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SCENARIO PROJECTIONS FOR REGION VII CHINA AND CENTRALLY PLANNED ASIAN ECONOMIES

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PREFACE

Results of the Energy Systems Program's seven years of study of global energy systems are documented in "Energy in a Finite World: A Global Systems Analysis", Ballinger, 1981. Part IV of that book entitled "Balancing Supply and Demand: The Quantitative Analysis" describes two scenarios of global economic and energy development. These scenarios were detailed for each of seven geographic regions. For all regions except China and centrally planned Asian economies (Region VII), the quantitative analysis was accomplished with the use of a set of energy models, as described in the book cited above. These models and these thorough analyses required relatively detailed data about the countries in each region. Such data were not available in the case of Region VII (C/CPA).

Global comprehensiveness was an important goal of our study. To achieve this goal, we decided to include Region VII (C/CPA) with as much detail as was justified by what information was available to us. We further simplified the inclusion of Region VII in our global analysis by making the assumption that the region would be self-sufficient and non-energy-exporting. Our information was not sufficient for analyzing this region in as much detail as the others in order to determine energy import requirements or export opportunities.

This Working Paper outlines the historical data base used and the simple energy demand model applied to Region VII (C/CPA). The optimizing energy supply model used for all other regions was also applied in Region VII.

The data base and projections described here should be regarded as very approximate and illustrative--much more so than those of the other regions.

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INTRODUCTION

Results of the Energy Systems Program's seven years of study of global energy systems are documented in *Energy in a Finite World: A Global Systems Analysis* (Energy Systems Program Group, 1981). Part IV of that book entitled "Balancing Supply and Demand: The Quantitative Analysis" describes two scenarios of global economic and energy development. These scenarios were detailed for each of seven geographic regions as defined in Appendix A. For all regions accept China and centrally planned Asian economies (Region VII), the quantitative analysis was accomplished with the use of a set of energy models, as described in the book cited above. These models and these thorough analyses required relatively detailed data about the countries in each region. Such data were not available in the case of Region VII (C/CPA). Instead, a much simpler energy demand model was used at a very aggregate level of detail. The energy demand projections from this model were, however, sufficiently detailed to allow the energy supply optimizing model (MESSAGE[1]) to be utilized as in all other regions.

This aggregate energy demand model is called SIMCRED.[2] It consists of four equations relating energy consumption (primary commercial, noncommercial and electricity) to population and

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[1] See Schrattenholzer (1981), and for a summary description of the set of models the book cited above or Basile (1980).

[2] See *Energy Systems and Development* (Parikh, 1980), which describes this model and its application to developing economies in general.

macroeconomic variables which were derived by regression analysis of data from over 70 countries at various levels of development.

SCENARIO PROJECTIONS FOR REGION VII (C/CPA)

Energy consumption data for 1975 for this region vary considerably from source to source. Our reconciliation of these sources is given in Appendix B. Also, a consistent historical series 1950-1975 constructed from one of these sources is given in Appendix C. These data are summarized in Table 1.

Table 1. Estimates of primary and final energy consumption for Region VII (C/CPA), 1950-1975 (GWyr).

	1950	1955	1960	1965	1970	1975
Primary energy	33	82	244	202	285	461
Final energy	30	73	193	168	244	393
Final electricity consumption	0.4	1.6	6.6	8	9	14

NOTE: See Appendix E for energy units and conversion factors.

In an earlier iteration of scenario projections of GDP and energy consumption for this regions, the resulting energy supply strategy was extreme for the High scenario. Oil resources were exhausted and massive coal production was necessary. Because of this extreme solution, we have modified our GDP projection downward in the High scenario to the values reported here. Of course, the extreme energy supply scenario could also have been modified by allowing this region to import oil but our basic assumption was self-sufficiency for this region.

Our revised projections are given in Table 2 for both the High and Low scenarios. The fraction of the population that is rural is a required input of the SIMCRED model. The values for rural population given here were projected by Jyoti Parikh.

The application of the SIMCRED model for projecting primary commercial energy and electricity involves three equations. First, the share of agriculture in GDP is projected based on rural population and per capita GDP according to

$$\log f_A = 0.458 \log r - 0.365 \log y + \text{constant} \quad , \qquad (1)$$

where f_A is the fraction of agriculture in GDP, r is the fraction of rural population, and y is per capita GDP. Transforming the equation from its logarithmic form gives

Table 2. Scenario projections for Region VII (C/CPA).

	1975		1985		2000		2015		2030
Population (10^6)	912		1097		1330		1550		1714
Growth rate (%/yr)		1.86		1.29		1.03		0.67	
Rural fraction	0.80		0.75		0.70		0.65		0.60
High Scenario									
GDP (10^9\$)[a]	320		521		939		1573		2450
GDP growth rate		5.00		4.00		3.50		3.00	
GDP per capita	351		475		706		1015		1430
Growth rate		3.07		2.68		2.45		2.31	
Low Scenario									
GDP (10^9\$)[a]	320		443		690		999		1345
GDP growth rate		3.30		3.00		2.50		2.00	
GDP per capita	351		404		519		645		784
Growth rate		1.41		1.69		1.46		1.32	

[a]Constant 1975 U.S. dollars.

$$f_A = k_1 \frac{r^{0.458}}{y^{0.365}} , \qquad (2)$$

where k_1 is a constant that can be determined by base year values.

Second, the primary commercial energy[3] is determined by non-agriculture GDP and per capita GDP as follows

$$\log e = 2.027 \log (1-f_A) + 1.011 \log y + \text{constant} , \qquad (3)$$

where e is per-capita primary commercial energy. In (3) the variable y has been substituted for per capita consumption which is specified in the reference. In the estimation and projections, however, consumption was assumed to be a given (0.8) fraction of GDP and so this multiplicative constant can be included in the constant term of Equation (3). Transforming from the logarithms gives

$$e = k_2 (1-f_A)^{2.027} y^{1.011} , \qquad (4)$$

[3]For the application of SIMCRED, primary energy must be considered on an oil-replacement basis. Once we have the SIMCRED projections for this category of primary energy and electricity, they will be converted to final and then to secondary energy for MESSAGE to determine primary energy consistent with all other regions in our study.

where again the constant k_2 can be determined by base year values.

Third, the equation for projecting electrical energy consumption involves the fraction of urban population and per capita GDP to give per capita electricity as follows

$$\log \text{elect} = 0.400 \log(1-r) + 1.158 \log y + \text{constant} \quad , \qquad (5)$$

where elect represents per capita final electricity consumption. The transformation yields

$$\text{elect} = k_3(1-r)^{0.499} y^{1.158} \quad , \qquad (6)$$

where k_3 can be determined by base year values.

These equations were estimated from cross-section data without taking energy prices into account. In the application of these equations for projection purposes, the effect of energy price increases should be included. In the reference for SIMCRED and its application to Latin America, Africa, and the Far East, this was done by assuming an energy price increase and a price elasticity which would then be applied to the projections based on Equations (4) and (6).

In this application of SIMCRED to Region VII (C/CPA), we will also apply a price effect term but only to the total primary energy and not to the equation for electricity. The rationale for not applying a price effect to the electricity projection is to account for the expected shift from the use of fossil fuels to electricity as the price for fossil fuels increases faster than that for electricity. Without any better estimate of the magnitude of this shift, we merely eliminate the downward effect in the model of the overall price effect on electricity use.

The base year values of the variables and constants are as follows:

$f_A = 0.29$;
$r = 0.80$;
$y = 0.351$ (10^3\$1975/capita);

which implies that $k_1 = 0.219$ and

$e = 0.505$ (kW/cap primary);

Table 3. Summary of energy consumption projections for Region VII (C/CPA) using SIMCRED.

	1975		1985		2000		2015		2030
High Scenario									
Share of agriculture GDP (%)	29		25		21		18		15
Primary energy[a] (GW)	461		791		1465		2511		3900
Primary energy-GDP elasticity, ε_p		1.11		1.05		1.05		0.99	
Final energy (GW)	393		675		1234		2091		3196
Share of electricity (%)	3.6		4.0		4.5		5.1		5.9
Low Scenario									
Share of agriculture GDP (%)	29		27		24		21		19
Primary energy[a] (GW)	461		644		1005		1464		1939
Primary energy-GDP elasticity, ε_p		1.03		1.00		1.02		0.95	
Final energy (GW)	393		548		845		1217		1589
Share of electricity (%)	3.6		4.0		4.6		5.2		5.9

[a]Oil replacement measurement basis.

which implies that $k_2 = 2.914$ and

$$\text{elect} = 0.01535 \text{ (kW/cap final)};$$

which implies that $k_3 = 0.115$.

The detailed application of the SIMCRED equations is given in Appendix D. The results in summary form are given in Table 3. The projections for primary energy and electricity were used, along with assumed values for the losses for fossil fuels, to estimate final energy requirements. The final energy projections for the High and Low scenarios are illustrated in Figures 1 and 2.

The final energy projections were converted to secondary energy terms for MESSAGE input and are given in Table D2 of Appendix D.

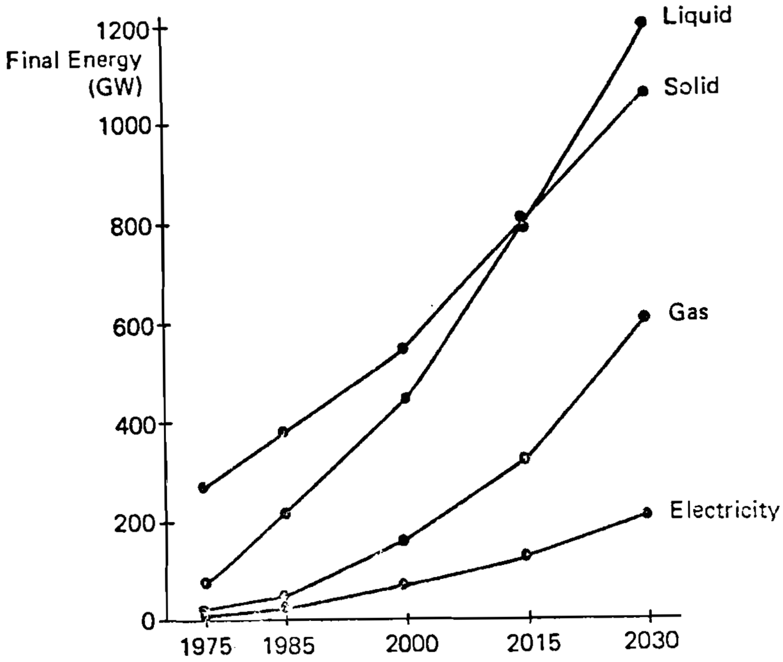

Figure 1. Projected final energy use for Region VII (C/CPA), High scenario.

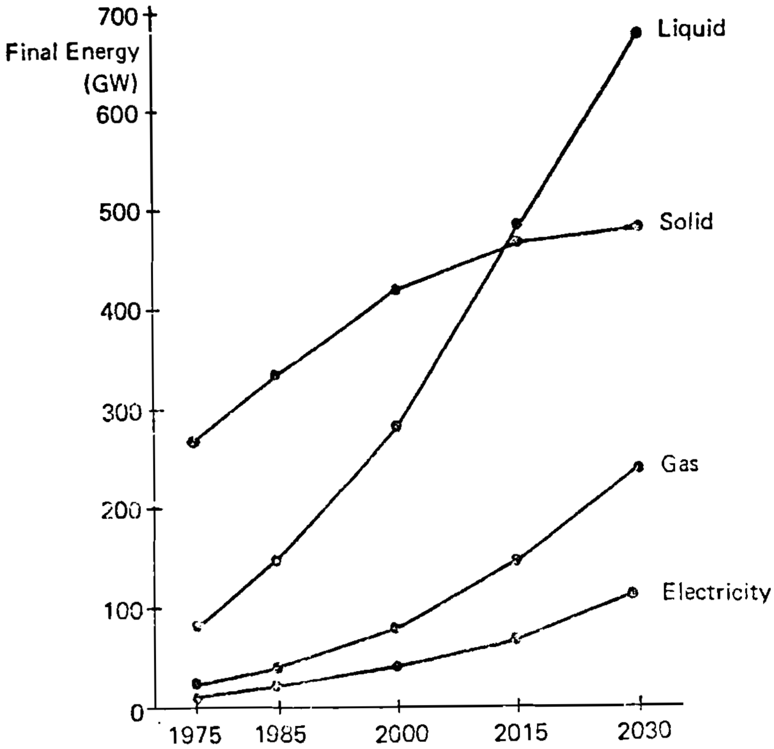

Figure 2. Projected final energy use for Region VII (C/CPA), Low scenario.

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Appendix A

The IIASA World Regions

REGION I: NORTH AMERICA (NA)

Developed market economies with energy resources.

Canada
United States of America

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

Developed centrally planned economies with energy resources.

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

REGION III: WESTERN EUROPE, JAPAN, AUSTRALIA, NEW ZEALAND, SOUTH AFRICA, AND ISRAEL (WE/JANZ)

Developed market economies with relatively few energy resources.

Member Countries of the European Community

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

Other Western European Countries

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

Others

Australia
Israel
Japan
New Zealand
South Africa

REGION IV: LATIN AMERICA (LA)

Developing economies with many energy resources and significant population growth.

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

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

Developing economies with some energy resources and significant population growth.

Africa

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

Asia

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

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

Developing economies with large energy resources.

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

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

Others

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

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

Developing centrally planned economies with modest energy resources.

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

Appendix B

Estimates of Energy Consumption for Region VII (1975)

All the sources of data for Region VII, and in particular the People's Republic of China, stress the uncertainty of any data reported. Since P.R.C. accounts for approximately 90% of the region's energy production and consumption, several sources for the P.R.C. were examined to try to understand the overall energy picture. The most complete sources used was Smil's China's Energy (1976) but other sources were examined as well. Smil's most recent data are for 1974; so for comparison purposes, the UN data in World Energy Supplies (1977) are given below for 1974 as well as 1975 for both the P.R.C. and Region VII.

Table B1. Primary energy consumption in Region VII, 1974 and 1975. Source: UN (1977).

	1974		1975	
	C.P. Asia	P.R.C.	C.P.Asia	P.R.C.
Solid	491	449	514	496
Liquid	80	73	99	92
Natural gas	4.0	4.0	4.7	4.7
Hydropower[a]	6.1	4.3	6.6	4.6
Total (10^6 mtce)	581	530	625	570
Thermal electric (10^9 kWh)	94	83	101	89

[a]Output resistive heat basis 10^9 kWh = 0.123 · 10^6 mtce; for primary equivalent multiply by 3.0.

<u>Coal</u>: There is reason to believe that the UN figures are really tons of *raw* coal rather than of coal equivalent. The World Energy Conference (1978) figure for Region VII (1975) is 350 · 10^6mtce. Other estimates for the P.R.C. in 10^6 mtce are 300 in 1973 and 287 or 251 in 1974. Here the WEC estimate is taken.
<u>Oil</u>: The UN and Smil estimates for 1974 oil consumption for the P.R.C. are similar and others are higher and lower. The U.N. figure for 1975 for Region VII is taken and rounded at 100 · 10^6 mtce.
<u>Gas</u>: Estimates vary widely. For P.R.C., Smil has 47 · 10^6 mtce for 1974; other estimates are 31 and 38 for 1974 and 13 for 1973 whereas the UN figure is 4. Within this wide range the value of 30 · 10^6 mtce for 1975 will be used for the Region.
<u>Hydropower</u>: Estimates vary widely. For P.R.C., the UN has 4.3, Smil and CIA 3.3, and others 6.1 and 4.2, all in 10^6 mtce, on output basis. Since Smil gives good detail on hydropower installations, etc., his figure for the P.R.C. is adopted for 1974. Using UN figures to update and expand to the Region, this gives 5.5 · 10^6 mtce for 1975 or 16.5 · 10^6 mtce on a primary equivalent basis.

Thermal electricity: The data given by Smil and by the UN are consistent.

The primary energy consumption in 1975 for Region VII is therefore estimated as shown below.

Table B2. Estimated primary energy consumption for Region VII, 1975. Sources: UN (1977), Smil (1976), WEC (1978), CIA (1975), Kambara (1974).

	10^6 mtce	GWyr	
Solid	350	325	
Liquid	100	93	
Gas	30	28	
Hydropower	16	15	(primary equivalent basis)
Total	496	461	
Thermal electric	37	34	(primary equivalent basis)

Using estimates of sectoral energy use given by Smil (1976) for 1974, this energy consumption estimate for 1975 can be allocated in an approximate way to broad economic sectors. By assuming conversion losses for coal, oil, and gas as 5%, 7%, and 10%, respectively, one can also estimate the final energy consumption. This is given in Table B3 following the worksheet format developed by the Workshop on Alternative Energy Strategies (WAES).

Table B3. National input worksheet for the supply/demand integration.
Country: Region VII
Year: 1975
Case: Base year
Units: GW

	(a) Coal	(b) Petro-leum	(c) (Syn. Liquids)	(d) Nat. Gas	(e) (Syn. Gas)	(f) (Heat)	(g) (Electri-city)†	(h) Hydro Energy	(i) Nuclear Energy	(j) Geothermal Energy and Other	(k) Total
(1) Transport	27	4		0			0				31
(2) Industry											
(3) Agric., Mining, Construction	141	78		13			13				245
(4) Commercial											
(5) Public	105	1		10			1				117
(6) Residential											
(7) Non-energy Uses											
(8) Final Energy Demand*	273	83		23			14				393
(9) Electricity**	35	3		2			-17	15			38
(10) Syn. Gas											
(11) Syn. Liquids											
(12) Heat											
(13) Energy Sector Self Consumption & Conversion Losses	17	7		3			3				30
(14) Primary Energy Input	325	93		28			0	15			461
(15) Indigenous Supply	325	93		28							
(16) Imports***											
(17) Exports											

*Includes nonenergy uses.
**Blocks 9g, 10e, 11c, and 12f must be negative to avoid double counting of energy from primary fuels.
***Includes imported products.
†Includes only electricity to be purchased by each sector.
NOTES: Based on sectoral breakdown given by Smil (1976) for 1974. Assumes primary/final conversion losses of 5%, 7%, and 10% for coal, oil, and gas, respectively.

Appendix C

Historical Energy Data for Region VII

We have used an estimate of 1975 energy consumption for Region VII different from the UN (1977) source. Many sources were checked and the final estimate is given in Appendix B. The Smil (1976) source which also has a historical series was relied on in most cases. So by using it (for China only) a new series can be estimated for the period 1950-1975 for Region VII.

This series (see Table C1) is first extended to 1975 by the 1974-1975 growth rate of primary energy for China that is given by UN (1977). Then it is normalized at 1975 and applied to our 1975 estimate for Region VII (China's energy consumption is about 90% of Region VII). As in UN (1977) hydroelectricity (which is anyway very small) is treated on the lower output heat-equivalent basis. Then the UN data for electricity are used to estimate final energy consumption. The primary energy values given have been converted to include hydroelectricity on a heat-equivalent basis consistent with our treatment in all other regions.

Table C1. Historical series for Region VII.

	1950	1955	1960	1965	1970	1975
Smil's estimate of primary energy (10^6 tce)	30	72	198	178	251	405[a]
Normalized at 1975	.074	.178	.489	.440	.620	1.0
Region VII estimate based on 1975 values (10^6 tce)	36	86	237	213	301	485
Hydroelectricity estimate from Smil extended (10^6 tce) (low-value)	0	1	2	2	3	6
Primary energy, total (10^6 tce)	36	88	241	217	307	497
Primary energy, total (GWyr/yr)	33	82	224	202	285	461
Estimated final energy (GWyr/yr)	30	73	193	168	244	396[b]

[a] Smil's estimate for 1974 is $377 \cdot 10^6$ tce. This was projected to 1975 by using the UN (1977) 7.5% growth rate of primary energy consumption between 1974 and 1975.

[b] Thermal electricity use of fossil fuels (estimated) is subtracted from primary fossil energy which is then converted to final energy by assuming 7% losses. Electricity production is then added to get total final energy. The value for 1975 is slightly different from the estimated value given in Appendix B on the supply/demand integration worksheet.

Appendix D

Application of SIMCRED Equations to Scenario Projections for Region VII

From the text, we have

$$f_A = 0.219 \frac{r^{0.458}}{y^{0.365}} \quad , \tag{D1}$$

$$e = 2.914 \ (1-f_A)^{2.027} y^{1.011} \quad , \tag{D2}$$

and

$$\text{elect} = 0.115 \ (1-r)^{0.499} y^{1.158} \quad . \tag{D3}$$

Using the projections for r and y given in Table 2 of the text, we can calculate primary commercial energy and final electricity. The price effect term is to be applied to the estimate for e, primary energy, and it is of the form p^{β} where β is the energy-price elasticity and p is the *effective* price for primary energy. To be consistent with our assumed price increases of a factor of three for final energy we should adjust for the changing fraction of electricity in final energy; but in this case, the electricity share is small and so the price increase factor of three is used for primary energy. The increase in effective price over time, taking account of lags in the adjustment of the economy, is assumed as follows: 1.0 for 1975, 1.25 for 1985, 1.75 for 2000, 2.25 for 2015, and 3.0 for 2030. The energy-price elasticity β is assumed to be -0.25 for the entire period.

The application of Eqs. (D1) and (D2) is given in detail in the accompanying Worksheets 1-H and 1-L for the High and Low scenarios, respectively. The application of Eq. (D3) is given in Worksheets 2-H and 2-L. The results are summarized in Table D1. The fuel mix in final energy terms is given in Worksheets 3-H and 3-L and shown in Figures D1 and D2. These energy demands are given in secondary terms in Table D2 which is necessary for a MESSAGE input.

Table D1. Summary of energy consumption projections for Region VII using SIMCRED.

	1975	1985	2000	2015	2030
High Scenario					
Share of agriculture GDP (%)	29	25	21	18	15
Primary energy[a] (GWyr/yr)	461	791	1465	2511	3900
Primary energy - GDP elasticity, ε_p		1.11	1.05	1.05	0.99
Final energy (GWyr/yr)	393	675	1234	2091	3196
Share of electricity (%)	3.6	4.0	4.5	5.1	5.9
Low Scenario					
Share of agriculture GDP (%)	29	27	24	21	19
Primary energy[a] (GWyr/yr)	461	644	1005	1464	1939
Primary energy - GDP elasticity, ε_p		1.03	1.00	1.02	0.95
Final energy (GWyr/yr)	393	548	845	1217	1589
Share of electricity (%)	3.6	4.0	4.6	5.2	5.9

[a]Oil replacement measurement basis.

Table D2. Secondary energy[a] projections for Region VII (GW).

	1975	1985	2000	2015	2030
High Scenario					
Solid	287	400	577	846	1113
Liquid	83	218	458	800	1200
Gas	26	56	178	356	667
Heat	0	0	11	22	65
Solar	0	0	10	40	90
Electricity	16	32	66	126	222
Total	412	706	1292	2190	3357
Low Scenario					
Solid	287	354	442	495	511
Liquid	83	150	286	488	680
Gas	26	44	89	167	267
Heat	0	0	11	16	33
Solar	0	0	10	30	60
Electricity	16	26	46	75	111
Total	412	574	884	1271	1662

[a]Losses assumed between final and secondary energy are 5% for solid fuels, zero for liquid fuels (accounted for in MESSAGE), 10% for gas, 8% for heat, zero for solar, and 15% for electricity.

Table D3. Primary energy projections for the High scenario using SIMCRED. Worksheet 1-H.

	1975	1985	2000	2015	2030
Fraction rural population, r	0.80	0.75	0.70	0.65	0.60
GDP per capita, y	0.351	0.475	0.706	1.015	1.430
Fraction agriculture GDP (C1), f_A	0.290	0.252	0.211	0.179	0.152
Primary energy/capita (C2) without price effect, e	0.505	0.762	1.267	1.984	2.994
Price increase, p	1.0	1.25	1.75	2.25	3.0
Primary energy/capita with price effect (β=-.25), $e \cdot p^{\beta}$	0.505	0.721	1.102	1.620	2.275
Population (10^6)	912	1097	1330	1550	1714
Primary energy (oil replacement) (GWyr/yr)	461	791	1465	2511	3900
Primary energy growth rate (%/yr)		5.55	4.19	3.66	2.98
GDP growth rate		5.00	4.00	3.50	3.00
Primary energy - GDP elasticity, ε_p		1.11	1.05	1.05	0.99

Table D4. Electricity demand projections for the High scenario using SIMCRED. Worksheet 2-H.

	1975	1985	2000	2015	2030
Fraction urban population, 1-r	0.20	0.25	0.30	0.35	0.40
GDP per capita, y	0.351	0.475	0.706	1.015	1.430
Electricity per capita (C3)	0.0153	0.0243	0.0421	0.0693	0.1102
Population (10^6)	912	1097	1330	1550	1714
Total final electricity (GWyr/yr)	14.0	26.7	56.0	107	189
Electricity growth rate (%/yr)		6.67	5.06	4.41	3.87
Total electricity primary equiv. basis (final · 3/0.85) (GWyr/yr)	49	94	198	378	667

Table D5. Final energy and fuel mix calculations for the High scenario. Worksheet 3-H.

	1975		1985	2000	2015	2030	
Primary energy (GWyr/yr)		461	791	1465	2511	3900	
Electricity primary equivalent (GWyr/yr)		49	94	198	378	667	
Nonelectricity primary energy · 0.93[a]		379	648	1178	1984	3007	
Fuel mix[b]							
Solid	(69%)	273	380	548	804	1057	(33%)
Liquid	(21%)	83	218	450	800	1200	(38%)
Gas	(6%)	23	50	160	320	600	(19%)
Heat		-	0	10	20	60	(2%)
Solar		-	0	10	40	90	(3%)
Electricity	(4%)	14	27	56	107	189	(6%)
Total final energy (GWyr/yr)		393	675	1234	2091	3196	

[a] For 1975, this formula yields 383 but original estimate on 1975 balance sheet is 393 - 14 = 379.

[b] For 1975, from WAES balance sheet; projection by assumption, with more gas than previous iteration and less liquid--liquid demand is consistent with transportation and feedstocks requirements on cross regional comparison. See also Figure D1.

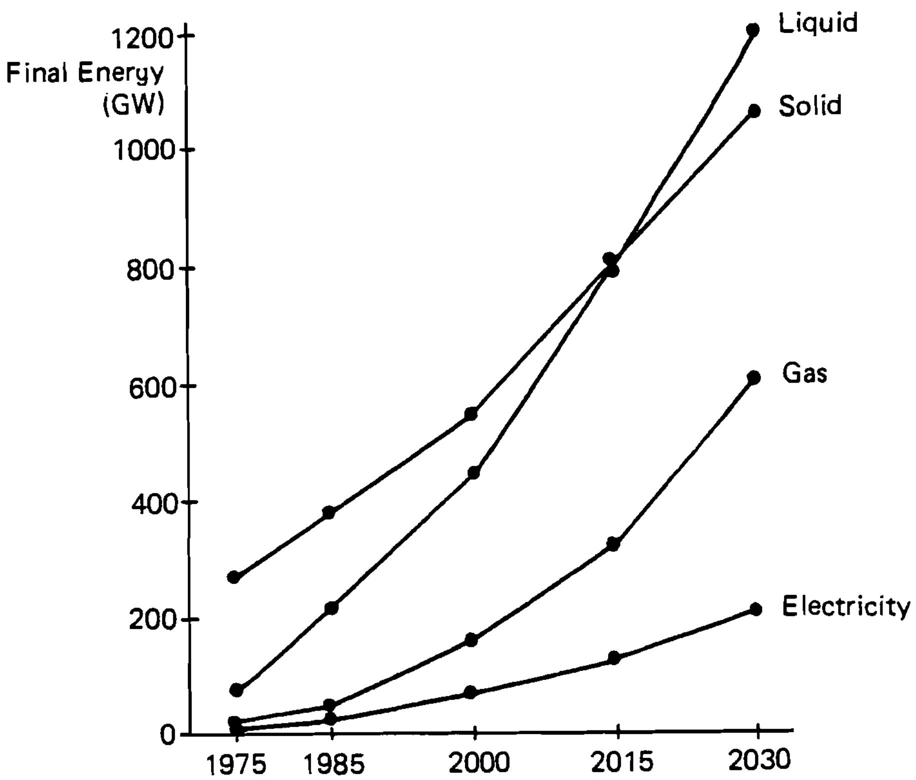

Figure D1. Fuel mix for Region VII (C/CPA), High scenario.

Table D6. Primary energy projections for the Low scenario, using SIMCRED. Worksheet 1-L.

	1975	1985	2000	2015	2030
Fractiona rural population, r	0.80	0.75	0.70	0.65	0.60
GDP per capita, y	0.351	0.404	0.519	0.645	0.784
Fraction agriculture GDP (C1), f_A	0.290	0.267	0.236	0.211	0.189
Primary energy per capita (C2) without price effect, e	0.505	0.620	0.869	1.157	1.489
Price increase, p	1.0	1.25	1.75	2.25	3.0
Primary energy/capita with price effect (β=-.25), $e \cdot p^{\beta}$	0.505	0.587	0.756	0.945	1.131
Population (10^6)	912	1097	1330	1550	1714
Primary energy (oil replacement) (GWyr/yr)	461	644	1005	1464	1939
Primary energy growth rate (%/yr)	3.40	3.01	2.54	1.89	
GDP growth rate	3.30	3.00	2.50	2.00	
Primary energy - GDP elasticity, ε_p	1.03	1.00	1.02	0.95	

Table D7. Electricity demand projections for the Low scenario, using SIMCRED. Worksheet 2-L.

	1975	1985	2000	2015	2030
Fraction urban population, 1-r	0.20	0.25	0.30	0.35	0.40
GDP per capita, y	0.351	0.404	0.519	0.645	0.784
Electricity per capita (C3)	0.0153	0.0202	0.0295	0.0410	0.0549
Population (10^6)	912	1097	1330	1550	1714
Total final electricity (GWyr/yr)	14.0	22.1	39.2	63.5	94.1
Electricity growth rate (%/yr)	4.67	3.89	3.27	2.66	
Total electricity primary equivalent basis (GWyr/yr) (final · 3/0.85)	49	78	138	224	332

Table D8. Final energy and fuel mix calculations for the Low scenario (GWyr/yr). Worksheet 3-L.

		1975	1985	2000	2015	2030
Primary energy		461	644	1005	1464	1939
Electricity primary equivalent		49	78	138	224	332
Nonelectricity primary equivalent · 0.931[a]		379	526	806	1153	1495
Fuel mix[b]						
solid	(69%)	273	336	420	470	485(30%)
liquid	(21%)	83	150	286	488	680(43%)
gas	(6%)	23	40	80	150	240(15%)
heat		-	0	10	15	30(2%)
solar		-	0	10	30	60(4%)
electricity	(4%)	14	22	39	64	94(6%)
Total final energy (GWyr/yr)		393	548	845	1217	1589

[a]See note on High scenario table.

[b]By assumption: more gas than previous iteration, smooth transition between coal and liquid as determined by graph Figure D2; also liquid appears sufficient to meet transportation and feedstock demand as determined by cross regional comparison.

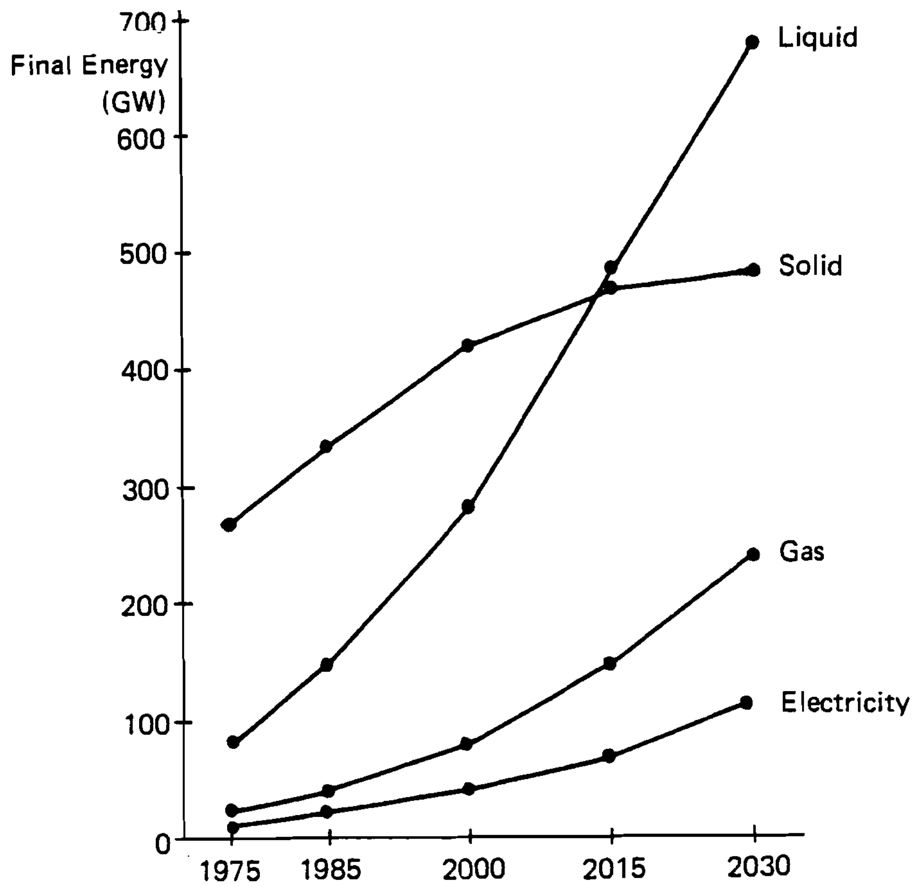

Figure D2. Fuel mix for Region VII (C/CPA), Low scenario.

Appendix E

Energy Units and Conversion Factors

Abbreviations

k = kilo	10^3	kWh	= kilowatt-hour
M = mega	10^6	kWyr	= kilowatt-year (8760 kWh)
G = giga	10^9	BTU	= British Thermal Unit
T = tera	10^{12}	cal	= calorie
		J	= joule

Energy Units (exact but rounded)

1 kWh = 3413 BTU	10^6 BTU = 293 kWh
1 kWyr = $29.9 \cdot 10^6$ BTU	10^6 BTU = 0.0334 kWyr
1 kWh = 860 kcal	10^6 kcal = 1163 kWh
1 kWyr = 0.0982 kcal	10^6 kcal = 0.133 kWyr
1 kJ = 0.948 BTU	1 BTU = 1.055 kJ

Weight and Volume Units of Energy Products (approximate)

Coal, metric ton (1000kg) of coal equivalent (mtce)

1 mtce is defined as $7.00 \cdot 10^6$ kcal,

which is $27.78 \cdot 10^6$ BTU or 0.929 kWyr.

Oil*, barrel (bbl), metric ton of oil equivalent (mtoe)

1 bbl oil is defined as $5.80 \cdot 10^6$ BTU which is 0.194 kWyr;

$1 \cdot 10^6$ bbl/day is then 70.83 GW.

1 mtoe is defined as 7.30 bbl, which is 1.417 kWyr.

Gas, cubic meter (m^3)

1 ft^3 natural gas is defined as 1000 BTU;

1 m^3 natural gas is then $0.0353 \cdot 10^6$ BTU or 1.18 kWyr.

$1 \cdot 10^{12}$ BTU	=	0.0334	GWyr	1 GWyr	= $29.9 \cdot 10^{12}$ BTU
$1 \cdot 10^6$ mtce	=	0.929	GWyr	1 GWyr	= $1.076 \cdot 10^6$ mtce
$1 \cdot 10^6$ mtoe	=	1.417	GWyr	1 GWyr	= $0.706 \cdot 10^6$ mtoe
$1 \cdot 10^6$ bbl	=	0.194	GWyr	1 GWyr	= $5.15 \cdot 10^6$ bbl
$1 \cdot 10^9$ m^3 n.g.	=	1.18	GWyr	1 GWyr	= $0.847 \cdot 10^9$ m^3 n.g.
$1 \cdot 10^6$ bbl/day	=	70.8	GW	1 GW	= $0.014 \cdot 10^6$ bbl/day

*World average crude S.G. 0.86 or API33.