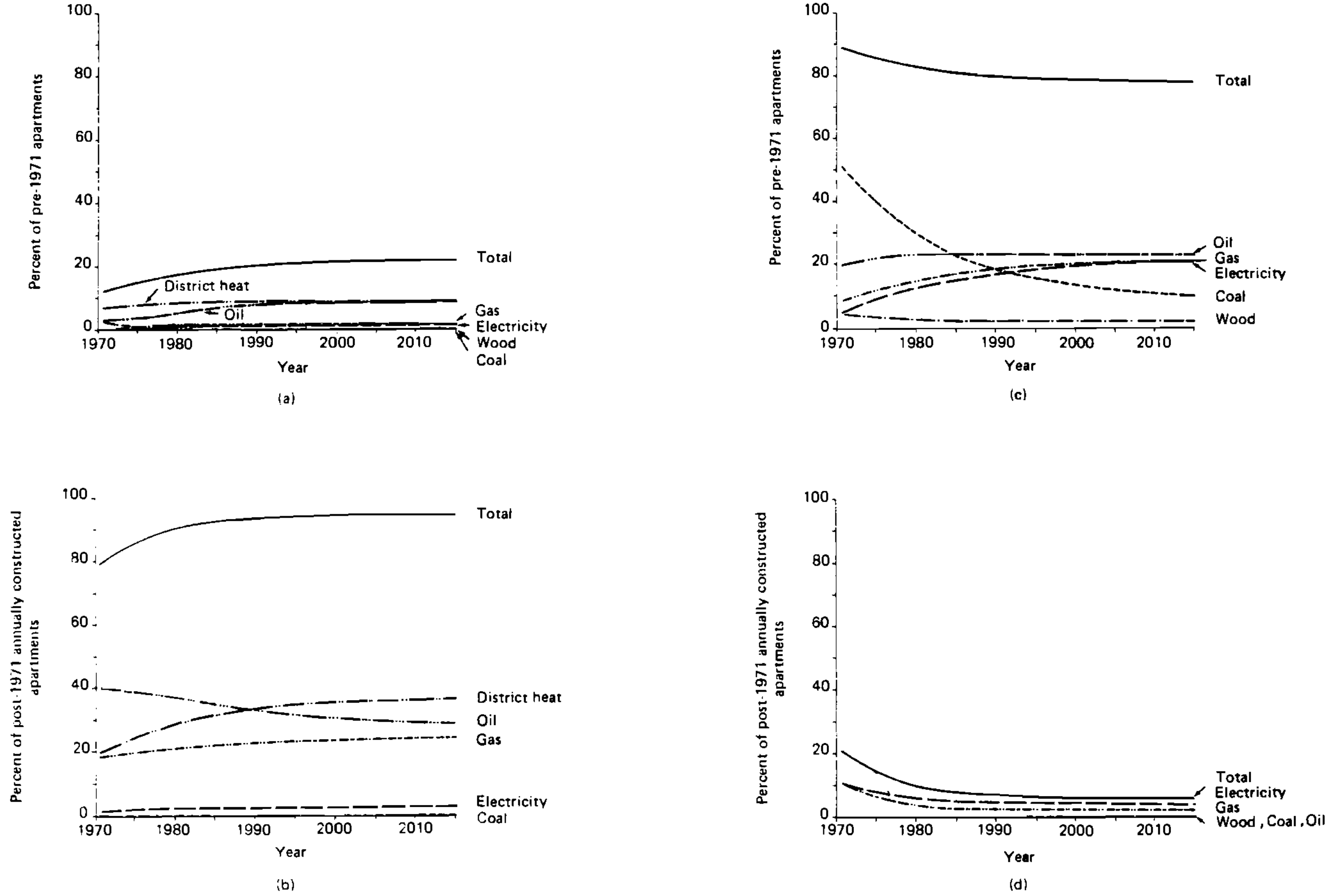
The change in fuel mix and appliance mix of the housing stock has two components: the retrofitting of pre-1971 units; and new construction. The type of fuel and, to a certain extent, the type of base appliances for single-family homes and apartments differ.

Retrofitting of pre-1971 apartments is difficult and costly. (In 1971, 91% had single ovens, two thirds of these using solid fuels (OeStZ, 1971d).) Here ownership patterns do not usually permit the united effort needed for retrofitting all units in an apartment block with central heating or district heat. Thus, fuel shifts occur for the most part without a change in the type of heating appliance, e.g., a coal single oven is most often replaced by an oil or a gas single oven. Owners of pre-1971 single-family units can show more initiative. Thus, a more rapid shift toward convenient appliances is assumed for this component of the housing stock.

The following figures show the changes in fuel mix and base appliances over time in relation to the housing type (pre-1971 single-family units, pre-1971 apartments, post-1971 single-family units and post-1971 apartments). The probability that a housing unit of a given type will be fitted with central heating is shown by the top curve in Figures G.2a, G.2b, G.2e, and G.2f. The six additional curves in these figures show the probability that these units use electricity, gas, oil, coal, or wood to fuel their central heating units. The probability that a home of a given type will have a single oven is similarly shown by the top curve in Figures G.2c, G.2d, G.2g, and G.2h. The six additional curves show the probability that these homes use electricity, gas, oil, coal, wood, or district heat to fuel their single ovens.

As Figures G.2a–G.2h show, in the scenarios new single-family units are fitted to a large percentage with convenient fuels and base appliances. The use of wood is continued, mostly in rural areas and always in connection with central heating.

In the scenarios, it is assumed that new apartments are also fitted with convenient fuels and base appliances. Here, emphasis is on district heat and gas.


Percent of pre-1971 apartments
100
80
60
40
20
0
1970
1980
1990
2000
2010
Year
Total
District heat
Oil
Gas
Electricity
Wood
Coal
Percent of post-1971 annually constructed apartments
District heat
Oil
Gas
Electricity
Coal
Percent of pre-1971 apartments
Total
Oil
Gas
Electricity
Coal
Wood
Percent of post-1971 annually constructed apartments
Total
Electricity
Gas
Wood, Coal, Oil

(a)

(b)

(c)

(d)

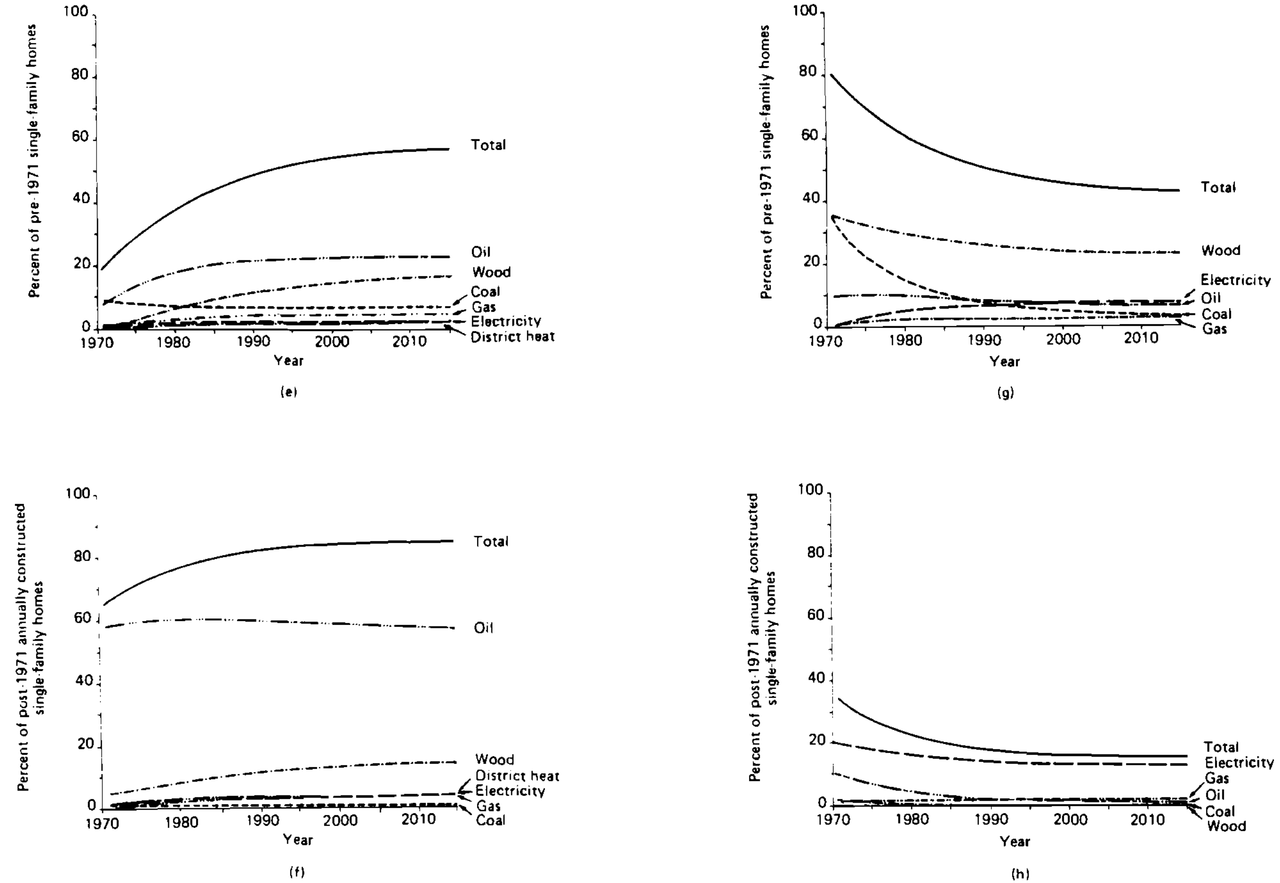


FIGURE G.2 Changes of fuel mix for base appliances by housing type over time frame of the scenarios. (a) Central heating; (b) central heating; (c) single-oven heating; (d) single-oven heating; (e) central heating; (f) central heating; (g) single-oven heating; (h) single-oven heating.

Space Heating Habits

The choice of the heating fuel and heating system influences room heating habits. An important assumption in this context is that units with coal- or wood-fired single ovens (approximately two thirds of all units in the year 1971 (OeStZ, 1971d) heat only one half of their floor space at any one time; on the other hand, units using convenient fuels and/or space heating appliances are assumed to have their entire floor space heated. Because post-1971 units are not fitted with single ovens using solid fuels, the amount of heated floor space per capita increases even more steeply than the construction of bigger new homes and declining family size suggest.

ASSUMPTIONS THAT VARY IN THE RESIDENTIAL SECTOR SCENARIOS

Lifestyle

SIZE OF NEW CONSTRUCTION

It has been assumed that an important variable reflecting lifestyle in connection with new construction is the size of annually constructed units.

The floor area of new construction is related to economic growth trends and, in all scenarios, increasing floor space per capita is assumed. However, the speed of this trend differs by scenario. The average size of a pre-1971 (old) housing unit is, according to Austrian census data, 66 m^2 (apartments = 53 m^2, single-family homes = 83 m^2). The average size of units built between 1961 and 1971 is 77 m^2 (OeStZ, 1961; 1971d). The average size of units constructed in 1971 was 82 m^2, apartments being on the average 67 m^2, single-family homes 105 m^2. In the scenarios, the floor area for new construction (starting from 1971 values) is assumed to increase annually by 0.8 m^2/yr until 2000 for the Base Case (S1), 1.0 m^2/yr until 2000 for the High Case (S2), and 0.4 m^2/yr for the Low Case (S3) and for the Conservation Case (S4).

ENERGY USE

For S1, S3, and S4, it is assumed that public attitudes toward energy use do not change in connection with space and water heat. The assumed annual average heating hours per home of 1,500 hours and the assumed water consumption of 40 liters per capita per day remain the same. For scenario S2, assumptions have been introduced for less restrained energy use. The heating hours increase 40% until the year 2000 and the hot water use increases from 40 liters per capita per day to 70 liters per capita per day.

HOUSEHOLD APPLIANCES

Saturation curves define appliance levels per home for a set of 14 appliances (washing machines, cooking stoves, televisions, etc.). The level and rate of saturation for each appliance is related to the growth of GNP. The energy consumption per appliance per housing unit is held constant over the simulation period, but the decreasing household size implies increased appliance use per capita. For S1, saturation levels are reached by about the year 2000; for S2, higher saturation levels are reached by about the year 1990; for S3 and S4, the same saturation levels as S1 are reached by about 2015. Figure G.3 shows the saturation curves of 14 household appliances in scenario S4. It should be noted that the data available for appliance use is "soft". As a basis for the starting values of appliance ownership, microcensus data has been used (OeStZ, 1975a,b,c). Starting values and saturation values – yearly average energy use per appliance – are shown in Table G.1.

Technological Changes

There are two complementary ways of reducing energy requirements for heating: behavioral measures which encourage energy conservation in space heating, such as individual unit heating controls; and technical measures which do not affect behavior, such as decreasing heat loss through building ceilings and walls and/or improved heating system efficiency. In the scenarios only technical measures have been considered.

HEAT LOSSES

There is general agreement that the heat loss of an average Austrian housing unit can be reduced by 50% to 60% of the present level, provided that an efficient insulation policy is applied (Oesterr. Institut f. Bauforschung, 1976). Data on heat loss and heating hours are "soft". This analysis assumes the values shown in Table G.2. The average annual heat losses for the pre-1971 units and for construction beginning in 1971 are assumed to be the same. In older units, high ceilings and poor window construction account for the high heat losses. In newer units, thin walls and large windows are responsible for the high heat losses.

The assumed 1971 average heat loss figures for existing units as well as those for newly constructed units are retained for S1 and for S2. For S3 and S4 heat losses for newly constructed units are decreased stepwise to 60% of the 1971 levels by 2000 for S3, and to 45% of 1971 levels by 2000 for S4. Retrofitting gradually reduces the average heat loss of pre-1971 housing stock by 15% for S3 and by 20% for S4.

HEATING SYSTEM EFFICIENCIES

The model calculations use matrices containing information about heating system efficiencies for various combinations of heating appliances, the fuel used and the housing

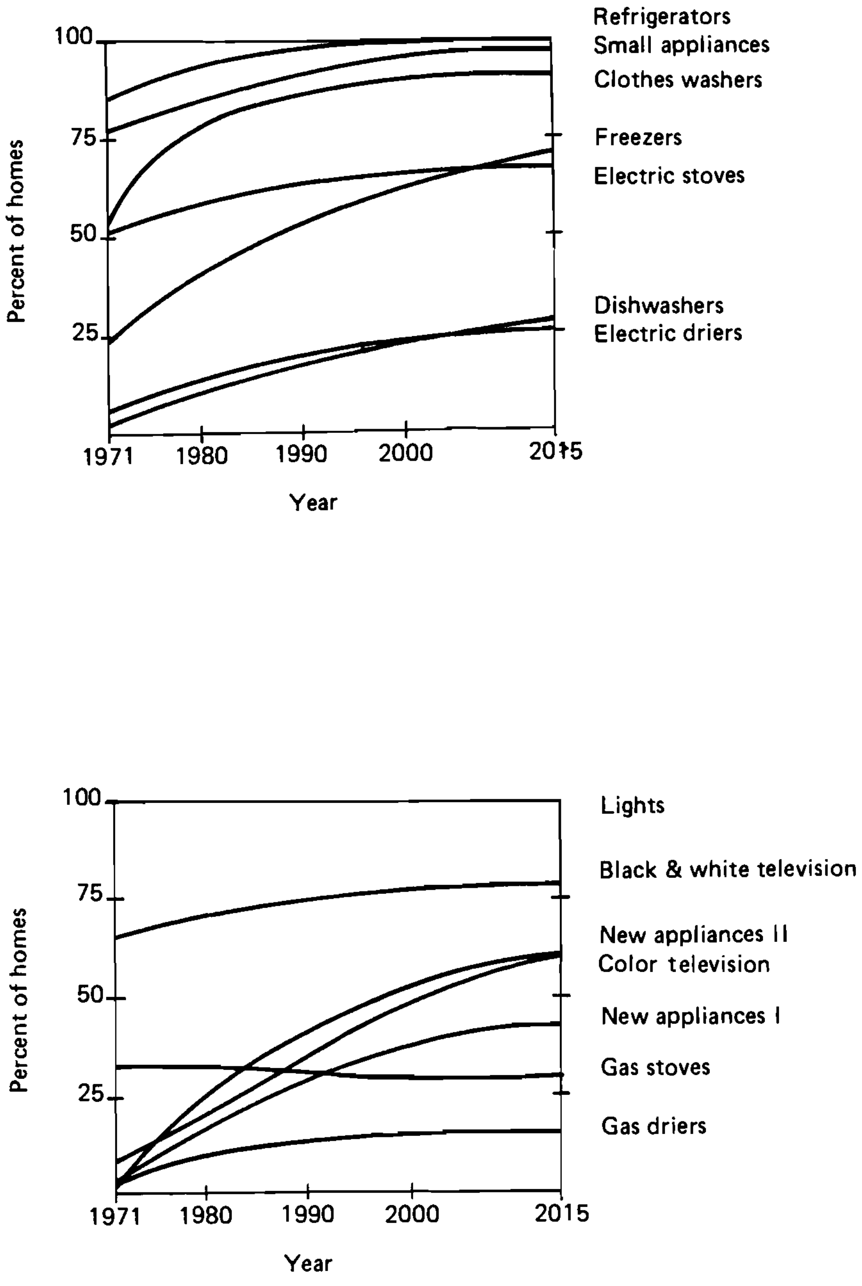


FIGURE G.3 Saturation curves for household secondary appliances, S4.

TABLE G.1 Initial and final ownership fractions and energy use of secondary appliances in the Austrian residential scenarios.[a]

	Ownership fraction, all scenarios 1971	Use[b] (10^6 kcal/yr)	Ownership fractions 2015		
			S1	S2	S3
Refrigerators	0.89	0.22	0.99	1.00	0.99
Freezers	0.24	0.43	0.70	0.87	0.70
Dishwashers	0.05	0.65	0.50	0.86	0.29
Clothes washers	0.52	0.34	0.94	1.00	0.90
Electric stoves	0.51	0.43	0.67	0.69	0.67
Electric driers	0.06	0.60	0.26	0.29	0.26
Black and white television sets	0.63	0.03	0.26	0.22	0.78
Color television sets	0.10	0.12	0.88	0.96	0.61
Small appliances	0.76	0.26	0.97	0.99	0.97
Lights	0.99	0.13	1.00	1.00	1.00
New appliances 1	0.03	0.17	0.61	0.96	0.61
New appliances 2	0.02	0.17	0.44	0.48	0.44
Gas stoves	0.34	1.1	0.30	0.30	0.30
Gas driers	0.04	0.7	0.16	0.16	0.16

			2015		
	1971		S1	S2	S3
Total energy use (10^9 kcal/yr)	3,690		8,610	10,090	8,200
Use per capita (10^3 kcal/yr)	494		1,042	1,221	992

[a] Columns may not add to totals because of rounding.

[b] For all scenarios energy use remains constant over the time frame of the simulation.

type. The efficiencies for 120 different combinations can be changed independently for each simulation year. (The 120 combinations are as follows: eight housing types – urban single-family units, pre- and post-1971; rural single-family units, pre- and post-1971; urban apartments, pre- and post-1971; rural apartments, pre- and post-1971 – times three base appliances – single ovens, central heating systems, and hot water appliances – times five fuels – electricity, gas, oil, coal, or wood.) Especially in this area, the available data is "soft" and limited. To allow an assessment of a policy pointing in this direction, it has been assumed that from 1980 onwards, up to 1990, a stepwise improvement of about 5% of the average yearly efficiencies will take place for scenario S3 and 10% for the same time period for S4.

TABLE G.2 Initial data on heat losses, Austria, 1971.

Home type	Time of construction	Average annual heat loss kcal/m^2/h	Components of change
Single-family homes	Old (pre-1971)	120	Demolition; retrofitting of remainder
	"New homes" constructed in 1971	120	Improvement for annually constructed homes
Apartments	Old (pre-1971)	90	Demolition; retrofitting of remainder
	"New homes" constructed in 1971	90	Improvement for annually constructed homes

SOURCE: Personal communication. E. Panzhauser, Institut fuer Hochbau und Entwerfen I, Technische Universitaet, Vienna.

Unconventional Energy Sources

Scenarios S1, S2, and S3 assume the continuation of current technologies and energy sources. A sensitivity study for S4 assumes the significant use of alternative technologies and energy sources (heat pumps, solar energy, etc.) for single-family units.

Appendix H

ANALYSIS OF PRODUCT MIX, AUSTRIA, 1964–1973*

The analysis is based on data for the 1964 index of industry production. Data are available for the years 1964 to 1973; starting in 1971, a new production index was introduced. These index schemes are used to determine the real growth in net production of the industry branches.

The major product categories distinguished in the 1964 index scheme are the following:

Mining products and magnesium (Bergbauprodukte und Magnesit)
Basic industry products (Grundstoffe)
Electricity (Elektrizitaet)
Initial products (Vorprodukte)
Building materials (Baustoffe)
Finished investment goods (Fertige Investitionsgueter)
Food and luxury foodstuffs (Nahrungs- u. Genussmittel)
Apparel (Bekleidung)
Consumer goods (Verbrauchsgueter)
Durable consumer goods (Langlebige Konsumgueter)

The distribution of net production among these product categories is shown in Figure H.1 for those industry branches that are not homogeneous with respect to this classification. The results of a comparison of product mix changes and of changes in energy intensiveness are summarized below.

1. Those sectors that show a significant and uniform shift in the product mix from basic industry products to consumer goods (paper production) or from finished investment goods to durable consumer goods (transportation

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*The analysis was made at the suggestion of K. Bayer, WIFO. We wish to express our gratitude to the WIFO for supplying the data for this analysis.

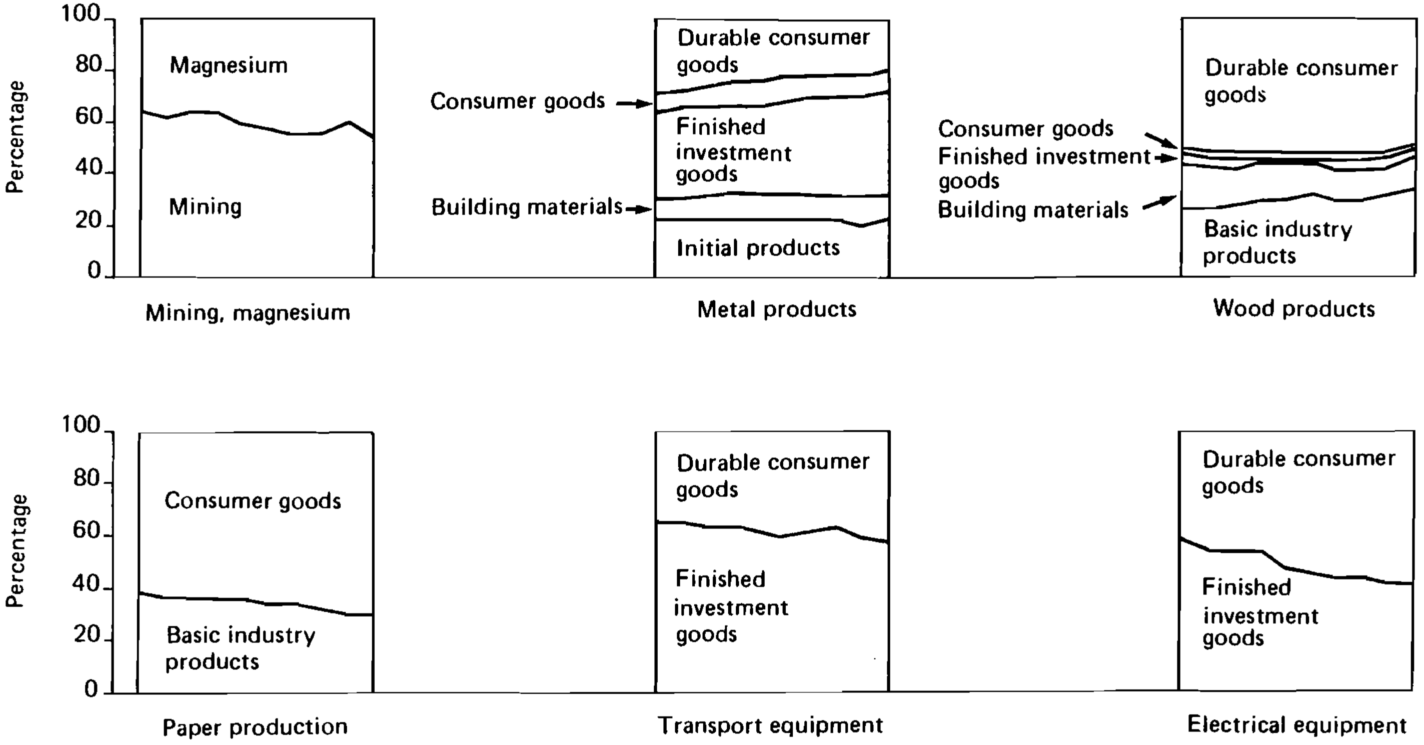

FIGURE H.1 Distribution of net production within industry branches, 1964–1973.

machinery and equipment, and electrical machinery and equipment) experienced a decline in their energy intensiveness.

2. In those sectors that showed a reverse shift from durable consumer goods to finished investment goods (fabricated metal products) or from building materials to basic industry products (wood products) one can observe a slight increase in energy intensiveness.

The results of the analysis indicate that the energy demand projections for industry could be improved by considering explicitly product mix changes within industry branches. Unfortunately, the analysis cannot be extended to the entire industrial sector because of lack of comparable data for the handicraft industry.

It should be stressed that the results obtained for the industrial sector are only indicative; a definite statement about possible energy savings will be possible only after a survey has been made of the technologies applied in the industry, the energy requirements of these technologies have been determined, and a comparison has been made of these data with either theoretical limits or reference figures found in countries with more advanced technologies.

Appendix I

ENERGY USES OF THE COMMERCIAL AND SERVICE SECTOR

A first step in breaking down energy demand in the commercial and service sector would be to separate the space heating component. According to the 1971 census of the housing stock in Austria, the floorspace in the nonresidential sectors amounts to approximately 50% of the residential floorspace. The floorspace within the nonresidential sector is roughly distributed as follows: one third industrial sector, two thirds commercial and service sector. Within this sector, the floorspace is almost equally divided among trade, public services, hotels and restaurants, and other activities. The nonresidential floorspace distribution by sector, by age, and by building type is shown in Figure I.1.

The breakdown of energy consumption of the U.S. commercial sector is shown in Table I.1. The definition of the commercial sector underlying this table corresponds to the definition of the commercial and service sector in the Austrian case study: it is defined as those activities that are not classified as mining, manufacturing, transportation, and residential. In the definition of end-use energy consumption, feedstocks (asphalt and road oils) are not included under the end-use energy grouping. Also, air conditioning is still negligible in Austria. Omitting these components in the 1968 distribution for the U.S., one arrives at a modified distribution that can be assumed to be close to the Austrian situation: space heating 63%, water heating 10%, refrigeration 10%, cooking 2%, other uses 15%. However, the component of specific uses of electricity seems higher in the U.S. than in Austria: refrigeration, lighting, and mechanical drives account for 25% of commercial end-use energy in the U.S. (after removing the feedstocks and air conditioning component), while the electricity fraction in the Austrian service sector is considerably lower: 13% in 1971, and 21% in 1980, according to scenario S1 (after removing the transportation component, i.e., gasoline and diesel consumption).

These considerations lead to the conclusion that in Austria space heating is almost as important a component of energy demand in the commercial and service sector as in the residential sector. Analyses concerning possible energy savings because

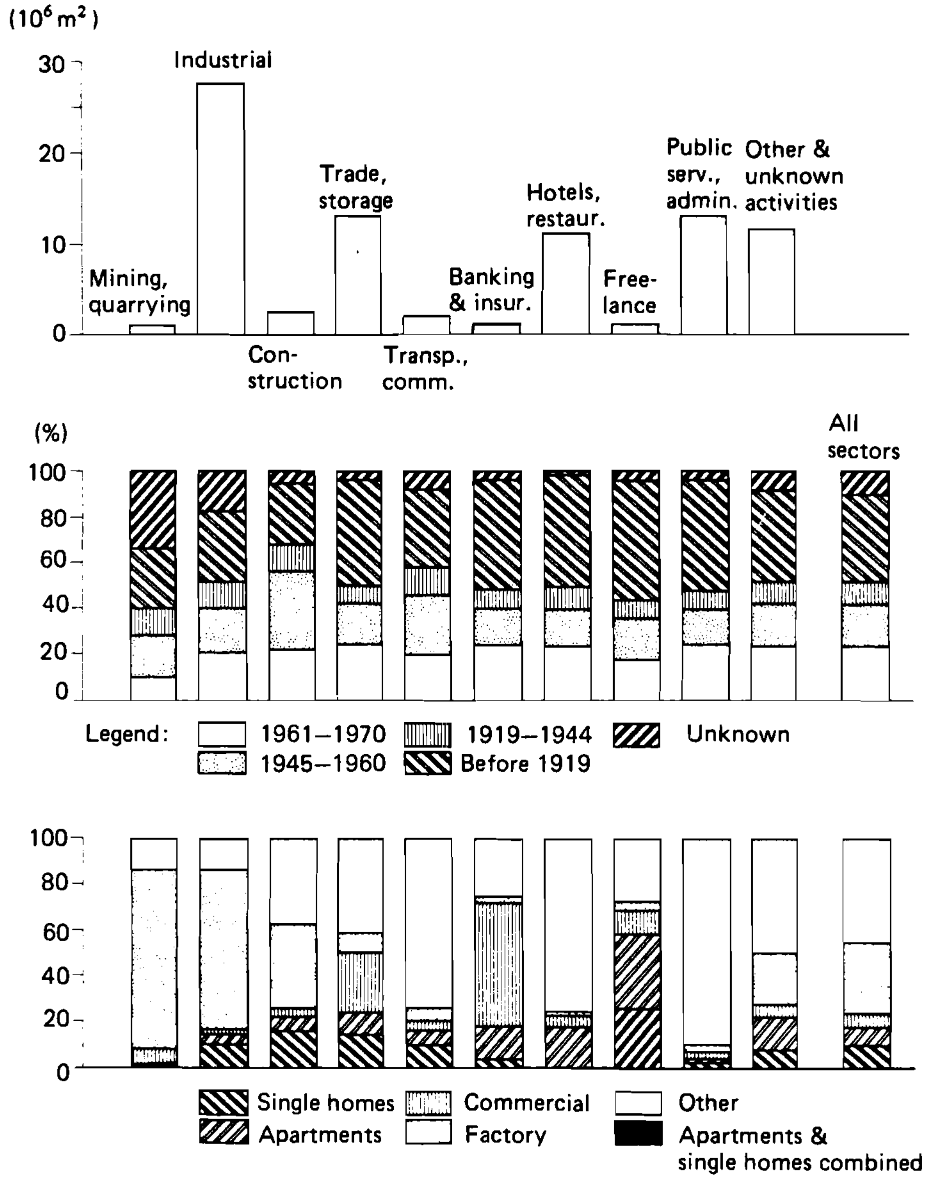

FIGURE I.1 Floorspace in Austria by sector, age, and building type.

TABLE I.1 Energy consumption in the U.S. commercial sector (percentage).

	1962	1968
Space heating	54.2	47.7
Asphalt and road oils	12.8	11.2
Water heating	9.5	7.5
Air conditioning	10.0	12.7
Refrigeration	9.3	7.6
Cooking	1.7	1.6
Other (lighting and mechanical drives, computers, elevators, escalators, office machinery, etc.)	2.5	11.7
TOTAL	100.0	100.0
% of total end-use	13.3	14.5

SOURCE: Stanford Research Institute (1972).

of better insulation can therefore be applied to the commercial and service sector as well. (Note that the data situation could be greatly improved by a combined survey or by a census on floorspace and equipment. Such a survey could provide the starting point for a model that calculates the energy demand in the commercial and service sector on the basis of physical characteristics, as has been done for the residential sector.)

Appendix J

COMPARISON OF HISTORICAL DATA AND MODEL RESULTS FOR FUEL MIX IN AUSTRIA, BY SECTOR, 1970–2015

TABLE J.1 Fuel mix data expressed as percentage of sectoral end-use energy. *M* denotes model results.

	Year	Elec.	H. coal	Coke	Lignite	Oil	Gases	Other	Gasoline
Agriculture and forestry									
	1970	5.7	0.0	0.0	1.2	0.0	0.0	52.5	5.3
	1975	7.3	0.0	0.0	0.7	0.0	0.0	45.3	6.7
M:	1975	8.1	0.0	0.0	0.6	0.0	0.0	42.5	7.3
M:	2015	10.0	0.0	0.0	0.5	0.0	0.0	40.0	7.5
Mining									
	1970	13.1	0.5	1.2	14.6	49.1	18.0	0.5	0.2
	1975	13.4	0.1	0.7	10.4	48.1	22.1	0.7	0.2
M:	1975	14.4	0.0	0.7	8.1	44.3	26.6	1.5	0.3
M:	2015	15.0	0.0	0.5	5.0	45.0	28.5	1.5	0.3
Primary metals									
	1970	9.8	0.0	0.0	0.0	13.1	75.9	0.0	0.3
	1975	13.4	0.0	0.0	0.0	6.1	79.7	0.0	0.1
M:	1975	12.9	0.0	0.0	0.0	1.5	84.9	0.0	0.1
M:	2015	13.0	0.0	0.0	0.0	1.0	85.4	0.1	0.1
Petroleum and natural gas									
	1970	14.7	0.6	42.5	1.8	19.1	18.9	0.0	0.0
	1975	17.4	0.3	45.6	0.7	18.8	16.9	0.0	0.1
M:	1975	15.3	0.6	45.1	1.8	18.2	18.8	0.0	0.1
M:	2015	16.1	0.6	49.8	1.2	15.4	16.6	0.0	0.1

TABLE J.1 *Continued.*

	Year	Elec.	H. coal	Coke	Lignite	Oil	Gases	Other	Gasoline
Stone, clay, cement									
	1970	8.7	5.1	2.4	2.7	60.6	16.0	0.1	0.5
	1975	10.1	2.0	0.4	0.5	54.8	25.7	0.1	0.6
M:	1975	11.9	3.6	2.4	1.7	50.5	23.8	0.1	0.6
M:	2015	12.5	1.5	2.2	0.5	35.2	38.3	0.1	1.0
Glass									
	1970	8.6	0.0	0.1	0.0	51.0	39.6	0.0	0.4
	1975	9.3	0.0	0.1	0.2	38.0	51.2	0.0	0.6
M:	1975	12.0	0.0	0.1	0.2	36.6	49.9	0.0	0.8
M:	2015	15.1	0.0	0.1	1.0	25.1	57.2	0.0	1.0
Chemicals									
	1970	30.8	0.3	4.4	4.4	41.5	14.3	0.4	3.3
	1975	27.1	0.0	1.8	0.2	18.8	48.6	1.6	0.7
M:	1975	25.9	0.2	1.6	1.3	17.6	49.8	1.7	0.9
M:	2015	23.5	0.1	1.4	1.0	5.0	65.0	2.5	0.5
Paper and paper products									
	1970	23.2	0.3	4.1	17.6	37.1	20.8	0.2	0.5
	1975	24.1	0.1	0.1	7.2	24.3	34.5	8.8	0.5
M:	1975	26.9	0.3	0.1	8.0	24.8	30.8	8.3	0.5
M:	2015	30.4	0.3	0.1	5.1	20.3	32.6	10.4	0.3
Wood products									
	1970	47.5	0.1	0.2	1.1	40.3	1.3	4.6	2.7
	1975	42.2	0.7	0.1	0.2	35.5	5.2	9.9	2.7
M:	1975	41.3	0.5	0.0	1.2	30.4	11.9	9.8	2.3
M:	2015	34.2	0.5	0.0	1.5	19.6	29.1	10.3	2.0
Food and tobacco									
	1970	22.5	0.3	1.5	1.8	56.9	12.5	0.2	1.8
	1975	22.9	0.1	1.8	0.5	54.6	13.8	0.5	2.2
M:	1975	23.5	0.2	1.4	1.2	51.6	15.0	0.3	2.6
M:	2015	25.2	0.2	1.4	1.3	45.5	17.7	0.8	3.0
Leather and leather products									
	1970	18.1	1.2	1.6	3.9	53.1	2.2	0.4	4.1
	1975	27.3	0.8	0.8	4.6	49.9	4.2	3.9	6.0
M:	1975	25.7	0.6	1.8	6.9	48.8	5.9	2.5	7.0
M:	2015	27.7	0.5	1.6	7.9	41.5	7.9	4.9	7.0

	Year	Elec.	H. coal	Coke	Lignite	Oil	Gases	Other	Gasoline
Textiles									
	1970	18.8	0.5	0.3	0.2	62.2	4.3	12.7	0.7
	1975	25.9	1.1	0.1	0.2	60.0	10.3	0.1	1.3
M:	1975	26.1	0.6	0.2	0.3	61.8	8.6	0.1	1.4
M:	2015	30.0	0.5	0.2	0.2	55.0	11.5	0.1	1.5
Clothes									
	1970	42.0	0.6	0.6	1.5	48.9	3.2	0.1	2.4
	1975	45.1	0.0	0.6	0.7	44.9	2.6	0.2	4.1
M:	1975	43.7	0.1	0.9	0.5	46.3	2.1	0.5	4.1
M:	2015	44.5	0.0	1.0	0.5	45.0	2.0	0.5	4.5
Machinery, metal products, vehicles									
	1970	32.5	0.6	1.4	1.3	41.5	16.4	0.1	3.9
	1975	32.4	0.2	0.8	1.4	31.4	24.8	0.6	4.5
M:	1975	31.3	0.0	0.7	1.4	32.0	27.1	0.4	3.8
M:	2015	27.1	0.0	0.5	1.0	23.6	39.9	0.9	3.0
Electrical machinery and equipment									
	1970	38.1	0.8	1.7	0.1	51.9	4.3	0.1	2.1
	1975	34.9	0.1	0.4	0.1	41.0	12.7	0.9	6.0
M:	1975	35.0	0.0	0.6	0.1	41.0	11.9	1.0	6.3
M:	2015	36.1	0.0	0.5	0.4	35.1	16.0	1.0	6.0
Construction									
	1970	4.3	0.0	0.0	0.0	44.1	0.0	0.2	4.2
	1975	5.6	0.0	0.0	0.0	35.8	0.0	0.2	5.5
M:	1975	5.9	0.0	0.0	0.0	33.5	0.0	0.1	4.8
M:	2015	8.9	0.0	0.0	0.0	28.1	0.0	0.1	5.0
Electricity, gas, water supply									
	1970	63.0	0.0	0.0	0.0	29.9	1.1	4.9	0.0
	1975	67.0	0.0	0.0	0.0	22.7	0.0	10.3	0.0
M:	1975	67.0	0.0	0.0	0.0	16.6	0.0	16.3	0.0
M:	2015	75.0	0.0	0.0	0.0	10.0	0.0	15.0	0.0
Trade									
	1970	3.3	1.2	10.2	3.8	62.1	0.8	1.0	4.0
	1975	14.8	1.3	4.3	1.6	35.8	6.1	0.6	17.9
M:	1975	16.1	1.6	4.2	1.5	30.9	7.5	0.6	18.7
M:	2015	20.0	2.0	4.0	1.5	22.0	10.0	0.5	20.0

TABLE J.1 *Continued.*

	Year	Elec.	H. coal	Coke	Lignite	Oil	Gases	Other	Gasoline
Transportation and communication									
	1970	5.8	11.8	1.8	4.2	3.1	0.1	0.1	34.0
	1975	6.4	1.8	0.7	0.3	2.5	0.2	0.6	40.0
M:	1975	7.4	3.4	0.5	0.4	2.5	0.4	0.3	38.3
M:	2015	9.9	2.0	0.0	0.0	2.0	0.1	0.0	36.1
Banking and insurance									
	1970	8.3	2.1	18.0	4.8	63.6	0.0	2.5	0.4
	1975	11.5	1.1	17.3	2.2	66.2	0.0	0.5	0.6
M:	1975	12.2	0.8	16.1	2.4	67.1	0.0	0.1	0.6
M:	2015	15.0	0.5	15.0	2.0	66.0	0.0	0.0	0.8
Hotels and restaurants									
	1970	3.6	1.0	9.0	3.4	60.8	4.8	5.2	2.6
	1975	16.2	2.2	3.5	2.4	61.9	7.0	2.5	2.8
M:	1975	13.2	1.9	3.7	3.2	62.7	8.0	2.4	3.2
M:	2015	17.0	2.0	3.0	2.0	60.0	10.0	2.0	3.0
Other services									
	1970	12.5	1.7	9.1	5.5	56.7	0.8	6.8	1.9
	1975	13.1	1.1	7.8	4.8	48.9	5.2	10.8	2.9
M:	1975	15.9	1.2	8.6	4.8	51.7	4.2	5.3	3.3
M:	2015	18.0	1.0	8.8	5.0	45.1	9.9	3.0	4.0

Appendix K

QUANTIFIED IMPACTS FOR SCENARIOS S1–S4

TABLE K.1 Selected quantified impacts for S1. The abbreviation PDL means person-days-lost; MT means metric tons.

	1971			1990			2015		
	Nonelec.	Elec.	Total	Nonelec.	Elec.	Total	Nonelec.	Elec.	Total
Annual fatalities	25	16	41	22	17	39	27	15	42
Occupational accidents (10^3 PDL per year)	142	93	235	126	104	230	159	101	260
Public accidents (10^3 PDL per year)	26	1	27	22	1	23	30	6	36
Occupational health (10^3 PDL per year)	81	61	142	63	68	131	76	69	145
Public health (10^3 PDL per year)	120	4	124	83	4	87	100	2	102
Total annual PDL (10^3)	369	159	528	294	177	471	365	178	543
Resource extraction land (km^2 per year)	10.0	5.7	15.7	12.6	5.8	18.4	17.2	5.3	22.5
Facilities land (km^2)	3.2	93	96.2	3.7	198	201.7	4.9	316	320
Radioactive waste (MT per year)	0	0	0	0	1.8	1.8	0	6.9	6.9
SO_2 emission (10^3 MT per year)	218	97	315	162	102	264	140	39	179
CO_2 emission (10^6 MT per year)	42	14	56	56	18	74	76	17	93

TABLE K.2 Selected quantified impacts for S2. The abbreviation PDL means person-days-lost; MT means metric tons.

	1971			1990			2015		
	Nonelec.	Elec.	Total	Nonelec.	Elec.	Total	Nonelec.	Elec.	Total
Annual fatalities	25	16	41	26	27	53	40	27	67
Occupational accidents (10^3 PDL per year)	142	93	235	152	162	314	243	175	418
Public accidents (10^3 PDL per year)	26	1	27	29	1	30	45	10	55
Occupational health (10^3 PDL per year)	81	61	142	76	107	183	115	122	237
Public health (10^3 PDL per year)	120	4	124	100	6	106	147	3	150
Total annual PDL (10^3)	369	159	528	357	276	633	550	310	860
Resource extraction land (km^2 per year)	10.0	5.7	15.7	15.2	8.3	23.5	27.0	9.0	36.0
Facilities land (km^2)	3.2	93	96	4.5	219	220	7.7	372	379.7
Radioactive waste (MT per year)	0	0	0	0	1.8	1.8	0	17.2	17.2
SO_2 emission (10^3 MT per year)	220	97	317	193	153	346	193	55	248
CO_2 emission (10^6 MT per year)	42	14	56	68	18	87	121	28	149

TABLE K.3 Selected quantified impacts for S3. The abbreviation PDL means person-days-lost; MT means metric tons.

	1971			1990			2015		
	Nonelec.	Elec.	Total	Nonelec.	Elec.	Total	Nonelec.	Elec.	Total
Annual fatalities	25	16	41	21	16	37	22	18	40
Occupational accidents (10^3 PDL per year)	142	93	235	122	99	221	131	113	244
Public accidents (10^3 PDL per year)	26	1	27	27	1	21	25	8	33
Occupational health (10^3 PDL per year)	81	61	142	62	65	127	63	72	135
Public health (10^3 PDL per year)	120	4	124	77	4	81	87	2	89
Total annual PDL (10^3)	369	159	528	288	169	450	306	195	501
Resource extraction land (km^2 per year)	10.0	5.7	15.7	12.2	5.4	17.6	14.2	6.2	20.4
Facilities land (km^2)	3.2	93	96.2	3.5	198	201.5	4.1	290	294
Radioactive waste (MT per year)	0	0	0	0	1.8	1.8	0	0	0
SO_2 emission (10^3 MT per year)	220	97	317	155	96	251	134	48	182
CO_2 emission (10^6 MT per year)	42	14	56	54	10	64	63	13	76

TABLE K.4 Selected quantified impacts for S4. The abbreviation PDL means person-days-lost; MT means metric tons.

	1971			1990			2015		
	Nonelec.	Elec.	Total	Nonelec.	Elec.	Total	Nonelec.	Elec.	Total
Annual fatalities	25	16	41	21	17	38	22	16	38
Occupational accidents (10^3 PDL per year)	142	93	235	119	99	218	126	97	223
Public accidents (10^3 PDL per year)	26	1	27	21	0	21	27	6	33
Occupational health (10^3 PDL per year)	81	61	142	63	65	128	66	65	131
Public health (10^3 PDL per year)	120	4	124	68	3	71	70	2	72
Total annual PDL (10^3)	369	159	528	271	167	438	289	170	459
Resource extraction land (km^2 per year)	10.0	5.7	15.7	10.8	5.2	16.0	11.6	4.8	16.4
Facilities land (km^2)	3.2	93	96.2	3.2	188	191.2	3.4	282	285.4
Radioactive waste (MT per year)	0	0	0	0	0	0	0	0	0
SO_2 emission (10^3 MT per year)	220	97	317	138	80	218	117	51	168
CO_2 emission (10^6 MT per year)	42	14	56	47	9	56	54	6	60

Appendix L

CONTROL FACTORS FOR SCENARIOS S1–S4

TABLE L.1 Control factors: particulates (PM). EF, emission factor (kg PM/10^6 kcal); BK, lignite; K, coke; SK, hard coal; O, oil; G, gas; H, wood.

Sector		EF (1970)	Fraction by which 1970 values are reduced							
					2000			2015		
			1980	1990	S1	S2	S3	S1	S2	S3
Electricity	BK	0.642	0.082	0.206	0.465	0.495	0.433	0.613	0.721	0.451
	O	0.142	0	0	0	0	0	0	0	0
	G	0.010	0	0	0	0	0	0	0	0
Industry	SK	0.957	0.093	0.233	0.542	0.588	0.448	0.691	0.813	0.500
	K	0.428	0.066	0.166	0.375	0.399	0.349	0.495	0.582	0.364
	BK	1.428	0.100	0.250	0.564	0.600	0.525	0.744	0.875	0.547
	O	0.214	0.019	0.047	0.106	0.113	0.098	0.139	0.164	0.103
	G	0.018	0	0	0	0	0	0	0	0
Commercial and service	SK	3.428	0	0	0	0	0	0	0	0
	K	1.714	0	0	0	0	0	0	0	0
	BK	2.000	0	0	0	0	0	0	0	0
	O	0.028	0	0	0	0	0	0	0	0
	G	0.018	0	0	0	0	0	0	0	0
Residential	G	0.018	0	0	0	0	0	0	0	0
	O	0.028	0	0	0	0	0	0	0	0
	K	2.714	0	0	0	0	0	0	0	0
	H	2.703	0	0	0	0	0	0	0	0

TABLE L.2 Control factors: SO_2. EF, emission factor (kg $SO_2/10^6$ kcal); BK, lignite; K, coke; SK, hard coal; O, oil; G, gas; H, wood.

Sector		EF (1970)	Fraction by which 1970 values are reduced								
			1971–1977	1981	1985	1990	2000	All four scenarios	S1	S2	S3,S4
Electricity	BK	2.80	0	0	0	0.076	0.229		0.614	0.676	0.614
	O	5.33	0	0.290	0.460	0.505	0.594		0.797	0.830	0.797
	G	0.001	0	0	0	0	0		0	0	0
Industry	SK	2.31	0	0	0	0.021	0.064		0.532	0.607	0.336
	K	2.57	0	0	0	0.053	0.158		0.579	0.647	0.403
	BK	2.65	0	0	0	0.061	0.184		0.592	0.657	0.421
	O	5.33	0	0.290	0.460	0.505	0.594		0.797	0.830	0.721
	G	0.001	0	0	0	0	0		0	0	0
Commercial and service	SK	1.93	0	0	0	0	0	0	0	0	0
	K	2.15	0	0	0	0	0	0	0	0	0
	BK	2.20	0	0	0	0.006	0.017	0.017	0	0	0
	O	1.995	0	0.360	0.447	0.447	0.447	0.447	0	0	0
	G	0.001	0	0	0	0	0	0	0	0	0
Residential	G	0.001	0	0	0	0	0	0	0	0	0
	O	1.995	0	0.495	0.450	0.450	0.450	0.450	0	0	0
	K	2.065	0	0	0	0	0	0	0	0	0
	H	0.0135	0	0	0	0	0	0	0	0	0

Appendix M

PRIMARY METALS AND THE MASKING PROBLEM

The primary metals sector includes iron and steel production, nonferrous metal production, and casting.* In the iron and steel industry, about 55% of the energy is consumed in the form of coke; fuel oil (18%), gas (20%), and electricity (6%) cover the rest. In the nonferrous metals industry, electricity is the dominant energy source (80%); about 12% of the energy is consumed in the form of fuel oil, and the remaining 8% are supplied by coke, gas, and some coal. In the casting industry, the distribution of the total energy consumption among energy sources is as follows: 18% electricity, 37% gas, 32% coke, and 13% fuel oil. The ratios of the total energy consumption of the three industries are approximately 33:3:2. Thus the weighted average distribution of the primary metals sector is as follows: 16% electricity, 45% coke, 18% fuel oil, 19% gas, and 2% coal. The total energy consumption depends, in turn, on the activity levels and on the specific energy consumption of the industries. The ratios of the value added of the three industries are, roughly, 4:1:1. The comparison of the ratios for total energy consumption and for value added shows that the ratios of the energy intensiveness of the three industries are, roughly, 8:3:2.

This example shows the dependence of both level and distribution of energy consumption of an inhomogeneous sector on the composition of the aggregate and on the specific energy requirements of individual industries included in the aggregate. The parameters associated with these aggregates must be carefully chosen.

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*The data refer to the year 1974, but the fuel mix varies slowly and can be considered typical for the current years. The data refer to industry only, but in the case of primary metals, handicraft industry represents a small fraction of total activity.

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