APPENDIX H INPUT DATA AND RESULTING ENERGY FORECASTS FROM THE STANFORD RESEARCH INSTITUTE ENERGY MODEL

I. NOMINAL CASE

The data used to generate the nominal case projections fall into three categories:

- o Demand data
- o Resource data
- o Process economics data.

All nominal case data have been extensively reviewed by both private firms and government agencies, including Arthur D. Little, Battelle, Bechtel, Bureau of Mines, Council on Environmental Quality, Department of the Interior, Environmental Protection Agency, Federal Energy Administration, Federal Power Commission, Gulf Oil, National Science Foundation, Office of Technology Assessment, Office of Management and Budget, Radian, Resources for the Future, Stanford Research Institute, and United States Geological Survey.

In the material that follows, the nominal case data most pertinent to the Synthetic Fuels Commercialization Program will be presented. A complete documentation of the nominal case data base will be published shortly.

1. Demand Data

The SRI energy model requires as input the demand forecasts for 14 end-use categories for the years 1975, 1985, 2000, and 2025. The units of end-use demand are "usable energy," such as space heat in the living room or industrial process steam. This differs from the more familiar projections of demand for distributed products, which do not consider end-use conversion efficiencies. This distinction enables the model to account for the effects of changes in end-use conversion processes over time, both in terms of economics and efficiencies. The high capital cost of end-use conversion makes it essential to consider end-use conversion explicitly.

For 1975, end-use demands were obtained by interpolation between Bureau of Mines[1/] estimates for 1974 and an FEA projection for 1977[2/]. For the years 1985, 2000, and 2025, the nominal case demand was 30%

[1/] Department of the Interior News Release, "U.S. Energy Use Down in 1974 After Two Decades of Increases," April 3, 1975.

[2/] The FEA data is the output from the Integrating Model of the Project Independence Blueprint Study under the assumptions of "Business as Usual" $7/bbl imported oil. It was provided through the courtesy of Dr. John Pearson.

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of the way between a low demand case and a high demand case based on the Ford Foundation's Historical Growth and Technical Fix scenarios, respectively.[3/] The historical growth case examines the consequences of continuing growth in energy consumption for the remainder of the century at the 1950-1970 average growth rat of 3.4% per year. The technical fix case is an attempt to anticipate the results of a variety of voluntary and mandatory energy conservation measures. The Ford Foundation study was used because:

- o It is recent (1974).
- o It analyzes multiple scenarios.
- o It projects end-use energy demand at nearly the level of detail required by the SRI-Gulf model.
- o Its projections extend beyond the year 1985 to the year 2000.
- o Its Historical Growth and Technical Fix projections bracket two pertinent FEA forecasts for the year 1985, which is as far as the Project Independence study forecasted.

The resulting high, low, and nominal forecasts for usable energy consumption are shown in Tables H-I-1 through H-I-3

As noted in Chapter II, the SRI primary resource projections do not include certain fuels and uses. To reconcile the SRI model primary resource projections with the demand estimates in Table 1, of the main text the following calculation is presented. The calculation illustrates which fuels are excluded. It begins with the demand in 1972 of 72.1 quads taken from Table 1 in Chapter II:

1972 demand	72.1
Losses in hydro and geothermal generation	(2.1)
Coke (coal)	(2.4)
Coke (petroleum)	(.2)
Lubes and waxes	(.4)
Asphalt and road oil	(1.2)
	65.8
Field use of natural gas	(2.4)
SRI model input	63.4

All SRI demand estimates and projections exclude the items in the above list.

[3/] A Time to Choose, Energy Policy Report of the Ford Foundation, Ballinger Publishing Company, Cambridge, Mass. 1974.

TABLE H-I-1 (a)

USABLE ENERGY FORECAST - HIGH DEMAND CASE

1975

CATEGORY	DEMAND REGION								
	1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.256	1.597	.754	.336	2.171	.532	1.117	.765	7.528
Drying	.121	.488	.290	.153	.414	.247	.339	.275	2.247
Air Conditioning	.020	.056	.260	.112	.084	.172	.108	.124	.936
Electromechanical	.062	.101	.155	.067	.201	.104	.124	.138	1.032
Subtotal	.459	2.242	1.459	.668	2.870	1.055	1.688	1.302	11.743
Transportation									
Automobile	.666	1.841	2.070	.850	2.528	1.490	1.931	1.634	13.010
Truck/Bus	.038	.140	.212	.093	.226	.153	.178	.173	1.213
Rail	.016	.057	.087	.046	.104	.076	.236	.110	.732
Marine	.048	.229	.119	.036	.022	.184	0.000	.172	.804
Aircraft	.083	.449	.352	.045	.266	200	.241	.635	2.091
Subtotal	.851	2.716	2.840	1.064	3.166	2.103	2.586	2.624	17.850
Industrial									
Process Steam	.100	.491	.434	.269	.934	1.065	.491	.302	4.175
Direct Heat	.044	.259	.236	.162	.565	.471	.239	.174	2.150
Electromechanical	.166	.287	.276	.285	.449	.240	.193	.252	2.047
Naptha Feedstock	.020	.204	.149	.066	.105	.083	.043	.046	.785
Gas Feedstock	.074	.610	.335	.190	.523	.581	.040	.219	2.582
Coal Feedstock	.306	.017	.017	.012	.056	.001	.006	.001	.112
Subtotal	.322	1.866	1.467	.984	2.762	2.441	1.014	1.074	11.651
Total	1.632	6.826	5.766	2.716	8.736	5.599	5.286	4.900	41.444

(Continued)

TABLE H-I-1 (b)

USABLE ENERGY FORECAST - HIGH DEMAND CASE

1985

CATEGORY	DEMAND REGION								
	1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.387	2.280	1.061	.468	2.880	.753	1.611	1.060	10.500
Drying	.176	.563	.395	.206	.579	.339	.473	.369	3.100
Air Conditioning	.066	.176	.960	.340	.268	.528	.340	.368	2.964
Electromechanical	.282	.559	.445	.202	.628	.318	.385	.415	3.154
Subtotal	.829	3.578	2.801	1.216	4.355	1.938	2.809	2.212	19.738
Transportation									
Automobile	.960	2.496	2.781	1.132	4.490	2.020	2.666	2.155	17.700
Truck/Bus	.059	.185	.277	.120	.303	.201	.239	.222	1.600
Rail	.023	.076	.117	.062	.143	.104	.326	.147	1.000
Marine	.083	.371	.192	.047	.037	.298	0.000	.272	1.300
Aircraft	.185	.946	.735	.093	.012	.421	.517	.891	4.400
Subtotal	1.304	4.074	4.102	1.454	4.985	3.044	3.748	3.687	26.000
Industrial									
Process Steam	.229	.974	.957	.594	1.967	2.348	1.083	.808	8.900
Direct Heat	.083	.462	.466	.320	1.035	.931	.473	.330	4.100
Electromechanical	.176	.523	.560	.578	.845	.486	.392	.440	4.000
Naptha Feedstock	.052	.350	.284	.126	.291	.158	.082	.083	1.476
Gas Feedstock	.131	1.020	.622	.354	.917	1.080	.075	.369	4.500
Coal Feedstock	0.000	.027	.030	.021	.096	.003	.014	.001	.188
Subtotal	.621	3.356	2.919	1.993	4.685	5.006	2.119	2.101	23.200
Total	2.754	11.010	9.822	4.663	14.025	9.988	8.676	8.000	68.936

(Continued)

TABLE H-I-1 (c)

USABLE ENERGY FORECAST - HIGH DEMAND CASE

2000

CATEGORY	DEMAND REGION								
	1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.481	2.786	1.282	.547	3.366	.857	1.817	1.464	13.100
Drying	.221	.694	.481	.242	.720	.389	.539	.514	3.600
Air Conditioning	.188	.208	1.180	.408	.408	.748	.476	.628	4.256
Electromechanical	.314	.867	.719	.293	.961	.449	.541	.711	4.620
Subtotal	1.116	4.555	3.653	1.570	5.955	2.443	3.373	3.317	26.022
Transportation									
Automobile	1.191	3.071	3.369	1.315	4.290	2.287	2.967	2.940	21.560
Truck/Bus	.165	.222	.329	.136	.304	.222	.262	.300	1.920
Rail	.040	.136	.200	.161	.251	.166	.518	.208	1.700
Marine	.170	.431	.265	.062	.046	.358	0.606	.359	1.750
Aircraft	.491	2.401	1.900	.232	1.606	1.017	1.235	2.030	11.050
Subtotal	1.896	6.391	6.043	1.844	6.559	4.050	5.002	6.615	38.400
Industrial									
Process Steam	.251	1.452	1.542	.662	2.922	3.883	1.711	1.277	14.100
Direct Heat	.137	.763	.812	.561	1.712	1.664	.608	.563	7.000
Electromechanical	.270	1.114	1.287	1.339	1.845	1.148	.885	1.184	9.000
Naptha Feedstock	.115	.714	.627	.286	.611	.358	.177	.182	3.059
Gas Feedstock	.274	2.071	1.367	.761	1.915	2.434	.168	.868	9.842
Coal Feedstock	0.000	.855	.367	.046	.193	.004	.030	.004	.359
Subtotal	1.155	6.169	5.702	3.969	9.198	9.491	3.771	3.970	43.460
Total	4.162	17.135	15.398	7.383	21.712	15.984	12.146	13.902	107.022

(Continued)

TABLE II-I-1 (d)

USABLE ENERGY FORECAST - HIGH DEMAND CASE

2025

CATEGORY	DEMAND REGION								
	1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.885	5.040	2.500	1.072	7.268	1.637	3.361	2.899	24.662
Drying	.407	1.255	.938	.474	1.354	.743	.997	1.618	7.166
Air Conditioning	.184	.485	2.301	.956	.767	1.429	.681	1.243	8.246
Electromechanical	.578	1.532	1.365	.574	1.807	.858	1.001	1.448	9.142
Subtotal	2.053	8.312	7.123	3.077	11.195	4.666	6.240	6.568	49.236
Transportation									
Automobile	2.191	5.555	6.570	2.577	8.065	4.368	5.526	5.920	40.773
Truck/Bus	.120	.492	.642	.267	.684	.424	.485	.594	3.616
Rail	.074	.246	.390	.198	.472	.317	.958	.570	3.225
Marine	.261	.070	.478	.118	.090	.684	0.000	.791	3.236
Aircraft	.903	4.408	3.705	.455	3.019	1.942	2.285	5.223	22.021
Subtotal	3.489	11.561	11.784	3.614	12.331	7.735	9.254	13.098	72.866
Industrial									
Process Steam	.046	2.627	3.107	1.886	5.493	7.417	3.165	2.520	26.769
Direct Heat	.252	1.344	1.583	1.100	3.219	3.178	1.495	1.115	13.285
Electromechanical	.512	2.015	2.510	2.624	3.469	2.193	1.637	2.186	17.145
Naptha Feedstock	.282	1.292	1.223	.569	1.149	.684	.327	.360	5.786
Gas Feedstock	.504	3.746	2.666	1.531	3.600	4.649	.296	1.663	18.655
Coal Feedstock	0.000	.099	.131	.090	.363	.608	.055	.008	.754
Subtotal	2.116	11.124	11.119	7.779	17.292	18.128	6.976	7.661	62.395
Total	7.658	30.997	30.026	14.471	40.819	30.529	22.470	27.526	204.496

TABLE II-1-2 (a)

USABLE ENERGY FORECAST - LOW DEMAND CASE

1975

CATEGORY	DEMAND REGION 1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.256	1.597	.754	.336	2.171	.532	1.117	.765	7.528
Drying	.121	.408	.290	.153	.414	.247	.339	.275	2.247
Air Conditioning	.020	.056	.260	.112	.084	.172	.108	.124	.936
Electromechanical	.062	.181	.155	.067	.201	.104	.124	.138	1.032
Subtotal	.459	2.242	1.459	.668	2.870	1.055	1.688	1.302	11.743
Transportation									
Automobile	.566	1.841	2.070	.850	2.528	1.490	1.931	1.634	13.010
Truck/Bus	.030	.140	.212	.093	.226	.153	.178	.173	1.213
Rail	.016	.057	.087	.046	.104	.076	.236	.110	.732
Marine	.048	.229	.119	.030	.022	.184	0.000	.172	.804
Aircraft	.083	.449	.352	.045	.286	.200	.241	.435	2.091
Subtotal	.851	2.716	2.840	1.064	3.166	2.103	2.586	2.524	17.850
Industrial									
Process Steam	.109	.491	.434	.269	.934	1.065	.491	.382	4.175
Direct Heat	.044	.259	.236	.162	.565	.471	.239	.174	2.150
Electromechanical	.066	.287	.276	.285	.449	.240	.193	.252	2.047
Naptha Feedstock	.029	.204	.149	.066	.165	.083	.043	.046	.765
Gas Feedstock	.074	.610	.335	.190	.533	.581	.040	.219	2.582
Coal Feedstock	0.000	.017	.017	.012	.056	.001	.008	.001	.112
Subtotal	.322	1.868	1.447	.984	2.702	2.441	1.014	1.074	11.651
Total	1.632	6.826	5.746	2.716	8.738	5.599	5.288	4.900	41.446

(Continued)

TABLE H-I-2 (b)

USABLE ENERGY FORECAST - LOW DEMAND CASE

1985

CATEGORY	DEMAND REGION								
	1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.324	1.912	.889	.392	2.414	.631	1.350	.888	8.600
Drying	.159	.509	.357	.186	.523	.306	.427	.333	2.800
Air Conditioning	.028	.080	.344	.148	.116	.232	.148	.160	1.256
Electromechanical	.088	.243	.206	.088	.274	.138	.168	.181	1.386
Subtotal	.599	2.744	1.796	.814	3.327	1.307	2.093	1.562	14.242
Transportation									
Automobile	.629	1.636	1.823	.742	2.287	1.324	1.747	1.412	11.600
Truck/Bus	.079	.277	.415	.180	.456	.302	.358	.333	2.400
Rail	.023	.078	.117	.062	.143	.104	.326	.147	1.000
Marine	.083	.371	.192	.047	.037	.298	0.000	.272	1.300
Aircraft	.139	.709	.551	.070	.459	.316	.388	.668	3.300
Subtotal	.953	3.071	3.098	1.101	3.362	2.344	2.819	2.832	19.600
Industrial									
Process Steam	.254	1.079	1.060	.658	2.113	2.602	1.200	.895	9.861
Direct Heat	.074	.412	.416	.286	.924	.831	.422	.295	3.660
Electromechanical	.079	.327	.350	.361	.528	.304	.245	.306	2.500
Naptha Feedstock	.053	.356	.289	.126	.296	.161	.084	.085	1.452
Gas Feedstock	.074	.574	.350	.199	.516	.608	.042	.219	2.582
Coal Feedstock	0.000	.030	.033	.023	.101	.003	.016	.001	.207
Subtotal	.534	2.778	2.498	1.655	4.478	4.509	2.009	1.801	20.262
Total	2.066	8.593	7.392	3.570	11.167	8.160	6.921	6.195	54.104

(Continued)

TABLE H-I-2 (c)

USABLE ENERGY FORECAST - LOW DEMAND CASE

2000

CATEGORY	DEMAND REGION 1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.290	1.680	.773	.330	2.331	.517	1.096	.883	7.900
Drying	.169	.530	.367	.185	.549	.297	.411	.392	2.900
Air Conditioning	.048	.128	.566	.232	.192	.356	.228	.300	2.044
Electromechanical	.149	.462	.337	.139	.456	.213	.256	.337	2.289
Subtotal	.656	2.740	2.037	.886	3.528	1.383	1.991	1.912	15.133
Transportation									
Automobile	.571	1.214	1.332	.520	1.695	.904	1.181	1.182	8.499
Truck/Bus	.151	.515	.760	.316	.842	.515	.606	.695	4.400
Rail	.045	.152	.274	.113	.266	.186	.579	.321	1.500
Marine	.169	.481	.245	.060	.048	.358	0.000	.399	1.700
Aircraft	.347	1.754	1.343	.164	1.135	.719	.873	1.865	8.200
Subtotal	1.123	4.116	3.904	1.173	4.000	2.682	3.239	4.462	24.699
Industrial									
Process Steam	.369	1.524	1.618	1.010	3.067	4.076	1.797	1.340	14.801
Direct Heat	.058	.476	.521	.360	1.100	1.076	.518	.361	4.500
Electromechanical	.096	.387	.448	.465	.641	.398	.307	.383	3.125
Naptha Feedstock	.098	.639	.560	.256	.546	.320	.159	.163	2.735
Gas Feedstock	.072	.543	.359	.205	.502	.639	.042	.220	2.582
Coal Feedstock	0.000	.054	.065	.045	.168	.004	.030	.004	.390
Subtotal	.723	3.623	3.571	2.335	6.044	6.513	2.853	2.471	28.133
Total	2.502	10.479	9.512	4.394	13.572	10.578	8.083	8.845	67.965

(Continued)

TABLE II-I-2 (d)

USABLE ENERGY FORECAST - LOW DEMAND CASE

2025

CATEGORY	DEMAND REGION 1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.326	1.858	.924	.396	2.683	.603	1.242	1.069	9.101
Drying	.190	.586	.439	.222	.632	.347	.466	.475	3.357
Air Conditioning	.068	.180	.948	.356	.284	.532	.256	.464	3.088
Electromechanical	.215	.570	.493	.214	.673	.318	.291	.523	3.297
Subtotal	.799	3.194	2.804	1.188	4.272	1.800	2.255	2.531	1[illegible].843
Transportation									
Automobile	.677	1.720	2.038	.749	2.500	1.351	1.714	1.832	12.631
Truck/Bus	.218	.730	1.163	.485	1.241	.770	.879	1.077	6.563
Rail	.065	.215	.343	.174	.413	.278	.840	.498	2.826
Marine	.157	.681	.375	.092	.071	.535	0.000	.618	2.529
Aircraft	.500	2.485	2.055	.252	1.673	1.074	1.267	2.891	12.197
Subtotal	1.617	5.831	5.974	1.802	5.898	4.008	4.700	6.916	36.746
Industrial									
Process Steam	.531	2.160	2.476	1.551	4.520	6.089	2.607	2.077	22.011
Direct Heat	.127	.674	.797	.553	1.621	1.594	.751	.559	6.676
Electromechanical	.138	.548	.685	.714	.945	.594	.445	.594	4.663
Naptha Feedstock	.141	.905	.857	.384	.804	.478	.231	.252	4.052
Gas Feedstock	.104	.769	.549	.314	.740	.955	.061	.341	3.833
Coal Feedstock	0.000	.077	.099	.069	.277	.006	.044	.006	.576
Subtotal	1.041	5.133	5.463	3.585	8.967	9.716	4.139	3.829	41.813
Total	3.457	14.158	14.241	6.575	19.077	15.524	11.094	13.276	97.402

TABLE H-I-3 (a)

USABLE ENERGY FORECAST - NOMINAL CASE

1975

CATEGORY	DEMAND REGION								
	1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.256	1.597	.754	.336	2.171	.532	1.117	.765	7,528
Drying	.121	.408	.290	.153	.414	.247	.339	.275	2,247
Air Conditioning	.020	.056	.260	.112	.064	.172	.108	.124	.936
Electromechanical	.062	.181	.155	.067	.201	.104	.124	.138	1.032
Subtotal	.459	2.242	1.459	.668	2.870	1.055	1.688	1.302	11,743
Transportation									
Automobile	.666	1.841	2.070	.850	2.528	1.490	1.931	1.634	13.010
Truck/Bus	.038	.140	.212	.093	.226	.153	.178	.173	1,213
Rail	.016	.057	.087	.046	.104	.076	.236	.110	.732
Marine	.048	.229	.119	.030	.022	.184	0.000	.172	.804
Aircraft	.083	.449	.352	.045	.286	.200	.241	.435	2.091
Subtotal	.851	2.716	2.840	1.064	3.166	2.103	2.586	2.524	17,850
Industrial									
Process Steam	.109	.491	.434	.269	.934	1.065	.491	.382	4.175
Direct Heat	.044	.259	.236	.162	.565	.471	.239	.174	2.150
Electromechanical	.066	.287	.276	.285	.449	.240	.193	.252	2.047
Naptha Feedstock	.029	.204	.149	.066	.165	.083	.043	.046	.785
Gas Feedstock	.074	.610	.335	.190	.533	.581	.040	.219	2.582
Coal Feedstock	0.000	.017	.017	.012	.056	.001	.008	.001	.112
Subtotal	.322	1.868	1.447	.984	2.702	2.441	1.014	1.074	11.851
Total	1.632	6.826	5.746	2.716	8.738	5.599	5.288	4.900	41.444

(Continued)

TABLE H-1-3 (h)

USABLE ENERGY FORECAST - NOMINAL CASE

1985

CATEGORY	DEMAND REGION								
	1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.343	2.022	.941	.415	2.554	.668	1.428	.940	9.310
Drying	.164	.525	.368	.192	.540	.316	.441	.344	2.890
Air Conditioning	.039	.109	.511	.206	.162	.321	.206	.222	1.774
Electromechanical	.122	.338	.278	.122	.380	.192	.233	.251	1.916
Subtotal	.668	2.994	2.097	.935	3.635	1.496	2.308	1.757	15.891
Transportation									
Automobile	.728	1.894	2.110	.859	2.648	1.533	2.023	1.635	13.430
Truck/Bus	.071	.249	.374	.162	.410	.272	.322	.300	2.160
Rail	.023	.078	.117	.062	.143	.104	.326	.147	1.000
Marine	.083	.371	.192	.047	.037	.298	0.000	.272	1.300
Aircraft	.153	.780	.606	.077	.505	.347	.427	.735	3.630
Subtotal	1.058	3.372	3.399	1.207	3.743	2.554	3.098	3.068	21.520
Industrial									
Process Steam	.246	1.047	1.029	.639	2.051	2.526	1.165	.869	9.573
Direct Heat	.077	.427	.431	.296	.957	.861	.437	.305	3.792
Electromechanical	.093	.386	.413	.426	.623	.359	.289	.361	2.950
Naptha Feedstock	.053	.354	.267	.127	.294	.160	.083	.084	1.444
Gas Feedstock	.091	.708	.432	.245	.636	.750	.052	.270	3.184
Coal Feedstock	0.000	.029	.032	.022	.098	.003	.015	.001	.201
Subtotal	.568	2.951	2.624	1.756	4.660	4.658	2.042	1.891	21.143
Total	2.286	9.318	8.121	3.898	12.038	8.708	7.447	6.736	58.554

(Continued)

TABLE II-I-3 (c)

USABLE ENERGY FORECAST - NOMINAL CASE

2000

CATEGORY	DEMAND REGION								
	1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.347	2.012	.926	.395	2.791	.619	1.312	1.057	9.460
Drying	.165	.579	.401	.202	.600	.325	.449	.429	3.170
Air Conditioning	.064	.170	.746	.309	.257	.474	.302	.398	2.720
Electromechanical	.198	.535	.449	.185	.607	.284	.341	.449	3.050
Subtotal	.794	3.296	2.522	1.091	4.256	1.701	2.406	2.333	18.400
Transportation									
Automobile	.687	1.771	1.943	.756	2.473	1.319	1.723	1.724	12.399
Truck/Bus	.125	.427	.631	.262	.699	.427	.503	.576	3.650
Rail	.043	.147	.217	.105	.271	.180	.561	.311	1.840
Marine	.109	.481	.245	.060	.048	.358	0.000	.399	1.700
Aircraft	.390	1.972	1.510	.184	1.276	.808	.982	2.097	9.220
Subtotal	1.355	4.798	4.546	1.374	4.768	3.092	3.768	5.108	28.809
Industrial									
Process Steam	.364	1.562	1.595	.996	3.023	4.018	1.771	1.321	14.591
Direct Heat	.103	.556	.608	.420	1.284	1.252	.605	.422	5.250
Electromechanical	.151	.605	.700	.727	1.002	.623	.480	.599	4.887
Naptha Feedstock	.102	.661	.580	.259	.505	.331	.164	.169	2.832
Gas Feedstock	.133	1.001	.661	.378	.926	1.177	.077	.466	4.760
Coal Feedstock	0.000	.054	.066	.045	.189	.004	.030	.004	.393
Subtotal	.851	4.381	4.210	2.825	6.990	7.406	3.128	2.921	32.713
Total	3.000	12.476	11.278	5.291	16.014	12.200	9.302	10.362	79.922

(Continued)

TABLE H-I-3 (d)

USABLE ENERGY FORECAST - NOMINAL CASE

2025

CATEGORY	DEMAND REGION 1	2	3	4	5	6	7	8	TOTAL
Residential/Commercial									
Space Heat	.494	2.813	1.397	.599	4.059	.913	1.078	1.618	13.769
Drying	.255	.797	.589	.298	.848	.466	.625	.638	4.506
Air Conditioning	.103	.271	1.354	.536	.429	.801	.443	.698	4.635
Electromechanical	.324	.859	.760	.322	1.013	.480	.504	.788	5.050
Subtotal	1.175	4.730	4.100	1.755	6.349	2.660	3.451	3.742	27.961
Transportation									
Automobile	1.131	2.871	3.397	1.333	4.170	2.256	2.858	3.058	21.074
Truck/Bus	.188	.631	1.007	.419	1.074	.666	.761	.932	5.079
Rail	.068	.224	.357	.160	.431	.290	.875	.520	2.946
Marine	.170	.738	.406	.100	.077	.580	0.000	.670	2.739
Aircraft	.621	3.086	2.550	.313	2.077	1.335	1.572	3.591	15.144
Subtotal	2.178	7.550	7.717	2.346	7.828	5.126	6.066	8.771	47.582
Industrial									
Process Steam	.565	2.300	2.635	1.651	4.812	6.487	2.775	2.212	23.436
Direct Heat	.165	.875	1.033	.717	2.100	2.069	.974	.726	8.659
Electromechanical	.250	.988	1.232	1.287	1.702	1.074	.603	1.072	8.408
Naptha Feedstock	.159	1.021	.967	.433	.907	.540	.260	.285	4.572
Gas Feedstock	.224	1.662	1.164	.679	1.598	2.063	.131	.738	8.280
Coal Feedstock	0.000	.084	.108	.075	.303	.006	.047	.007	.631
Subtotal	1.363	6.930	7.160	4.843	11.423	12.240	4.990	5.038	53.986
Total	4.717	19.210	18.977	8.944	25.599	20.026	14.507	17.551	129.530

2. Resource Data

The SRI energy model explicitly considers the following types of primary resources:

- o Domestic natural gas
- o Domestic crude
- o Shale oil
- o Western (low sulfur) coal
- o Eastern (high sulfur) coal
- o Nuclear fuel
- o Imported fuels
- o Hydroelectric and geothermal.

The availability and production costs of all the primary resources with the exception of imported fuels and hydroelectric and geothermal are described in terms of resource curves--the marginal cost of the next increment of production versus cumulative production--for each production region. Thus the model accounts for the increasing prices due to depletion. Oil and gas imports are handled by specifying the prices of imports exogenously; the nominal case assumes a continued strong cartel and thus that import prices increase over time. For hydroelectric and geothermal energy, which provide relatively small amounts of energy, both quantity and price are specified as inputs.

The resource curves for gas, oil, shale, coal, and nuclear fuel are shown in Chapter II, Figure 1. The price assumptions on imported fuels are summarized in Table H-I-4. (Recall that these nominal case import prices assume a continued strong cartel.) Hydroelectric and geothermal data are not included in this appendix because they have no major influence on the introduction of synthetic fuels.

TABLE H-I-4

PRICES OF IMPORTS
(1975 Dollars)

Year	Crude (dollars per barrel)	Liquid Natural Gas (dollars per Mcf)	Methanol (dollars per barrel)
1975	$11.00	$2.60	$10.04
1985	14.50	3.43	13.23
1995	16.01	3.78	14.61
2000	16.65	3.94	15.20

3. Process Economics Data

The SRI energy model requires data on the following types of processes:

- o Synthetic fuels production
- o Electric power generation
- o Transportation
- o Refining
- o Distribution
- o End-use conversion.

The nominal case process economics data for synthetic fuels production and electric power generation are given in Tables H-I-5 and H-I-6. Other process economics data are of lesser importance from the point of view of the Synthetic Fuels Commercialization Program and are thus omitted from this appendix.

The synthetic fuels process economics data are consistent with an estimate of synthetic process economics generated by Dr. Sid Katell, Bureau of Mines. Minor differences in product prices are due to different financial assumptions (investment tax credit, income tax rate, depreciation schedule) and different size plants. The nominal case hydrogen, solvent refined coal, fuel oil, and beneficiation [4/] were generated through the data review process noted earlier. The data presented in this section do not represent official opinion of Gulf Oil or SRI. The data set should be regarded as a summary of information available to the government, assembled for use in this analysis by SRI, and refined through the review process described above.

Careful definition of each of the data items in Table H-I-5 and H-I-6 will be included in a forthcoming SRI report. Such a description is available on a limited basis in an interim report issued in May 1975 by SRI to the Council on Environmental Quality.

[4/] Coal washing to remove pyritic sulfur.

TABLE H-I-5
SYNTHETIC FUELS PROCESS DATA

	Process	Year Available	Required Price 1/ ($/MMBtu)	Discount Rate (%)	Specific Capital Cost 2/ ($/MMBtu/Yr)	Specific Operating Cost ($/MMBtu)	Efficiency	Technological Change Limit	Technological Change Rate	Time to Construct	Book Life	Tax Life	Comments
99	High Btu Gas (Lurgi) LS/LBtu Coal	1986	$3.79	11.2	$ 8.09	$ .61	.555	.9	.01	4	25	20	
100	High Btu Gas (Lurgi) HS/HBtu Coal	1985	4.01	11.2	9.71	.97	.555	.9	.01	4	25	20	250 MMCF/day, byproducts burned or regasified, .97 MMBtu/MCF gas
158	High Btu Gas (Advanced) LS/LBtu Coal	1987	2.35	11.2	5.15	.52	.619	.9	.05	4	25	20	
159	High Btu Gas (Advanced) HS/HBtu Coal	1987	2.29	11.2	4.87	.54	.651	.9	.05	4	25	20	
108	Low Btu Gas (Lurgi) LS/LBtu Coal	1982	2.11	11.2	4.95	.37	.67	.9	.01	4	25	20	1200 MMCF/day, air blown, .15 MMBtu/MCF gas
109	Low Btu Gas (Lurgi) HS/HBtu Coal	1982	2.11	11.2	5.55	.60	.67	.9	.01	4	25	20	
116	Hydrogen LS/LBtu Coal	1985	2.26	11.2	4.95	.37	.55	.9	.01	4	25	20	500 MMCF/day, partial oxidation coal, .33 MMBtu/MCF
117	Hydrogen HS/HBtu Coal	1985	2.49	11.2	5.55	.50	.55	.9	.01	4	25	20	
148 [102]	Fuel Oil LS/LBtu Coal	1986	3.05 2.65	17.9 [13.2]	6.02	.60	.60	.65	.21	5	25	20	100,000 BBL/day 90% syncrude cost
147 [101]	Fuel Oil HS/HBtu Coal	1986	2.53 2.16	17.9 [13.2]	4.56	.56	.60	.84	.09	4	25	20	
140	Syncrude LS/LBtu Coal	1987	1.55	17.9	6.69	.71	.62	.65	.23	4	25	20	100,000 BBL/day
141	Syncrude HS/HBtu Coal	1987	2.74	17.9	5.07	.59	.572	.84	.03	4	25	20	
105	Methanol LS/LBtu Coal	1986	6.95	17.9	14.37	1.49	.502	.8	.05	5	25	20	5000 ton/day partial oxidation coal
107	Methanol HS/HBtu Coal	1986	7.07	17.9	14.37	1.49	.502	.8	.05	5	25	20	
106	Refined Solid LS/LBtu Coal	1986	2.02	13.2	6.33	.44	.70	.9	.05	4	25	20	100,000 BBL/day total liquids
105	Refined Solid HS/HBtu Coal	1985	1.87	11.2	3.83	.38	.7	.9	.05	4	25	20	
58	Thermo-catalytic decomp. water	1995	5.932	13.2	20.00	.75	.50	.9	.05	6	25	20	
20	Methanol High Btu Gas	1980	2.86	13.2	6.00	.60	.57	.9	.05	4	25	10	methanol from North Slope gas
52	Shale Oil Upgrading	1981	2.48	17.6	1.26	.15	.90	.35	.05	4	25	16	Upgrades raw shale oil to sweet syncrude
59	Benefaction HS/HBtu Coal	1980	1.050	13.2	5.00	.99	.50	.9	.01	4	25	20	Gravity separation, removes pyritic sulfur; only 6% of HS/HBtu coal can be cleaned to present EPA standards by this method.

1/ Assumes HS/HBtu coal @ $13/ton; LS/LBtu coal @ $7/ton; raw shale oil @ $11/bbl; 7% investment tax credit; double declining balance depreciation; nuclear fuel @ .34/MMBtu; high Btu gas feeding methanol plant @ $.50/MMBtu.

2/ Includes interest during construction.

TABLE H-I-6
ELECTRIC POWER PROCESS ECONOMICS

No	Process Description	Year Available	Capital Cost per kW of Capacity ($/kW)1/	Operating Cost Excluding Feedstock (mills/kWh)	Heat Rate (Btu/kWh)	Technological Change Limit	Technological Change Rate	Equity Fraction	Book Life (Years)	Tax Life (Years)	Time to Construct (Years)	Capital Cost per Annual MMBtu Capacity ($/MMBtu/yr)	Operating Cost per MMBtu ($/MMBtu)	Thermal Efficiency	Comments
43	Base load nuclear	1975	551	8	10,665	9	03	35	35	28	6	18 40	23	37	LWR, 1000 MW
178	Intermediate load nuclear	1975	687	1.0	11,370	9	.03	35	35	28	6	22 98	23	29	25% more expensive than base load nuclear plant to account for cycling
200	Base load advanced reactor	1995	809	1 5	n a	85	05	35	35	28	6	27 00	45	10 0	1000 MW
201	Intermediate advanced reactor	1995	1,017	2 0	n.a.	85	05	35	35	28	6	33 92	59	8 0	25% more expensive than advanced base load nuclear plant to account for cycling
50, 96	LS/LBtu coal power	1975	300	63	9,224	.9	02	35	30	28	4	10 07 11 79	18	37	
51, 97	HS/HBtu coal power	1975	353 380 447	1 55	9,151	875	.02	35	30	28	4	12 71 14 95	46	35	Includes stack gas desulfurization
111	High Btu gas boiler power	1975	215	.46	10,028	.9	.02	35	30	28	4	7 19	14	34	
49, 137	Low sulfur resid power	1975	235	.50	9,480	9	.02	.35	30	28	4	8 36	15	30	Stack gas desulfurization not required
110	SRC power	1982	275	.63	8,982	9	.02	.35	30	28	4	9 70	18	.38	
46	Gas turbine, high Btu gas	1975	123	1 25	13,652	.8	04	.35	15	10	1	4 11	37	25	
47	Gas turbine, distillate	1975	123	1 25	13,652	8	.04	35	15	10	1	4 11	37	25	
55	Gas turbine, methanol	1975	123	1.25	13,652	8	04	35	15	10	1	4 11	37	25	
112, 118	Combined cycle, LS coal	1982	450 529	2.47	11,376	85	04	.35	25	20	4	15 05 17 70	13	3	Includes low Btu gas from coal
113, 119	Combined cycle, HS coal	1982	475 558	2 47	11,376	85	04	35	25	20	4	15 89 18 69	13	3	
42	Combined cycle, methanol	1975	180	92	8,533	85	06	35	20	15	1	6 03	22	4	
53	Combined cycle, high Btu gas	1975	180	92	8,533	.85	06	35	20	15	1	6 03	22	4	Both steam and gas turbines
114	Combined cycle, distillate	1975	180	.92	8,533	85	06	35	20	15	1	6 03	22	4	
56	Shale oil power	1975	250	.50	9,480	.9	07	35	30	28	4	8 36	15	36	Same economics as resid power

LS/LBtu = low sulfur/low Btu
HS/HBtu = high sulfur/high Btu
SRC = solvent refined coal
MM = million
M = thousand
bbl = barrel
LWR = light water reactor

1/ Excludes interest during construction.

II. NOMINAL CASE PROJECTIONS

This appendix, discusses the nominal case in considerably more detail than Chapter II of the main text. The term nominal case is used to denote the base case, which uses the best estimate for each of the data items. Part of the nominal case data set was summarized in the previous section of this appendix, the remainder will appear in a forthcoming SRI report.

The nominal case discussion begins with a description of the supply-demand balance at the primary resource level. Then the discussion concentrates on the liquid and gaseous fuels markets, synthetic fuels, and finally, on various items of interest not only to the Synthetic Fuels Commercialization Program but energy policy makers in general. Note that all prices and volumes presented in this section are market clearing prices and volumes in the classical economic sense.

1. Primary Resources

The volumes and prices that balance supply and demand at the primary resource level are shown in Figures H-II-1 and H-II-2. The legend for the plots entitled "Total Primary Energy" requires a brief explanation. In order to find the production level for a particular fuel, find the curve overstruck with the symbol associated with that fuel in the legend. The production level for this fuel is the distance between the curve overstruck with its symbol and the curve immediately below it on the plot. This procedure applies to all plots that show production volumes. For plots that show prices, the price curve for a particular fuel is simply the curve on the plot that is overstruck with the symbol for that fuel listed in the legend. The equilibrium volumes and prices in Figures H-II-1 and H-II-2 reflect not only the effects of resource economics but also the effects of primary conversion, transportation, distribution, and end-use conversion economics on the demand for primary resources. The curves in Figures H-II-1 and H-II-2 are identical to Figures 2 and 3 in Chapter II through the year 2000, but are extended here to the year 2023. The discussion in Chapter II can be expanded to include the following statements:

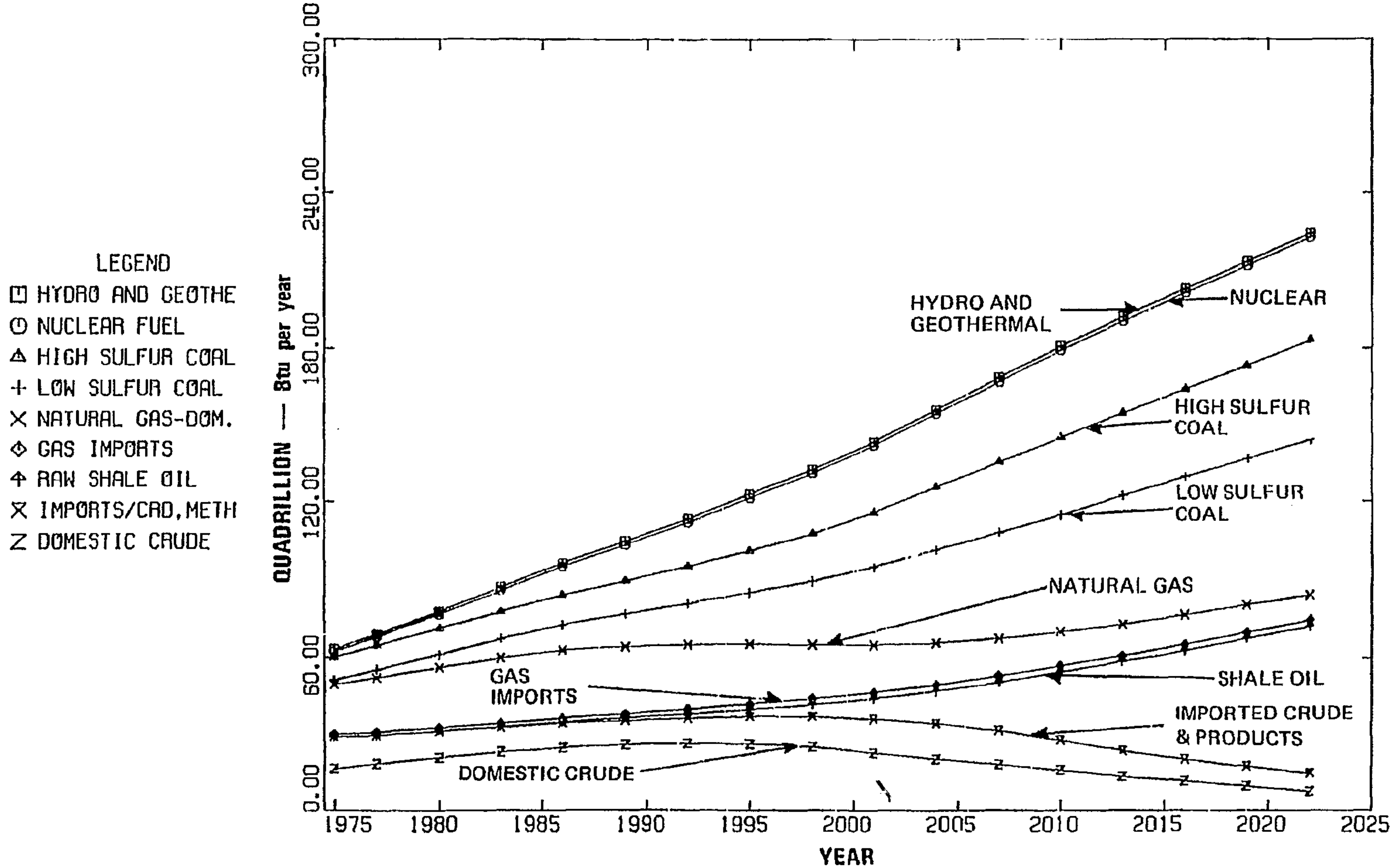
- The demand for primary energy grows from 63.4 quads in 1975 to 224.1 quads in 2023, which is roughly a 2.7% growth rate.

- Shale oil production grows dramatically between 1995 and 2023, becoming the second largest source of energy on a Btu basis in 2023. Shale production is 57.5 quads or 27.0 million bbl/day in 2023.

- The volume of imported crude remains surprisingly constant over the entire 48-year horizon.

- Domestic crude oil and natural gas are virtually exhausted in 2023; the major sources of energy in 2023 are coal, shale, and nuclear.

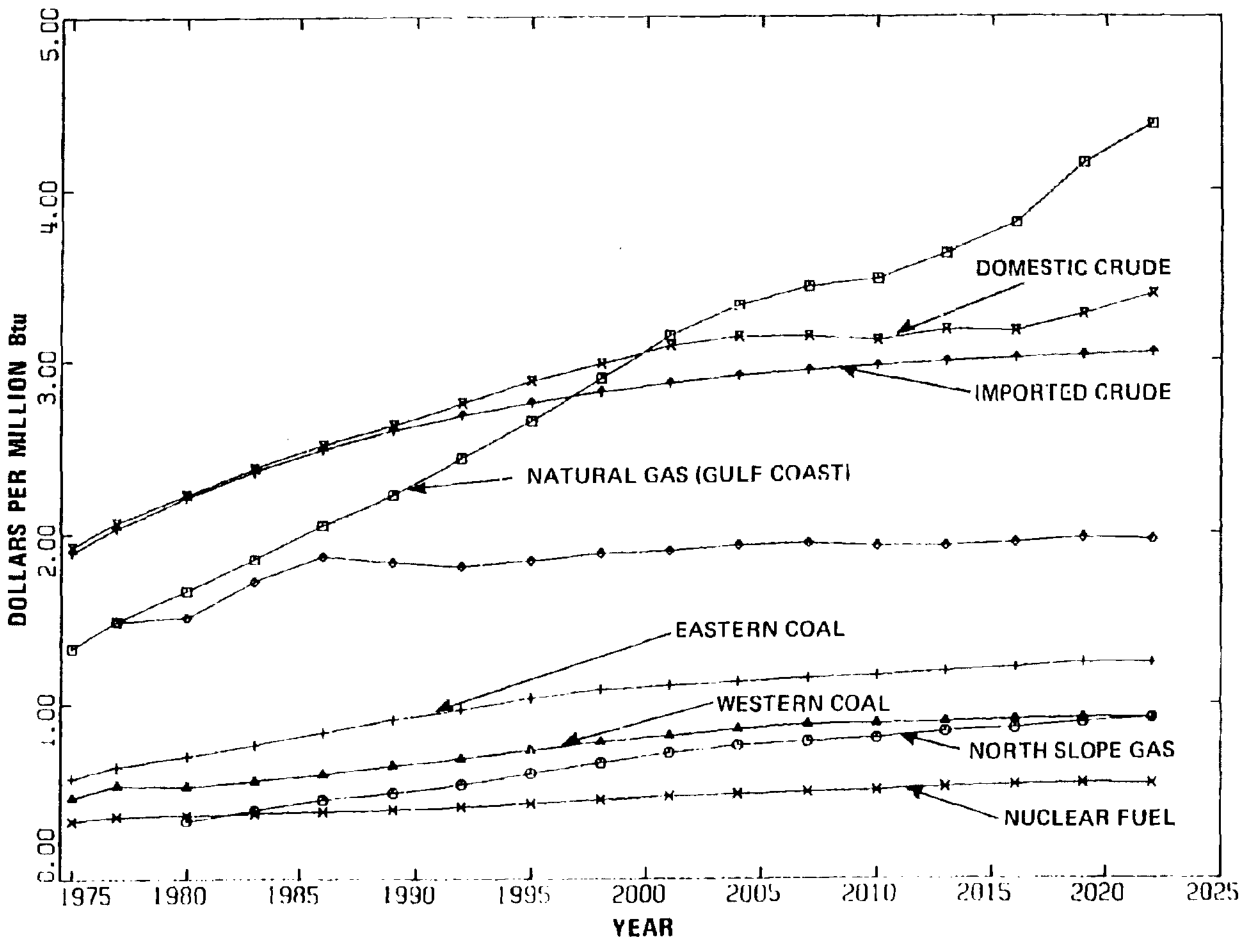
- Prices of coal, shale, and nuclear fuel are virtually constant



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE H-II-1

LEGEND
- ⊡ NAT.GAS/GULF CST
- ⊕ NAT.GAS/N. SLOPE
- △ POWDER RIV COAL
- + SO.ILL/W.KY COAL
- × NUCLEAR FUEL
- ◇ RAW SHALE OIL
- ⊕ CRD IMPRTS-DELVD
- ⊠ CRDE OIL/GLF CST



NOMINAL CASE —PRICES OF SELECTED PRIMARY RESOURCES BY LOCATION

FIGURE H-II-2

over the 48-year horizon because:

- Synthetic fuels are based on large resources of coal and shale, so that depletion effects are small.
- Learning effects offset depletion effects.

° Nuclear fuel holds a relatively constant share of the market from 1990 onward as virtually all base load power is nuclear and electricity is price competitive only in special markets.

2. Synthetic Fuels

Synthetic fuels are principally aimed at two markets: the gaseous fuel market and the liquid fuel market. The aggregate of the liquid and gaseous fuels markets is discussed in Chapter II of the main text whereas this appendix discusses the two separately.

The demand for gaseous fuels will be filled from one of the following sources:

- Domestic natural gas production
- Gas imports
- Synthetic gases
  - High Btu gas
  - Low Btu gas
  - Hydrogen

Correspondingly, the demand for liquid fuels will be filled from one of the following sources.

- Domestic crude oil production
- Crude imports
- Synthetic liquids
  - Coal syncrude
  - Shale syncrude
  - Utility fuel oil
  - Solvent refined coal
  - Methanol

In the simplest sense, synthetic gases are designed as substitutes for natural gas, and synthetic liquids are designed as substitutes for crude oil or refinery products. Thus, the term gaseous fuels will be assumed to include direct substitutes for natural gas, and liquid fuels will be assumed to include direct substitutes for crude oil and refinery products. The discussion of liquid and gaseous fuels will be confined to the 1975-2000 period to be consistent with Chapter II of the main text. Later in this text the discussion will return to the period 1975-2023.

3. Gaseous Fuels Market

Figure H-II-3 illustrates the production of synthetic gas over time, the corresponding price of synthetic gas, and the size of the synthetic gas industry expressed in terms of dollar sales. The dollar sales over time curve is simply the product of the synthetic gas production and the synthetic gas price over time. Figure H-II-4 compares the volume, price and sales of synthetic gas to those of natural gas and imported gas. Several important aspects are noted below:

- High Btu gas is produced from western and eastern coal in roughly equal volumes.
- High Btu gas from second generation technology is attractive; Lurgi technology with methanation is unattractive.
- Low Btu gas from coal and hydrogen from coal exceed high Btu gas from coal in the short term, but high Btu gasification grows most rapidly.
- Nuclear power and coal replace natural gas in the electric utility industry.
- The market share of high Btu gas in the industrial sector declines during the forecast period. It is partially replaced by low Btu gas, hydrogen, and direct use of coal.
- Residential and commercial use of gaseous fuels grows slightly, but most of the growth in demand is supplied by electricity.
- Low Btu gas and hydrogen are limited by the transportation costs of coal, low Btu gas, and hydrogen.
- Total dollar sales of natural gas peaks six years after domestic production of gas because the price rises faster than production declines.

The sales of gas reveal the strength of the gas industry both with regard to the level of production and to the price. The interesting trend to note is that natural gas is initially strengthened because of rising prices but later weakened because of falling production, while synthetic gas is initially weak but grows rapidly because of high prices. Data

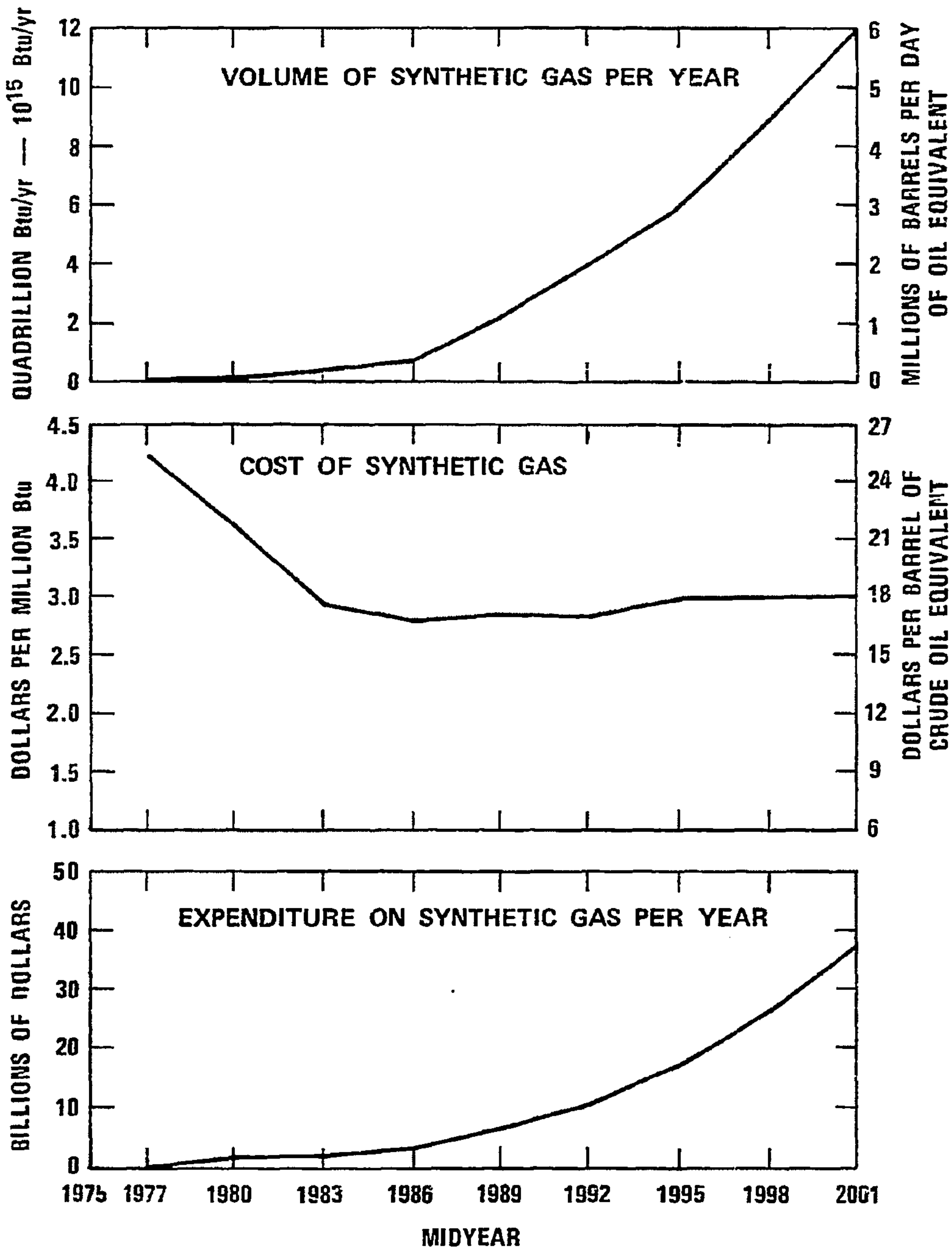


FIGURE H-II-3 SYNTHETIC GAS PRODUCTION: NOMINAL CASE

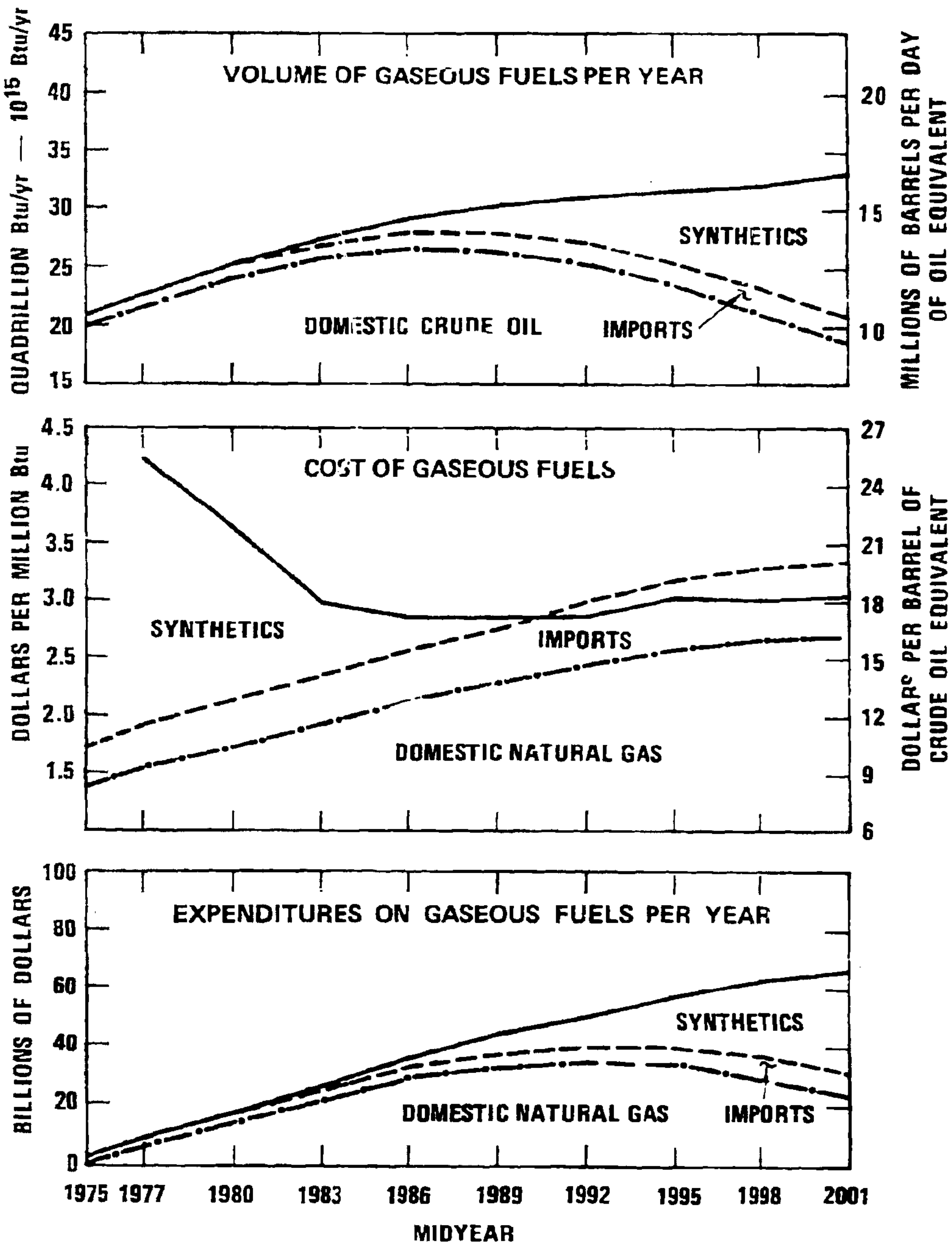


FIGURE H-II-4 GASEOUS FUELS: NOMINAL CASE

TABLE H-II-1

GASEOUS FUELS - NOMINAL CASE

Year	Volume (quadrillion [10^{15}] Btu/year)				Average Cost (1975 dollars per million Btu/year)				Expenditures (billions of 1975 dollars/year			
	Domestic Natural Gas	Gas Imports	Synthetic Gas	Total Gaseous Fuels	Domestic Natural Gas	Gas Imports	Synthetic Gas	Total Gaseous Fuels	Domestic Natural Gas	Gas Imports	Synthetic Gas	Total Gaseous Fuels
1975	19.708	1.015	0.000	20.723	1.38	1.73	--	1.40	27.197	1.756	0.000	28.953
1977	21.439	1.096	0.020	22.555	1.56	1.93	4.20	1.58	33.445	2.115	0.084	35.644
1980	23.727	1.219	0.116	25.062	1.73	2.13	3.60	1.76	41.048	2.596	0.418	44.062
1983	25.507	1.342	0.437	27.286	1.94	2.34	2.93	1.96	49.484	3.140	1.280	53.904
1986	26.402	1.474	1.074	28.950	2.14	2.56	2.80	2.19	56.500	3.772	3.007	63.279
1989	26.024	1.619	2.294	29.937	2.29	2.75	2.85	2.36	59.595	4.452	6.534	70.581
1992	25.054	1.780	3.889	30.723	2.45	2.97	2.84	2.53	61.382	5.287	11.039	77.700
1995	23.263	1.965	6.083	31.311	2.58	3.16	3.00	2.70	60.019	6.209	18.232	84.460
1998	20.852	2.178	8.846	31.876	2.66	3.27	3.00	3.01	55.466	7.122	26.587	89.175
2001	18.339	2.329	12.147	32.815	2.70	3.34	3.00	2.86	49.515	7.779	36.466	93.750

used to construct Figures H-II-3 and H-II-4 can be found in Table H-II-1.

4. Liquid Fuels Market

Figure H-II-5 illustrates the production of synthetic liquids over time, the corresponding price of synthetic liquids, and the size of the synthetic liquids industry expressed in terms of dollar sales. The dollar sales over time curve is the product of the volume and price. Figure H-II-6 compares the volume, price, and sales of synthetic liquids to domestic crude and imported crude. The important aspects of liquid fuels are:

- Most synthetic liquids are produced from shale.
- Residual fuel oil and syncrude from coal are economically unattractive; solvent-refined coal is moderately attractive.
- Most liquid fuels such as gasoline and distillate are consumed in the transportation sector.
- Liquid fuels maintain their market share in the industrial sector.
- Residential and commercial use of liquid fuels increases slightly, but electricity supplies most of the growth in demand.
- Distillate turbines are used in peak power generation.
- Total dollar sales of domestic crude peak three years after domestic production of crude peaks because the price rises faster than domestic production declines.

As in the case of gas, the domestic crude oil industry is initially strengthened because of rising prices, but then declines because of falling production. The data underlying Figures H-II-5 and H-II-6 can be found in Table H-II-2.

5. Total Synthetic Fuels

Figure H-II-7 shows the production of synthetic fuels over time. Note that synthetics are dominated by shale syncrude and high Btu gas from coal. Figure H-II-7 extends Figure 8 in the main text through the year 2023.

The following statements can be inferred from the data:

- In terms of Btu's produced, oil shale is the largest synthetic fuel industry from 2000 on; high Btu gas is the largest through 2000.

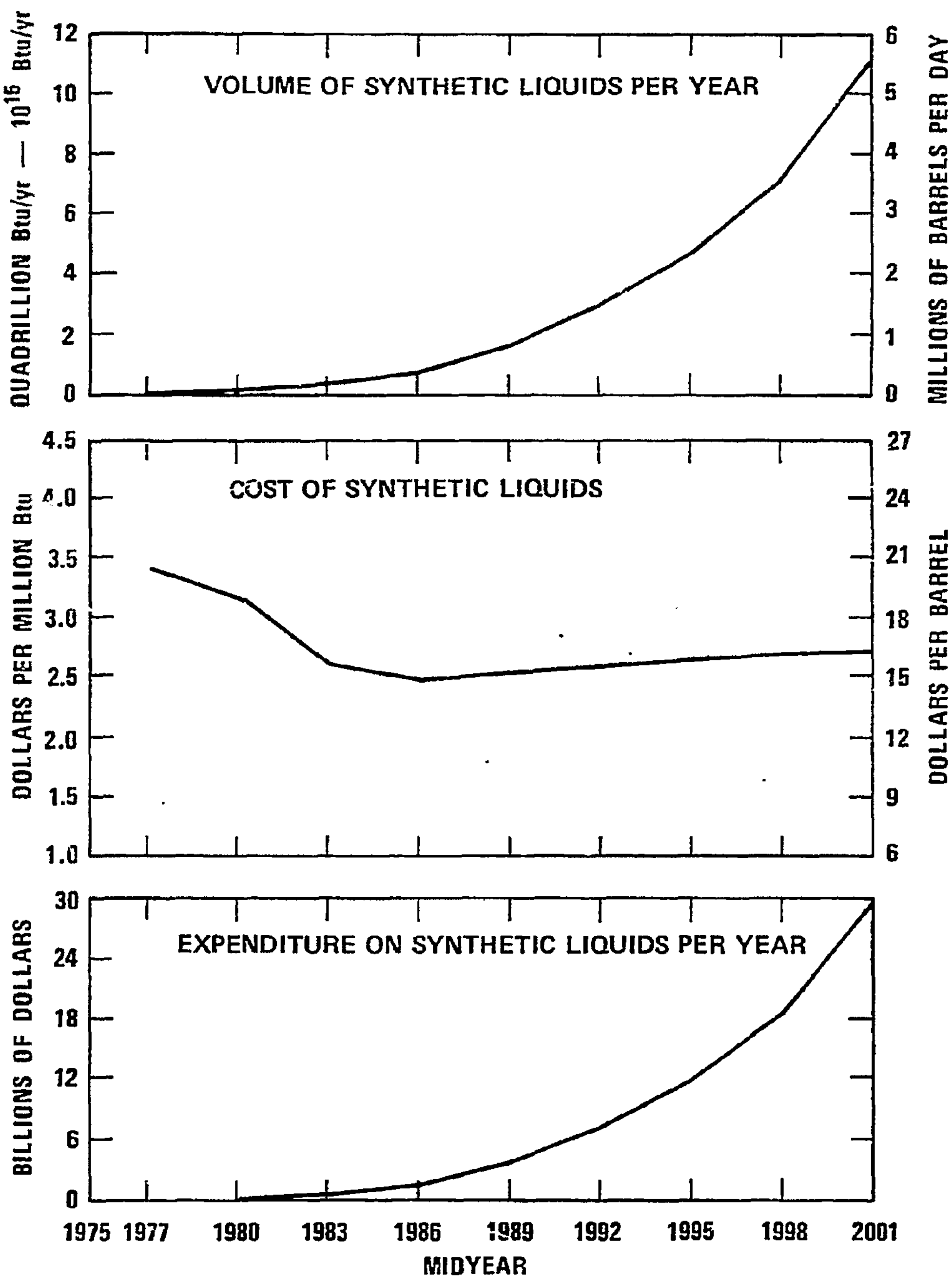


FIGURE H-II-5 SYNTHETIC LIQUIDS: NOMINAL CASE

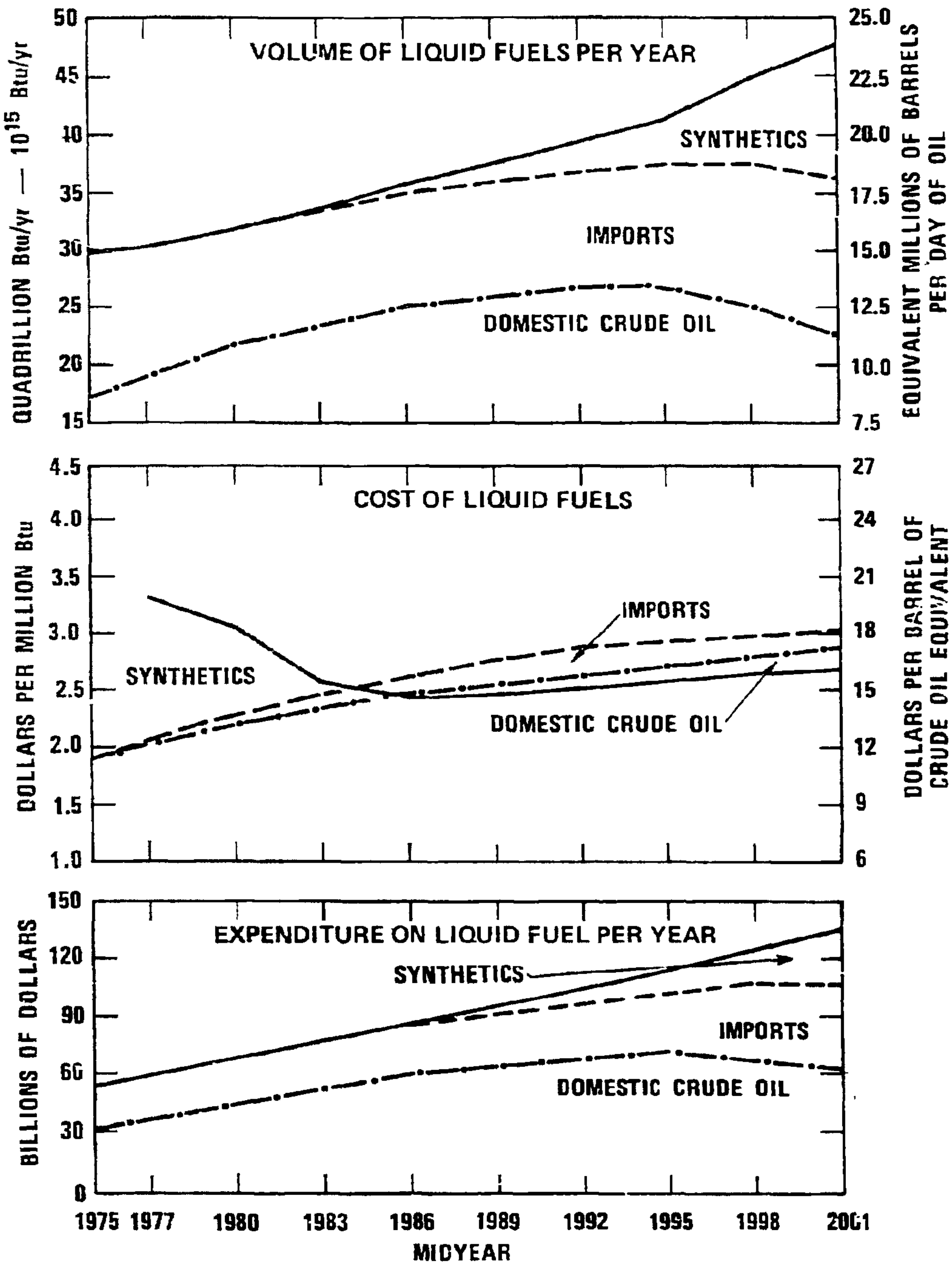
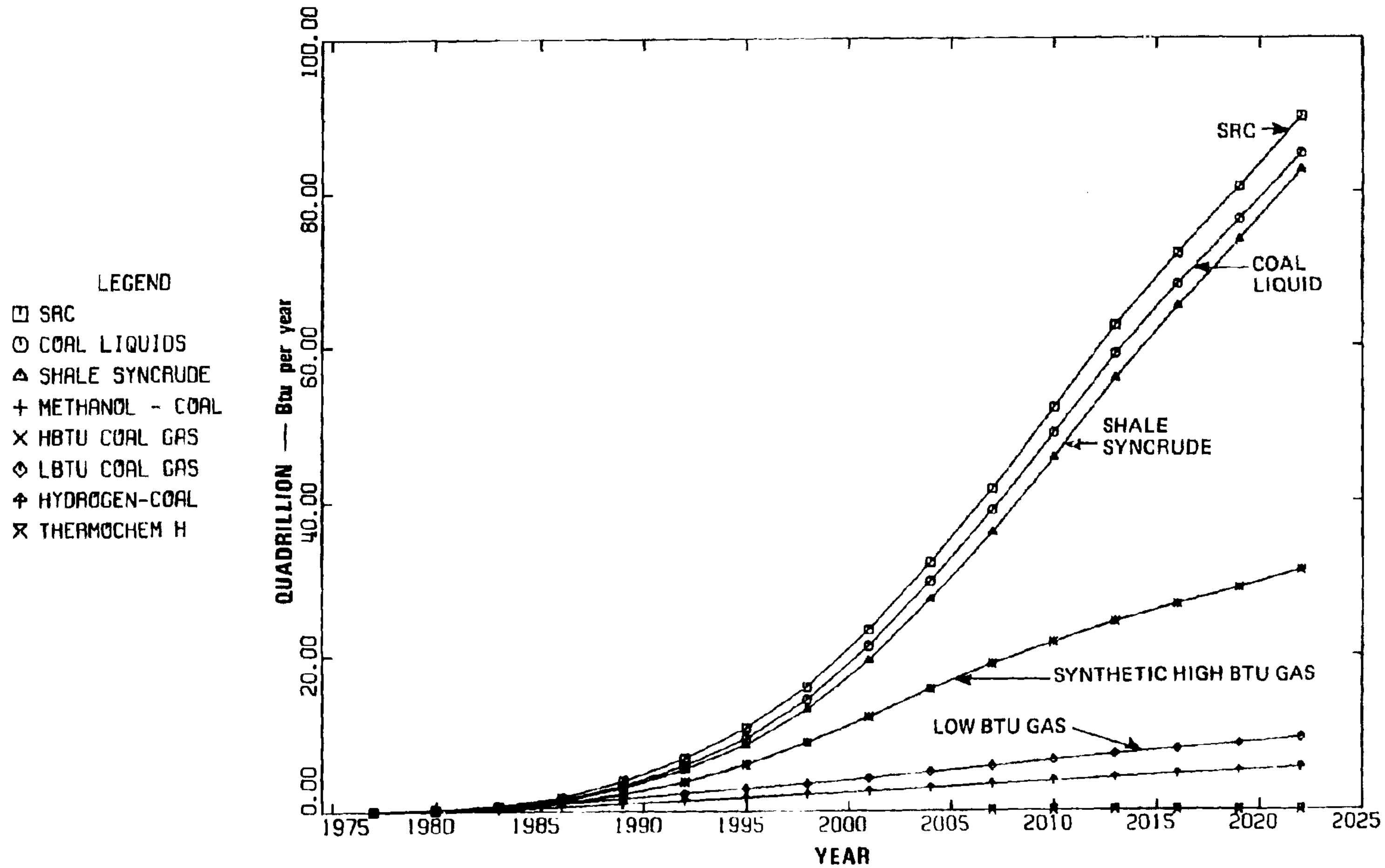


FIGURE H-II-6 LIQUID FUELS: NOMINAL CASE

TABLE H-II-2

LIQUID FUELS - NOMINAL CASE

Year	Volume Quadrillion Btu/year - 10^{15} Btu/year				Average Cost 1975 Dollars per million Btu/year				Expenditures Billions of 1975 Dollars/year			
	Domestic Crude Oil	Liquid Fuels Imports	Synthetic Liquids	Total Liquid Fuels	Domestic Crude Oil	Liquid Fuels Imports	Synthetic Liquids	Total Liquid Fuels	Domestic Crude Oil	Liquid Fuels Imports	Synthetic Liquids	Total Liquid Fuels
1975	16.607	12.570	0.000	29.177	1.92	1.90	--	1.91	31.885	23.883	0.000	55.768
1977	18.555	11.308	0.006	29.869	2.06	2.05	3.33	2.06	38.223	23.294	0.020	61.537
1980	21.100	10.400	0.027	31.527	2.21	2.30	3.11	2.24	46.631	23.920	0.084	70.635
1983	23.108	9.961	0.249	33.318	2.36	2.46	2.56	2.39	54.535	24.504	0.638	79.677
1986	24.750	[illegible].799	0.747	35.296	2.48	2.61	2.44	2.45	61.380	25.575	1.821	86.776
1989	25.957	9.736	1.694	37.387	2.56	2.77	2.49	2.61	66.450	26.969	4.212	97.631
1992	26.613	10.010	3.[illegible]7	39.630	2.64	2.87	2.53	2.69	70.258	28.729	7.608	106.595
1995	26.455	10.864	4.[illegible]31	41.976	2.73	2.92	2.59	2.76	72.222	31.723	12.066	116.011
1998	25.168	12.105	7.144	44.417	2.80	2.99	2.63	2.82	70.470	36.194	18.772	125.436
2001	22.786	13.386	11.161	47.333	2.87	3.05	2.65	2.87	65.396	40.827	29.583	135.810



SYNTHETIC FUEL PRODUCTION

FIGURE H-II-7

- In the year 2000, coal liquids, solvent-refined coal, low Btu gas, and hydrogen together produce about the same amount of energy as oil shale.

- Methanol from coal and thermochemical decomposition of water are not attractive.

- It is difficult to justify the so-called hydrogen economy; hydrogen is unattractive due to high production, transportation, and distribution costs.

a. Methane

Methane from coal (high Btu gas) is quite attractive as shown in Figure H-II-7; Figure H-II-8 illustrates the sources of methane in the U. S. As can be seen, domestic gas production peaks in the early 1980's and falls rapidly, being replaced by North Slope gas and synthetic gas from coal.

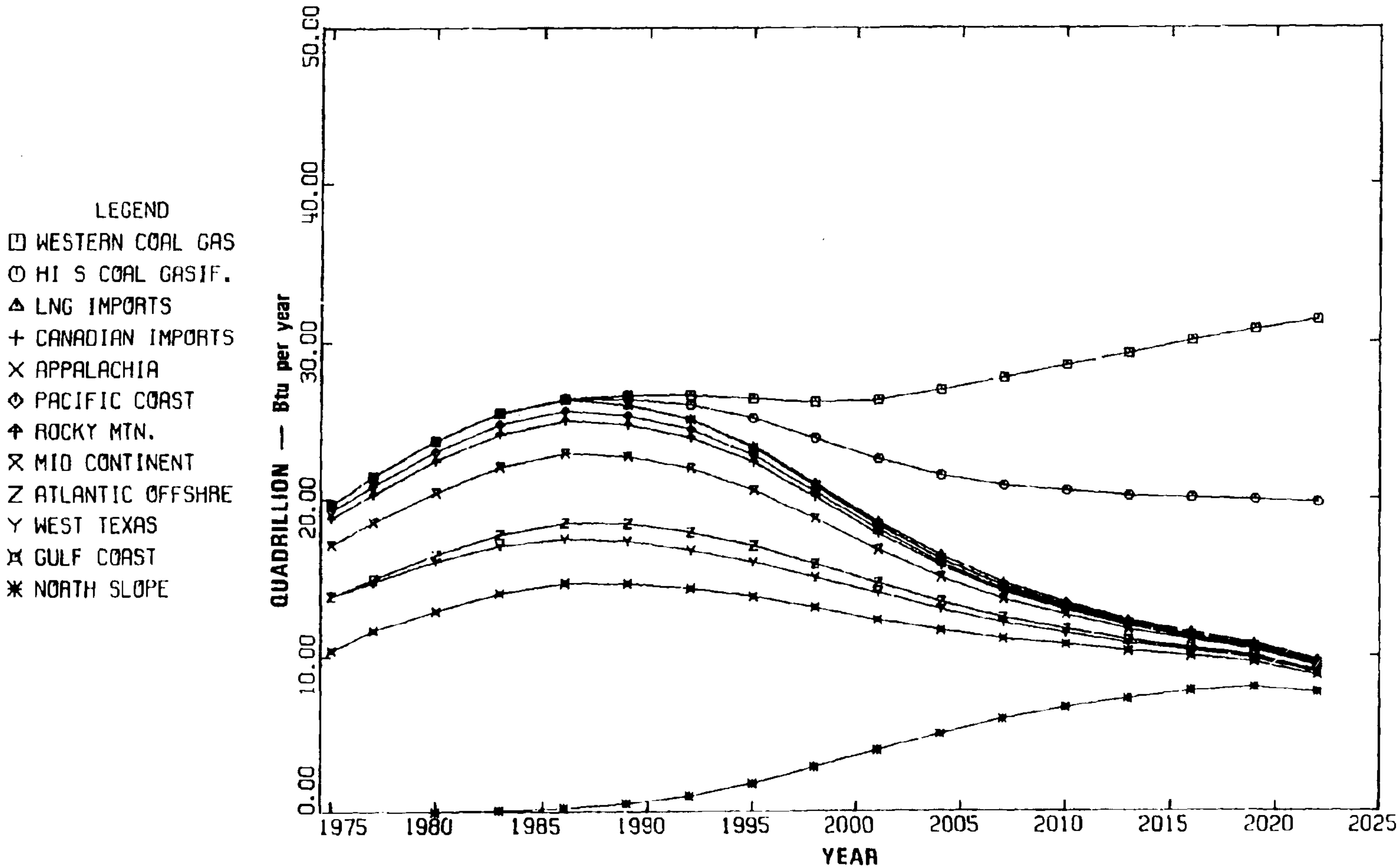
[Note that the early increase in domestic production has not properly accounted for lag time between higher gas prices and higher gas production between 1975 and 1980. Data generated by the SRI Energy Model for the first five years may not be accurate because decisions made during the past several years that affect the first several years in the model's time horizon have not been explicitly modeled. The model was built to analyze long-term decisions; the effect of initial decisions and conditions in 1975 is negligible by the early 1980's.]

Referring again to Figure H-II-8, note that synthetic methane captures 50% of the total market by about 2010. North Slope gas escalates rapidly in the early 1990's but is slowed several years later because of the price limitation imposed by synthetic gas. It should be pointed out that data on North Slope gas is optimistic; thus, a sensitivity was run with lower North Slope gas availability and the effect on the energy balance was slight. Finally, the volume of LNG imports is negligible due to their high cost.

b. Liquid Fuels

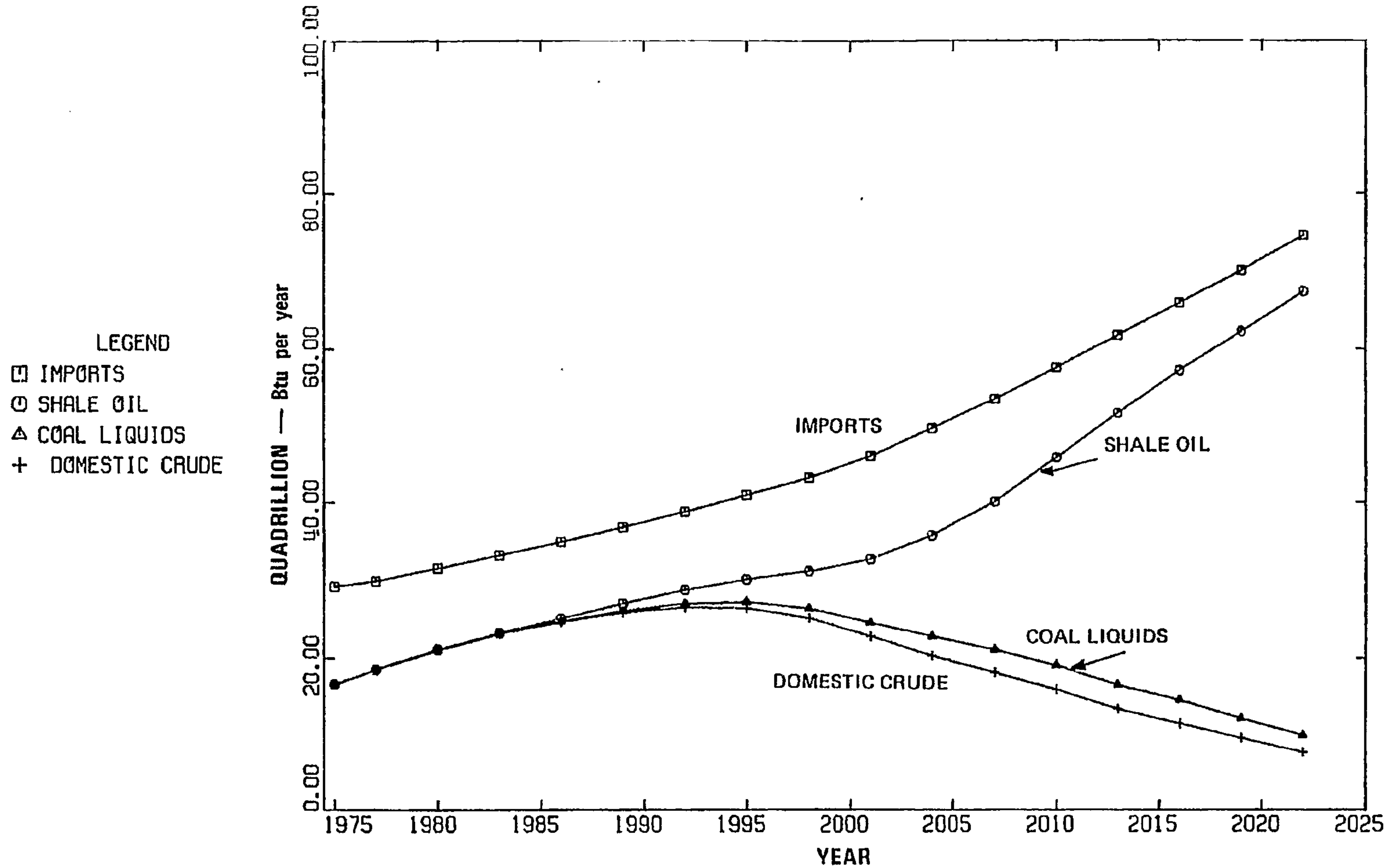
Figure H-II-9 illustrates the sources of liquid fuels as computed in the nominal case. As discussed earlier, domestic production peaks in 1993 and then declines because it is no longer price competitive. The domestic oil production envelope in Figure H-II-9 is "Hubbert's pimple" as projected by the SRI Energy Model. Price-quantity relationships are used to predict the "pimple" in the context of economic equilibrium rather than extrapolation of past trends.

The remainder of the liquid fuels market is satisfied by imports and shale oil. Initially, imports fill the entire gap, but shale oil production increases dramatically after 1995. The bulge in imports in 2000-2010 results from shale oil growing so fast that shortages in key secondary materials are experienced; consequently higher short-term prices occur. By 2010, the short-term effects are largely gone, and shale oil prices drop due to an easing in the secondary materials market. Thus,



NOMINAL CASE—HIGH Btu GAS PRODUCTION AND IMPORTS

Figure H-II-8



NOMINAL CASE—SOURCES OF LIQUID FUELS

FIGURE H-II-9

shale oil captures 46% of the liquids market by about 2010 and 77% by 2023.

c. Electric Utilities

The electric utility sector of the U. S. energy market is a large consumer of fuel, competing for most industrial and residential fuels. Interfuel competition in the electric utility sector is complex because electric power generating plants range from extremely capital intensive nuclear power plants to extremely low-capital gas turbine plants.

The electric utility sector is assumed to produce three types of power as defined by the load duration curve: base, intermediate, and peak. Figure H-II-10 illustrates the national total base load power generation by various plants. Note that gas and liquid fuels are replaced rapidly by coal to some degree and nuclear power to a large degree. The reason is that either nuclear fuel or coal can produce the least expensive base load power, depending on coal transportation distances. On the average, however, the cheapest base load power comes from nuclear fuel.

Note that second generation nuclear technology is relatively unimportant having only a small effect after 2010. Base load power represents roughly 70% of the total energy generated by electric utilities and hence is the most important with regard to interfuel competition.

Figure H-II-11 illustrates intermediate load power generation for the entire U. S. by fuel type. Intermediate load power is completely dominated by coal. Methane and resid lose market share rapidly.

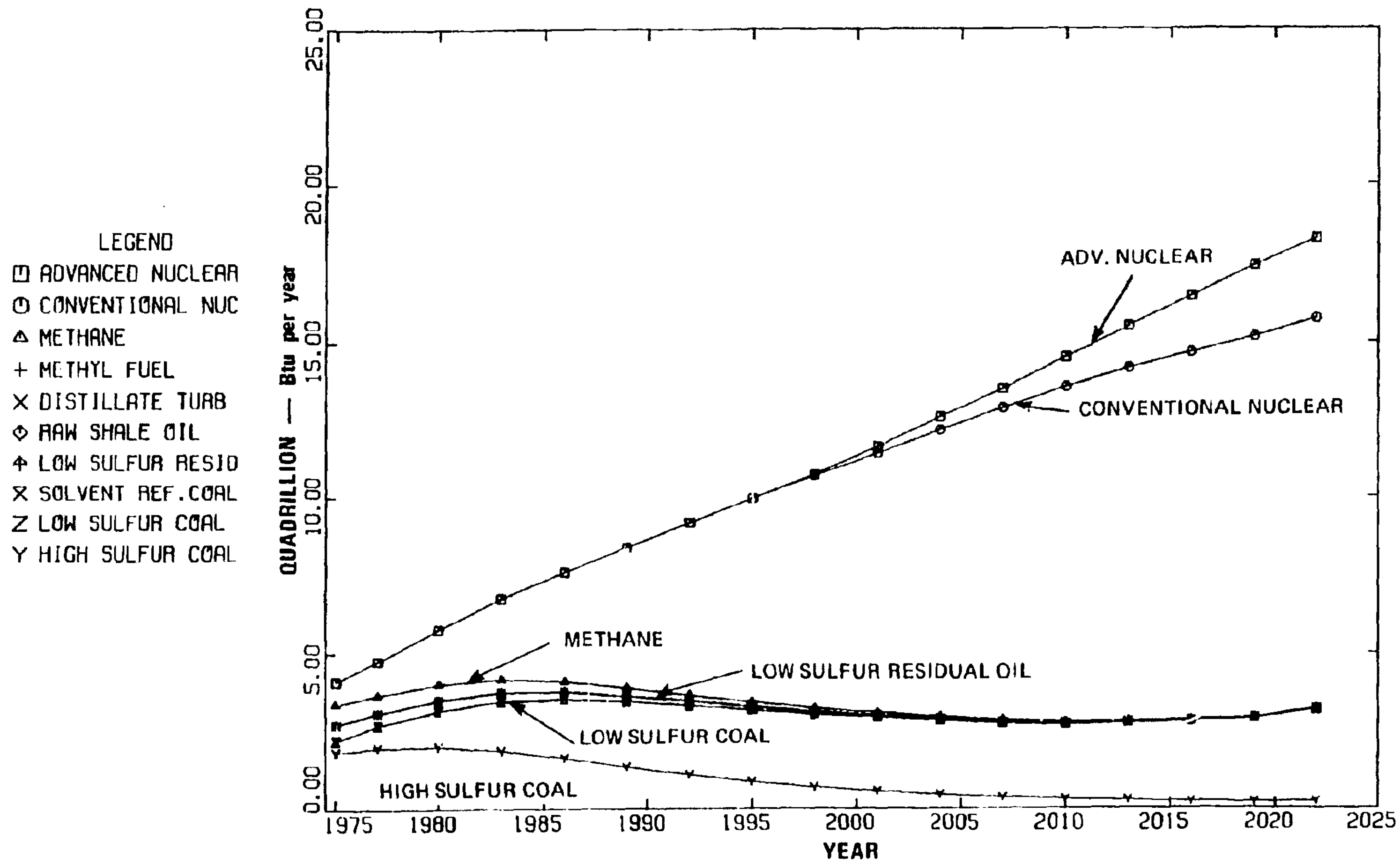
Figure H-II-12 represents peak power generation for the entire U. S. Peak power is generated by an assortment of plants including high Btu gas plants, distillate turbine, resid, and low sulfur coal. The increase in peak power generation from gas is due to old gas plants moving from base and intermediate to peak power generation. Peak power accounts for only about 5% of the total energy generated by electric utilities; thus it has a minor effect on interfuel competition. However, it has a significant effect on the price of electricity due to its high cost.

6. Product Volumes and Prices

Figure H-II-13 shows the volumes of distributed products in the east north central region (Chicago market) consistent with the nationwide supply-demand balance. Implicit in this balance are the economics of primary resource production, conversion processes, transportation, distribution, and end-use conversion processes. The surprising feature of this figure is that market shares remain relatively constant. The implication is that distributed products will almost always be similar to those at present whereas the sources of these products will be substantially different. The reason for such consistency is obvious when the prices of distributed products are shown.

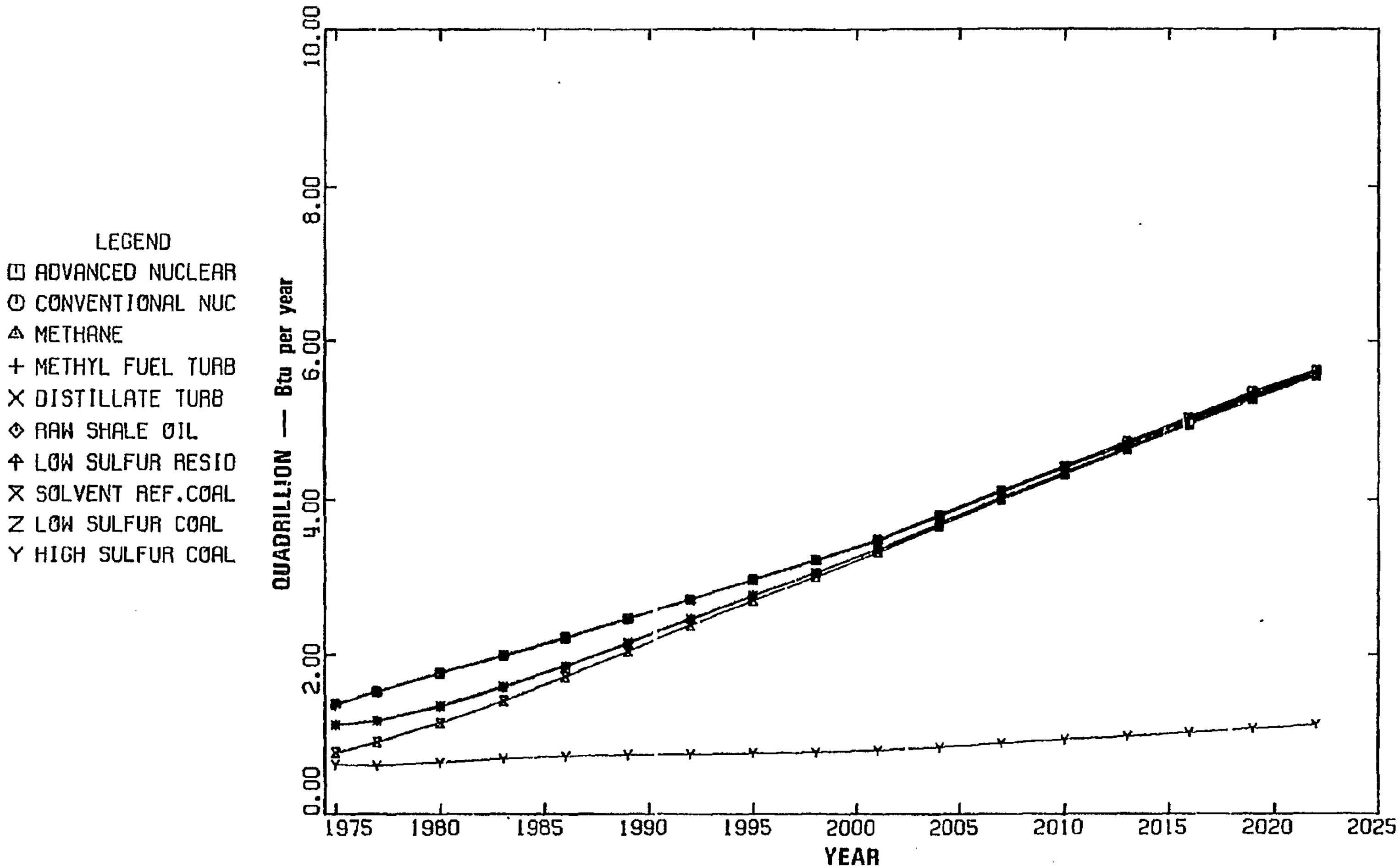
Figure H-II-14 shows the market clearing prices of distributed products in the industrial sector of the east north central region. Note how flat all prices are. Domestic gas and oil prices increase until 1985-1990, when they reach the prices of synthetic gas and imported crude. The key observation is that prices do not change relative to each other; thus market shares will not change, as demonstrated in Figure H-II-13. (The large price decreases of some fuels in 1980-1985 are the result of mathematics in the model and should be ignored.)

Figure H-II-14, illustrates another important fact: the electric economy is difficult to justify. Distributed electricity is much more expensive than even the premium distributed liquid or gas -- $7.40/MMBtu for electricity versus $3.50/MMBtu for distillate or methane. The electric economy could be justified only if the prices of electricity and liquid and gaseous fuels become closer over time; the constant prices in Figure H-II-14 do not predict such a crossing. The reason is simply that electricity competes directly with many of the fuels used to produce it. Thus the differential between electricity prices and other fuel prices is set by electric power generation costs.



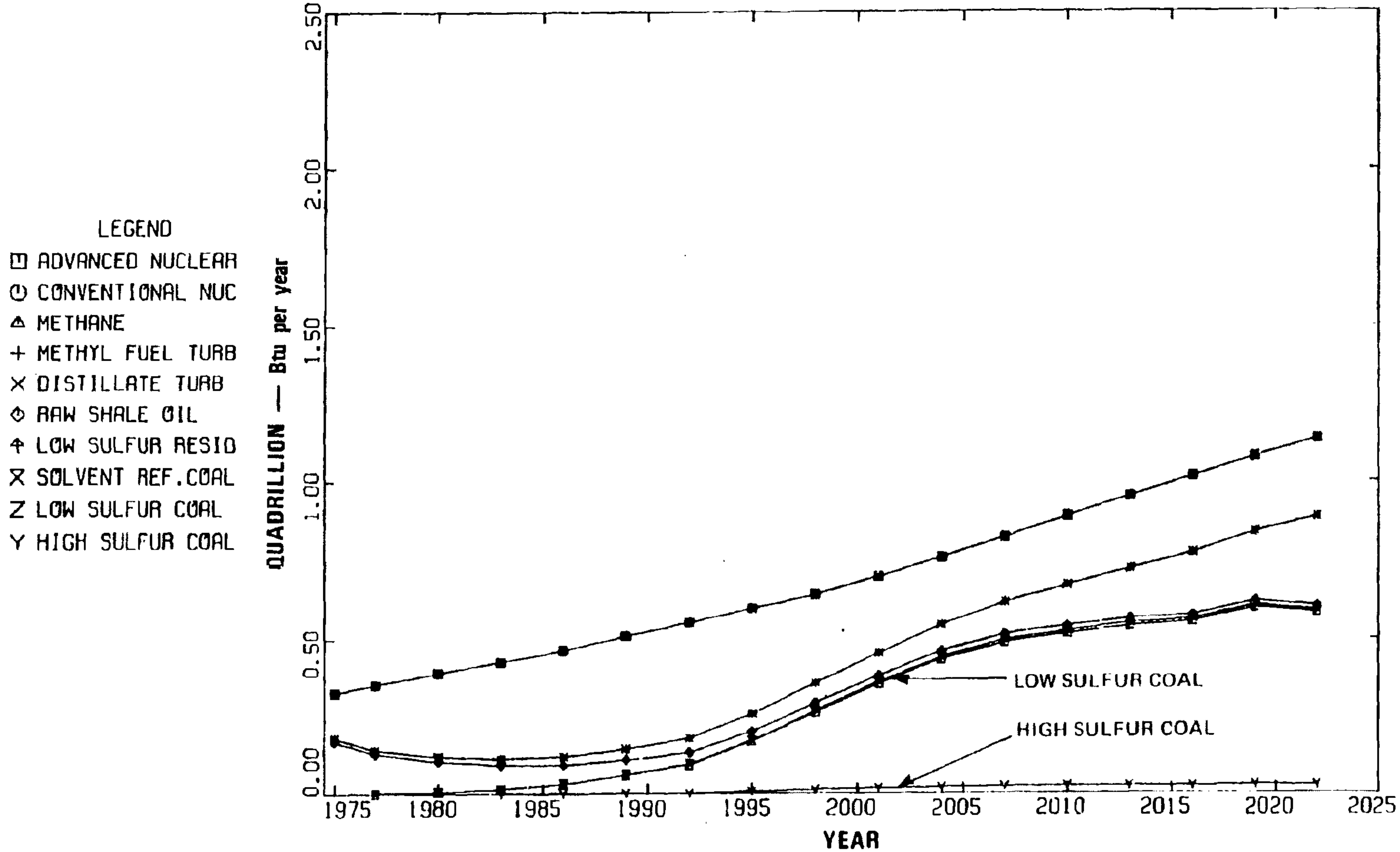
NOMINAL CASE---TOTAL BASE LOAD ELECTRIC POWER GENERATION

FIGURE H-II-10



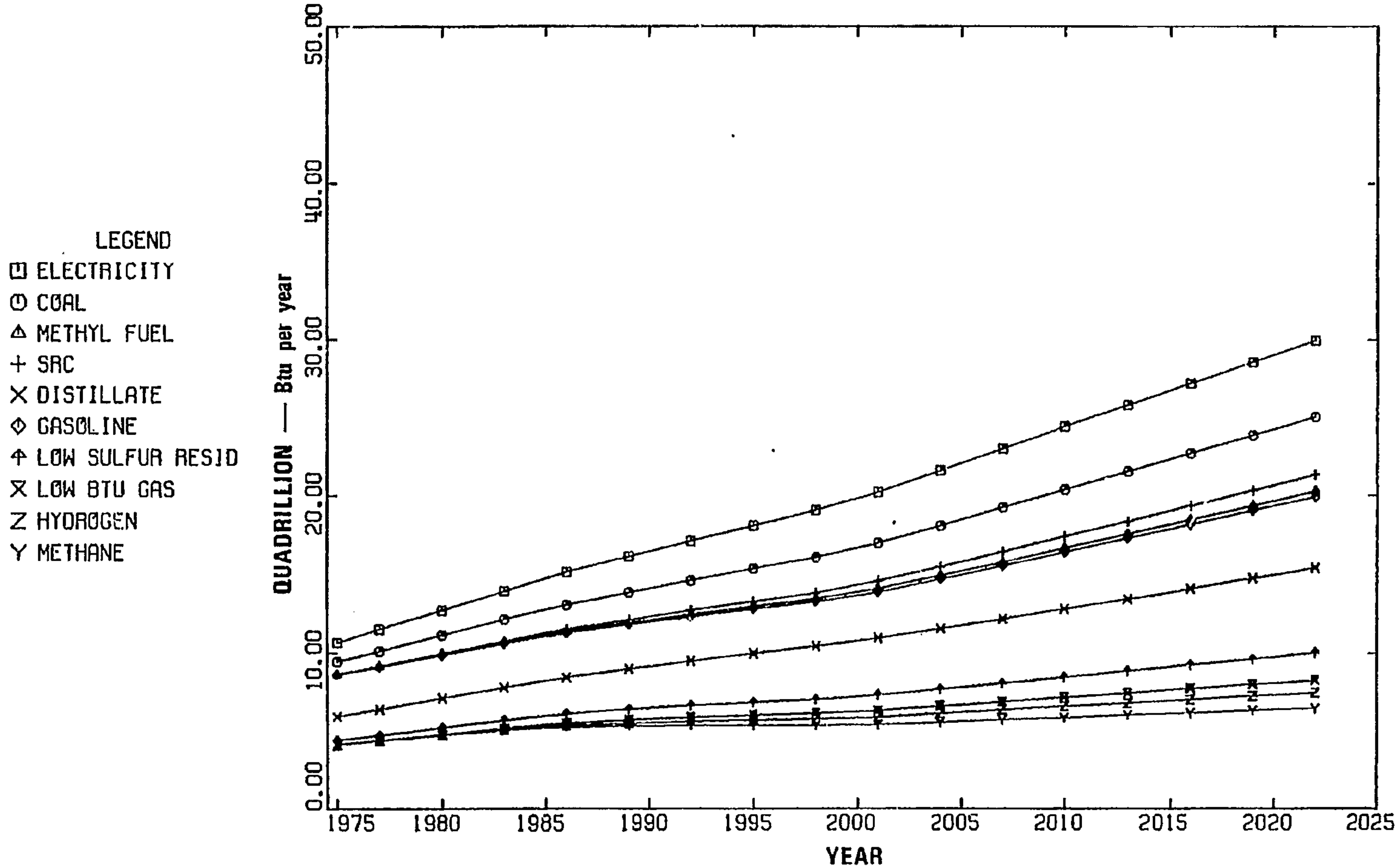
NOMINAL CASE—TOTAL INTERMEDIATE LOAD ELECTRIC POWER GENERATION

FIGURE H-II-11



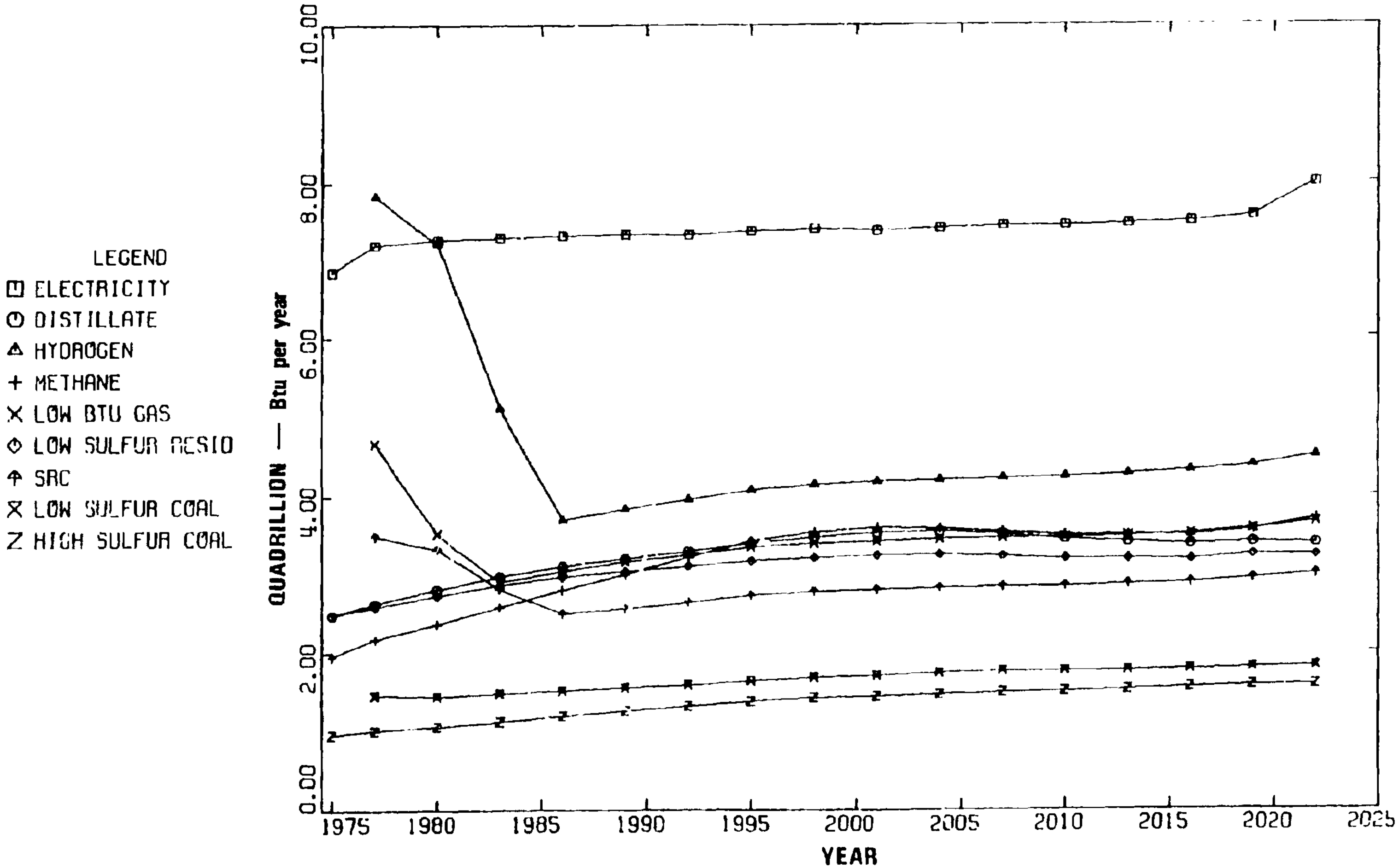
NOMINAL CASE—TOTAL PEAK LOAD ELECTRIC POWER GENERATION

FIGURE H-II-12



DISTRIBUTED PRODUCTS – EAST NORTH CENTRAL REGION

FIGURE H-II-13



NOMINAL CASE—AVERAGE PRICES OF INDUSTRIAL FUELS AT PLANT GATE/EAST NORTH CENT

FIGURE H-II-14

III. SENSITIVITY ANALYSIS

The sensitivity analyses presented in this section illustrate the effect on the energy projections--in particular, those for synthetics and imports-- of uncertainty in key variables. The sensitivity cases discussed in Chapter II of the main report are expanded here. In addition, sensitivities to other variables are presented. The variables which were examined are:

- Import prices, high and low.
- Availability of domestic oil and gas, high and low.
- Cost of synthetic fuels, high and low.
- Demand, high and low.
- Nuclear availability, high and low.
- Shale cost, high only.
- Synthetics timing, five-year delay.
- Synthetic gas cost, high and low.
- Penalty on industrial burning of coal.
- Coal cost, high and low.
- DCF rate, high only.
- No hydrogen.
- High import price with high and low availability of domestic oil and gas.
- High import price with high synthetics cost.

The results of these sensitivity analyses are summarized in Table H-III-1. The table shows (1) domestic production, imports, and synthetics in the liquid and gaseous fuels markets, and (2) the prices of certain distributed fuels. Using this table, the different sensitivity cases can be directly compared. Note, however, that large changes in an outcome variable do not necessarily reflect extreme sensitivity --the changes in the sensitivity variable must also be considered and its range of values checked for reasonableness. Only then should a judgement be made about the effect of a particular input variable on a particular outcome variable.

VOLUMES AND PRICES OF ENERGY IN THE UNITED STATES, 1986 AND 1995

Material	Nominal Case	Low Import Price	Constant Import Price	High Import Price	Low Oil and Gas	High Oil and Gas	Low Synfuel Price	High Synfuel Price	Low Demand	High Demand	Synfuel Delayed Five Years	Low Nuclear Availability	High Nuclear Availability
Volume (quadrillion Btu/year)													
1986													
Syngas[a]	1.071	0.713	0.867	1.170	1.113	0.827	1.328	[illegible]	0.910	1.189	0.528	1.018	0.981
Shale liquids[b]	0.310	0.009	0.116	0.761	0.399	0.171	1.001	1.007	0.309	0.558	0.010	0.285	0.311
Coal liquids[c]	0.107	0.227	0.292	0.361	0.181	0.278	0.596	[illegible]	0.388	0.115	0.174	0.168	0.391
Total synthetics	1.821	0.979	1.275	2.301	2.293	1.276	2.925	0.819	1.676	2.372	0.721	1.731	1.710
Oil imports	9.791	18.175	12.595	4.181	11.557	4.288	8.219	10.788	7.116	17.265	10.507	10.161	9.616
Total synthetics and imports	11.615	19.151	13.870	6.985	16.850	5.561	11.171	11.637	[illegible]	19.637	11.228	11.892	11.365
Domestic oil	21.750	18.918	23.212	28.823	20.560	30.078	25.359	21.191	[illegible]	21.805	21.651	21.768	21.766
Domestic gas	26.103	25.196	26.798	26.660	21.231	30.130	26.901	25.790	25.213	28.965	26.311	26.936	26.195
Gas imports	1.173	3.180	1.612	1.470	1.557	1.470	1.172	1.482	1.471	1.611	1.175	1.177	1.173
Total gas	27.876	28.676	28.113	28.130	25.788	31.600	28.173	27.272	26.681	[illegible]	27.801	28.113	27.668
1995													
Syngas[a]	6.081	9.750	3.718	1.180	9.039	1.018	7.936	2.771	4.320	11.06[illegible]	4.365	6.010	[illegible]
Shale liquids[b]	2.531	0.102	0.119	5.955	3.617	3.145	6.753	0.121	2.358	3.527	1.181	2.631	2.177
Coal liquids[c]	2.121	0.791	1.018	3.619	2.317	1.601	2.918	0.873	2.205	1.980	1.077	1.796	2.159
Total synthetics	10.731	1.611	5.215	11.077	14.973	6.097	17.637	3.765	8.883	16.590	2.523	10.167	10.179
Oil imports	10.861	31.807	23.063	2.619	16.307	3.621	5.761	15.021	6.951	22.210	12.671	11.586	10.812
Total synthetics and imports	21.605	35.150	28.278	18.726	31.360	9.721	23.131	18.789	15.837	38.801	20.197	22.051	21.001
Domestic oil	26.155	13.702	19.911	28.611	20.175	31.463	26.607	26.167	25.172	26.153	26.151	26.303	26.155
Domestic gas	21.263	20.029	22.318	21.560	18.069	30.335	22.501	21.292	21.963	21.509	21.240	21.612	21.281
Gas imports	1.965	8.195	4.811	1.895	2.236	1.896	1.913	2.337	1.906	2.923	2.023	2.052	1.950
Total gas	25.228	11.831	27.162	23.155	20.305	12.231	21.507	26.629	23.869	27.132	26.263	25.691	25.231
Price (dollars/million Btu at plant gate)[d]													
1986													
Low sulfur coal	1.52	1.41	1.45	1.51	1.51	1.18	1.51	1.18	1.47	1.61	1.50	1.55	1.50
Distillate	3.10	2.24	2.31	3.10	3.18	2.82	3.05	1.11	3.05	3.47	3.12	1.11	3.10
Methane	2.80	2.38	2.52	2.81	3.18	2.32	2.71	2.91	2.61	[illegible]	2.8[illegible]	2.88	2.77
Electricity	7.33	7.10	7.11	7.38	7.11	7.19	7.36	7.26	7.17	5.70	7.30	[illegible]	6.72
1995													
Low sulfur coal	1.63	1.51	1.52	1.68	1.65	1.58	1.68	1.56	1.57	1.78	1.61	1.72	1.61
Distillate	3.11	2.38	2.61	3.72	3.18	3.23	3.21	3.18	3.55	4.17	3.15	3.12	3.11
Methane	3.45	2.91	3.07	4.18	4.57	2.95	3.22	3.71	4.22	4.77	3.52	3.56	3.39
Electricity	7.38	7.15	7.19	7.13	7.38	7.31	7.39	7.30	7.22	7.72	7.10	8.00	6.68

[a] Syngas = high Btu coal gas, low Btu coal gas, hydrogen, and thermochemical hydrogen.

[b] Shale liquids = shale crude and methanol.

[c] Includes solvent-refined coal.

[d] East North Central Region.

Table H-III-1 (Concluded)

Material	Low Coal Price	High Coal Price	Low SNG Cost	High SNG Cost	High Oil Shale Price	High Discount Rate	Premium on Industrial Coal	No Hydrogen	High Synfuels and High Import Price	Low Oil and Gas High Import Price	High Oil and Gas High Import Price
Volume (quadrillion Btu/year)											
1986											
Syngas*	1.173	0.858	1.490	0.886	1.075	1.023	1.179	0.513	0.713	1.503	0.841
Shale liquids†	0.333	0.329	0.327	0.335	0.007	0.223	0.315	0.317	0.097	1.200	0.189
Coal liquids‡	0.497	0.311	0.337	0.463	0.409	0.380	0.481	0.424	0.257	0.701	0.284
Total synthetics	2.005	1.498	2.154	1.684	1.491	1.626	2.008	1.284	1.067	3.407	1.314
Oil imports	9.230	10.684	9.586	9.817	10.260	10.027	10.018	9.819	5.996	7.747	2.970
Total synthetics and imports	11.235	12.182	11.740	11.531	11.751	11.653	12.026	11.103	7.063	11.154	4.284
Domestic oil	21.952	24.661	21.688	24.912	24.574	24.739	21.811	21.787	28.220	25.207	30.955
Domestic gas	26.391	26.815	27.214	25.891	26.490	26.[illegible]	26.761	26.601	25.992	24.812	30.502
Gas imports	1.471	1.489	1.471	1.479	1.474	1.481	1.474	1.474	1.470	1.472	1.470
Total gas	27.863	28.154	28.685	27.373	27.964	28.175	28.238	28.078	27.462	26.281	31.972
1995											
Syngas*	7.201	3.742	10.091	3.763	6.133	6.400	6.670	4.597	3.453	8.736	3.140
Shale liquids†	2.622	2.607	2.677	2.731	0.085	1.874	2.721	2.711	0.679	5.251	2.211
Coal liquids‡	2.943	1.210	1.617	2.609	2.294	1.411	2.423	2.215	1.437	4.049	1.919
Total synthetics	12.766	7.559	14.385	9.103	8.512	9.685	11.814	9.523	5.569	18.036	7.270
Oil imports	9.413	13.159	10.628	10.856	13.162	12.257	11.230	10.902	7.979	4.922	1.581
Total synthetics and imports	22.179	20.718	25.013	19.959	21.674	21.942	23.014	20.425	13.548	22.958	8.851
Domestic oil	26.492	26.337	26.190	26.432	26.357	26.618	26.460	26.406	30.387	27.021	31.903
Domestic gas	22.561	24.514	21.410	24.084	23.283	23.310	23.533	23.359	24.618	19.632	30.666
Gas imports	1.915	2.479	1.901	2.196	1.971	2.116	1.978	1.963	1.902	1.901	1.891
Total gas	24.479	26.993	23.314	26.280	25.254	25.426	25.511	25.322	26.[illegible]20	21.536	32.560
Price (dollars/million [illegible] at plant gate)§											
1986											
Low sulfur coal	1.42	1.75	1.51	1.51	1.31	1.53	1.52	1.51	1.49	1.57	1.48
Distillate	3.09	3.12	3.10	3.10	3.12	3.29	3.11	3.11	3.59	3.64	2.91
Methane	2.71	3.00	2.66	2.90	2.80	2.95	2.82	2.79	3.04	3.25	2.30
Electricity	7.12	7.68	7.36	7.31	7.33	7.94	7.33	7.32	7.31	7.49	7.20
1995											
Low sulfur coal	1.32	1.80	1.66	1.62	1.64	1.65	1.61	1.63	1.59	1.75	1.59
Distillate	3.39	3.43	3.41	3.40	3.47	3.62	3.41	3.41	4.10	3.83	3.37
Methane	3.24	3.77	3.09	3.68	3.44	3.62	3.45	3.42	3.90	3.68	3.01
Electricity	7.22	7.86	7.38	7.36	7.39	8.09	7.38	7.39	7.35	7.46	7.34

*Syngas = high Btu coal gas, low Btu coal gas, hydrogen, and thermochemical hydrogen.

†Shale liquids = shale syncrude and methanol.

‡Includes solvent-refined coal.

§East North Central Region.

In the remainder of this appendix, the sensitivity cases are discussed individually.

1. Import Prices

Probably the most important competition with synthetic fuels comes from imported crude and LNG. The viability of synthetic gases and liquids is determined by the relative costs of crude imports to synthetic liquids and LNG imports to synthetic gases. The price of imports is set by a combination of cartel behavior, world energy demand, and, to a lesser extent, U.S. energy demand; therefore, the price of imports is highly uncertain.

Lacking a comprehensive model of the world energy market, the price of imports was taken to be exogenously determined and the sensitivity of synthetics production and imports to the price of imports was tested. As expected, the timing of synthetic fuel use is strongly affected by the price of imported crude oil. If the price of imports remains high, synthetic fuels will be quite attractive by 1985-90 whereas if the price of imports drops, synthetic fuels will not be required in large quantities until depletion drives world oil and gas prices up.

The key insight from this sensitivity run is: The price and thus the production of domestic crude is set by the price of imported crude; the price and thus the production of domestic natural gas is set by the price of synthetic gas once it becomes available.

The nominal case import price curves for crude oil, LNG, and methanol are given by the following equations:

$$P_{crude}(t) = 18 - 7(.94)^t \quad \$/bbl$$

$$P_{LNG}(t) = 4.26 - 1.66(.94)^t \quad \$/Mcf$$

$$P_{methanol}(t) = 16.40 - 6.40(.94)^t \quad \$/bbl$$

where t is the number of years elapsed since mid-1975. The price of imported crude is plotted in Figure 9 in Chapter II. Imported crude prices begin at \$11/bbl and rise to \$18/bbl; imported LNG begins at \$2.60/Mcf and rises to \$4.26/Mcf; and imported methanol begins at \$10/bbl and rises to \$16.40/bbl in the nominal case.

The high import price case assumes the 1975 imported crude oil cost to be \$14/bbl instead of \$11. All three nominal case price curves are scaled up by the ratio 14/11 = 1.27 to give the high import price case. The low import price case is not a multiple of the nominal case; but is estimated directly. Table H-III-2 gives prices as a function of time for all three fuels in all three sensitivity cases.

TABLE H-III-2

IMPORT PRICE SENSITIVITIES

IMPORT PRICES (1975 DOLLARS)

Year	Imported Crude ($/bbl)			Imported LNG ($/Mcf)			Imported Methanol ($/bbl)		
	Low	Nominal	High	Low	Nominal	High	Low	Nominal	High
1975	11.00	11.00	13.74	2.60	2.60	3.24	10.04	10.04	12.51
1986	8.83	14.50	18.10	2.08	3.43	4.27	8.06	13.23	16.49
1995	9.62	16.01	19.99	2.27	3.78	4.71	8.78	14.61	18.21
2001	10.30	16.65	20.80	2.43	3.94	4.91	9.40	15.20	18.95

The effect of high, nominal, and low import prices is shown for the gaseous and liquid fuels markets in Figure H-III-1 and Table H-III-3. The liquid and gaseous markets react quite differently to changes in import price. On one hand, the liquid fuels market is vulnerable to world market forces, being strongly affected by the price of imports; thus, cartel action can have a large effect on liquid fuels. On the other hand, the gaseous fuels market depends heavily on synthetic gas development; cartel action has less effect on the market.

To illustrate the effect of high and low import prices on the energy system as a whole, the supply-demand balance at the primary resource level is shown for the high, nominal, and low import price cases in Figures H-III-2, H-III-3, and H-III-4. Note that imported crude captures much less of the market as its price rises; it is replaced by shale and domestic crude. In effect, the cartel can price itself out of the U.S. market if its price remains at or above that of shale oil after 1985-90. However, the cartel can capture virtually the whole U.S. liquid fuels market if its prices drop substantially and its reserves last 25 years or more at those low prices.

The important insights are:

- High import prices lead to a considerable reduction in crude oil imports; production of synthetic liquids and domestic oil increases to replace imported crude.
- Low import prices reduce production of synthetic liquids and even reduce domestic oil production.
- High import prices induce a substitution of gaseous for liquid fuel. This substitution occurs mainly in the residential and industrial markets.
- High import prices stimulate domestic production of crude oil through 1986, but higher prices (due to depletion) drive down domestic production after 1986.
- High import prices do not stimulate domestic gas production because synthetic gas will set the price of natural gas after 1986.
- The price and volume of domestic crude oil is determined principally by competition from imported crude.
- The price and volume of domestic natural gas is determined principally by competition from synthetic gas after 1985.
- Synthetic liquids are strongly affected by the price of crude imports. If imports are priced higher, synthetic liquids look attractive; if imports are priced lower, synthetic liquids look unattractive.
- Synthetic gas is only moderately affected by import prices.

- Subsidies for synthetic gas plants may be attractive at low import prices; subsidies for synthetic liquid plants can become large if import prices drop.

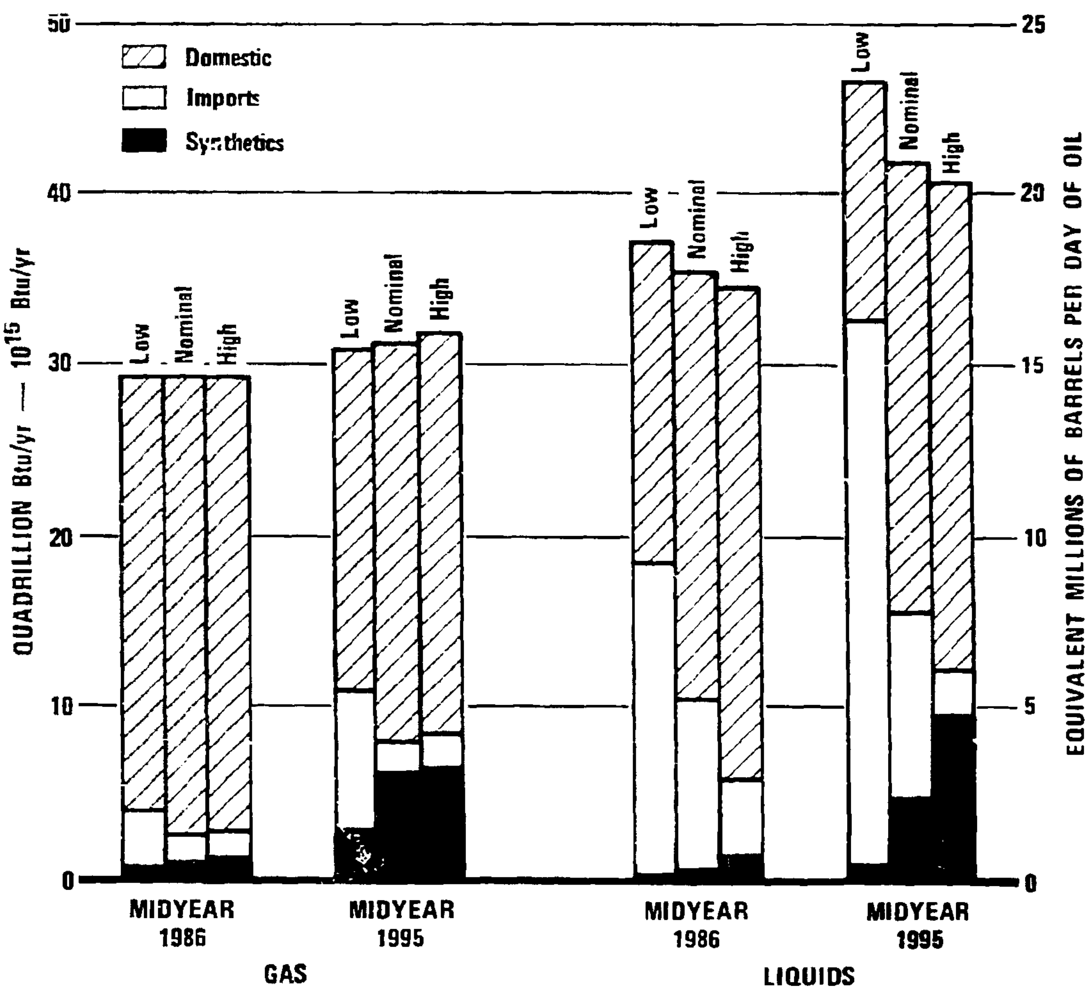


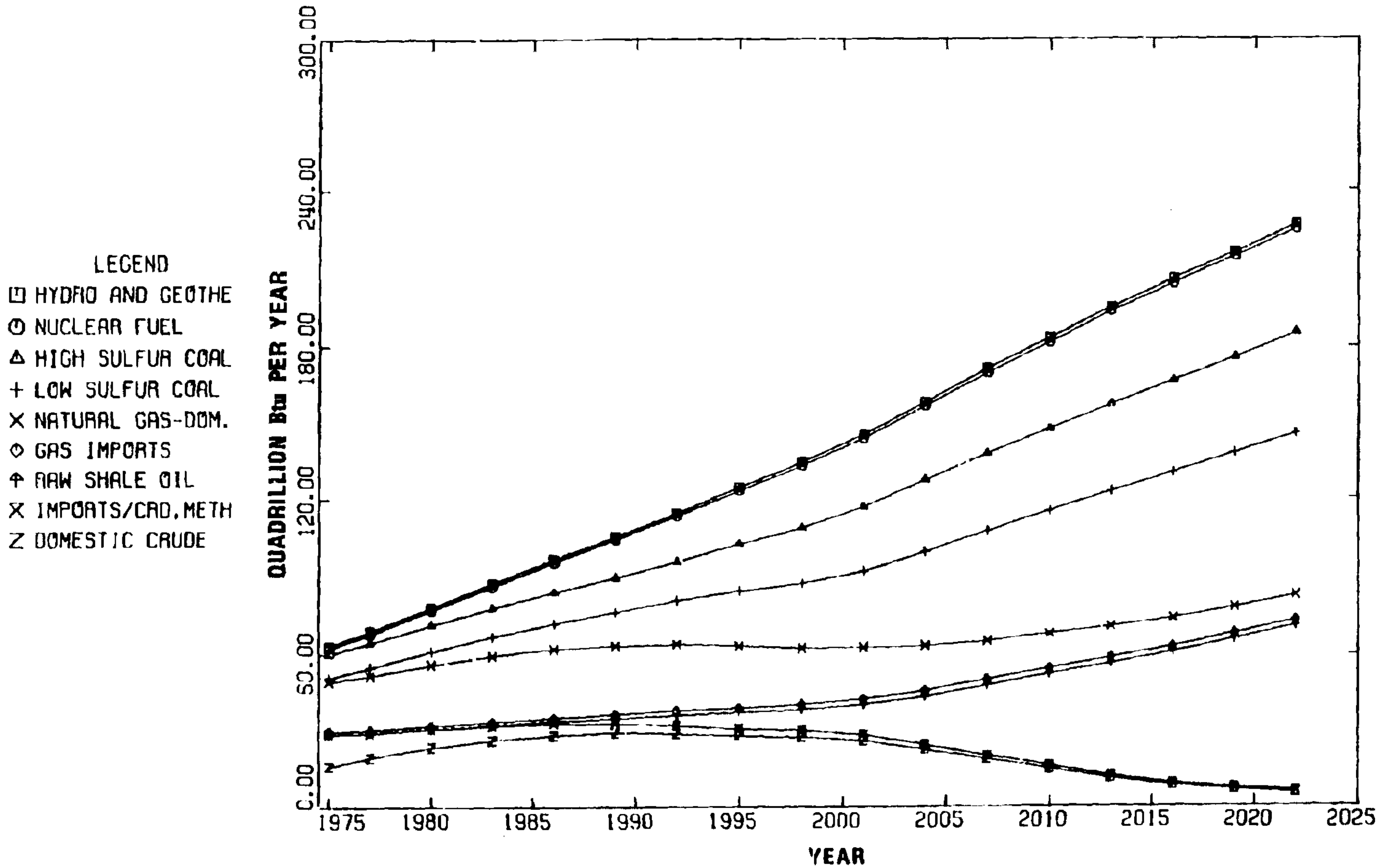
FIGURE H-III-1 FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO IMPORT PRICE

Table H-III-3

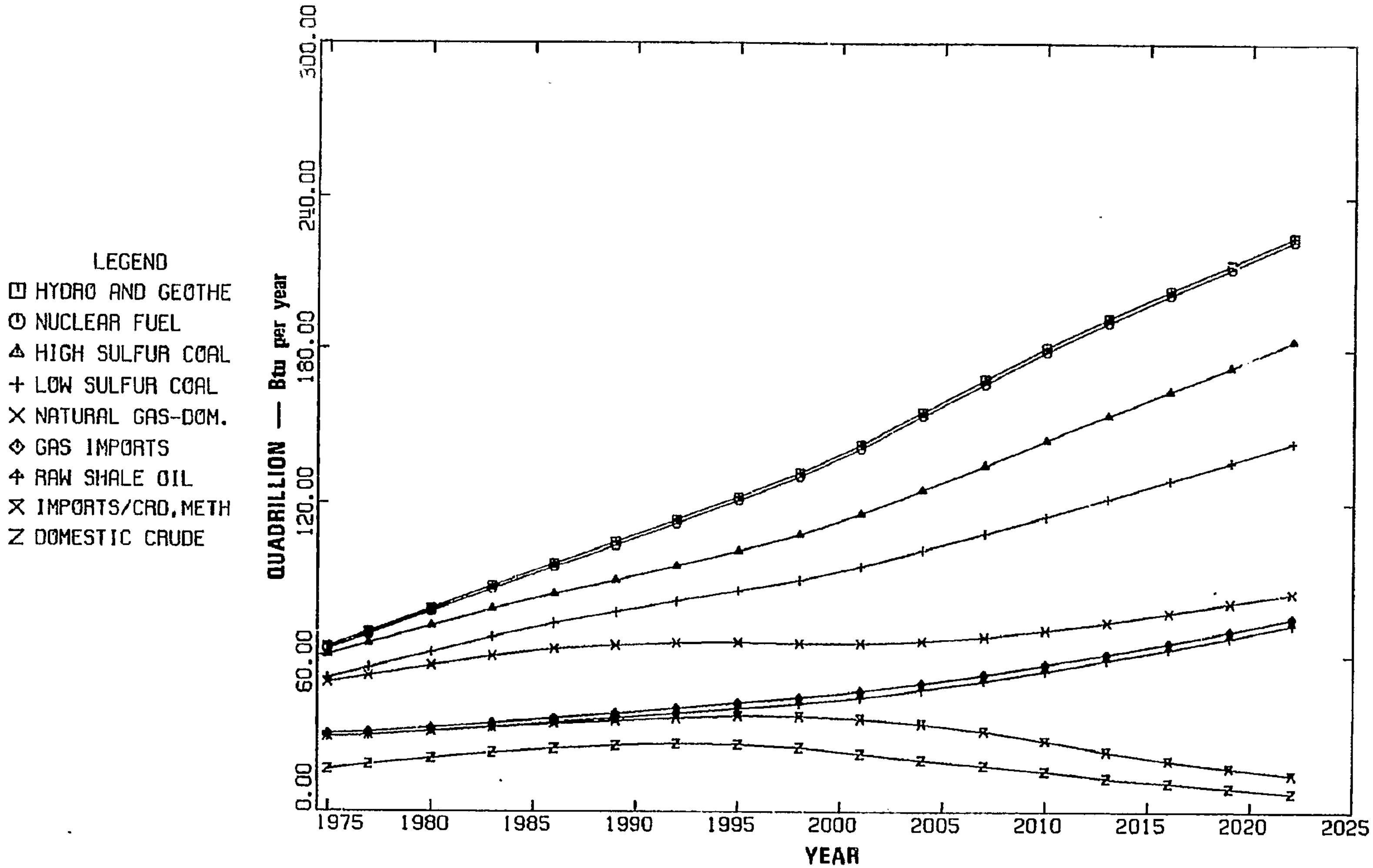
FUTURE DEMAND OF GAS AND OIL--
SENSITIVITY TO IMPORT PRICES

Quadrillion Btu/year (10^{15} Btu/year)

	1986			1995		
	High Import Price	Nominal	Low Import Price	High Import Price	Nominal	Low Import Price
Synthetic Gas	1.2	1.1	.7	6.5	6.1	2.8
Imported Gas	1.5	1.5	3.2	1.9	2.0	8.2
Domestic Natural Gas	26.7	26.4	25.5	23.6	23.3	20.0
Synthetic Liquids	1.3	.8	.2	9.6	4.7	.9
Imported Crude	4.5	9.8	18.2	2.6	10.9	31.8
Domestic Crude	28.8	24.8	19.0	28.6	26.5	13.7

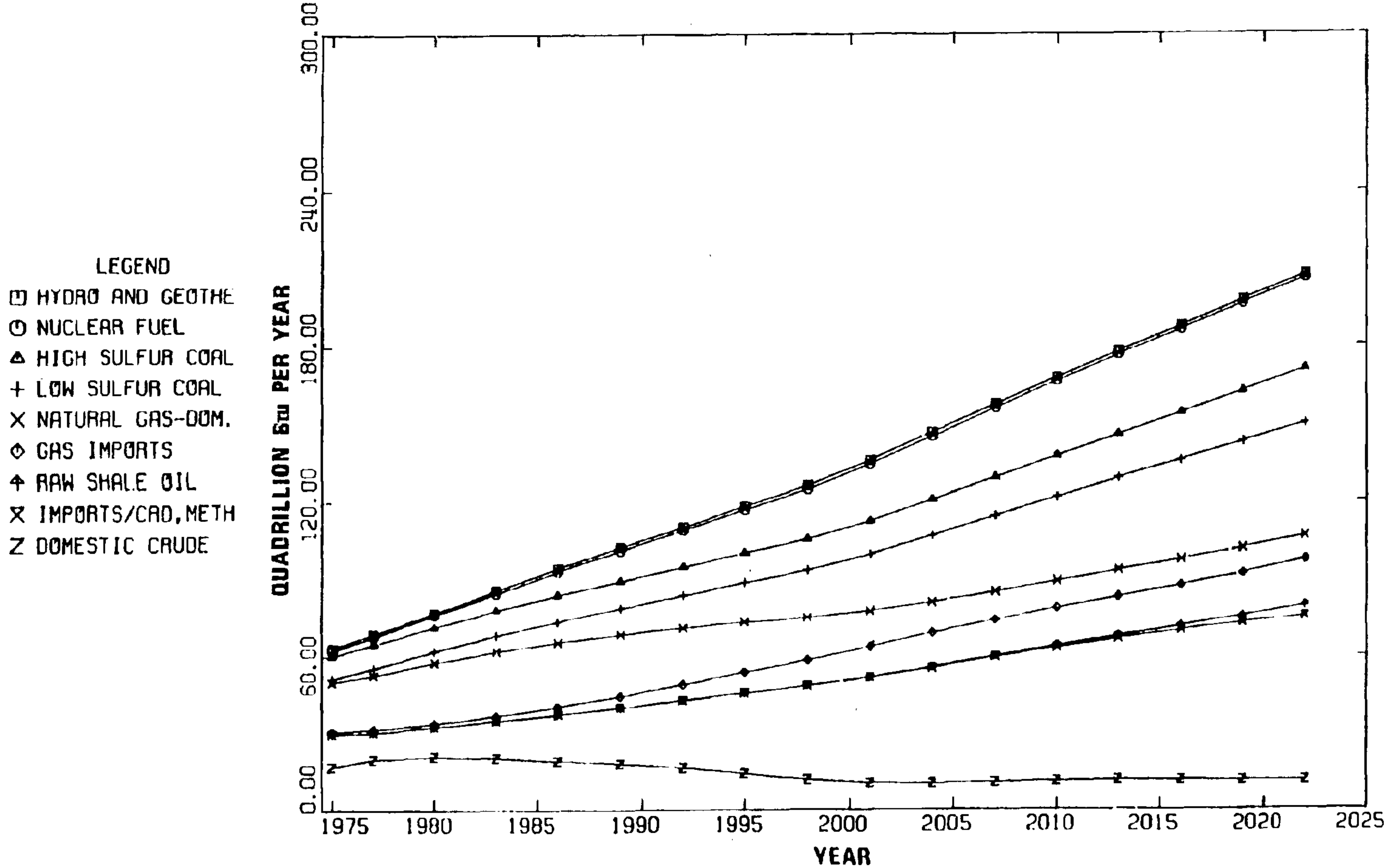


High Import Prices
FIGURE H-III-2



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE H-III-3



Low Import Prices

FIGURE H-III-4

2. Availability of Domestic Oil and Gas

Synthetic liquids and gases will eventually replace our diminishing domestic oil and gas supplies; the time and rate of this replacement depends on the amount of domestic oil and gas that can be produced at or below the price of competing synthetic fuels. The replacement is complicated by the fact that imported gas and crude oil may compete with both synthetics and domestic production.

A brief look at the oil and gas reserve estimates in Chapter II of the main text illustrates the tremendous uncertainty in these estimates. Certainly, if oil and gas are much more abundant than is now believed, the use of synthetic fuels will be significantly delayed. Conversely, if oil and gas are much scarcer than is now believed, synthetic fuels may be needed sooner.

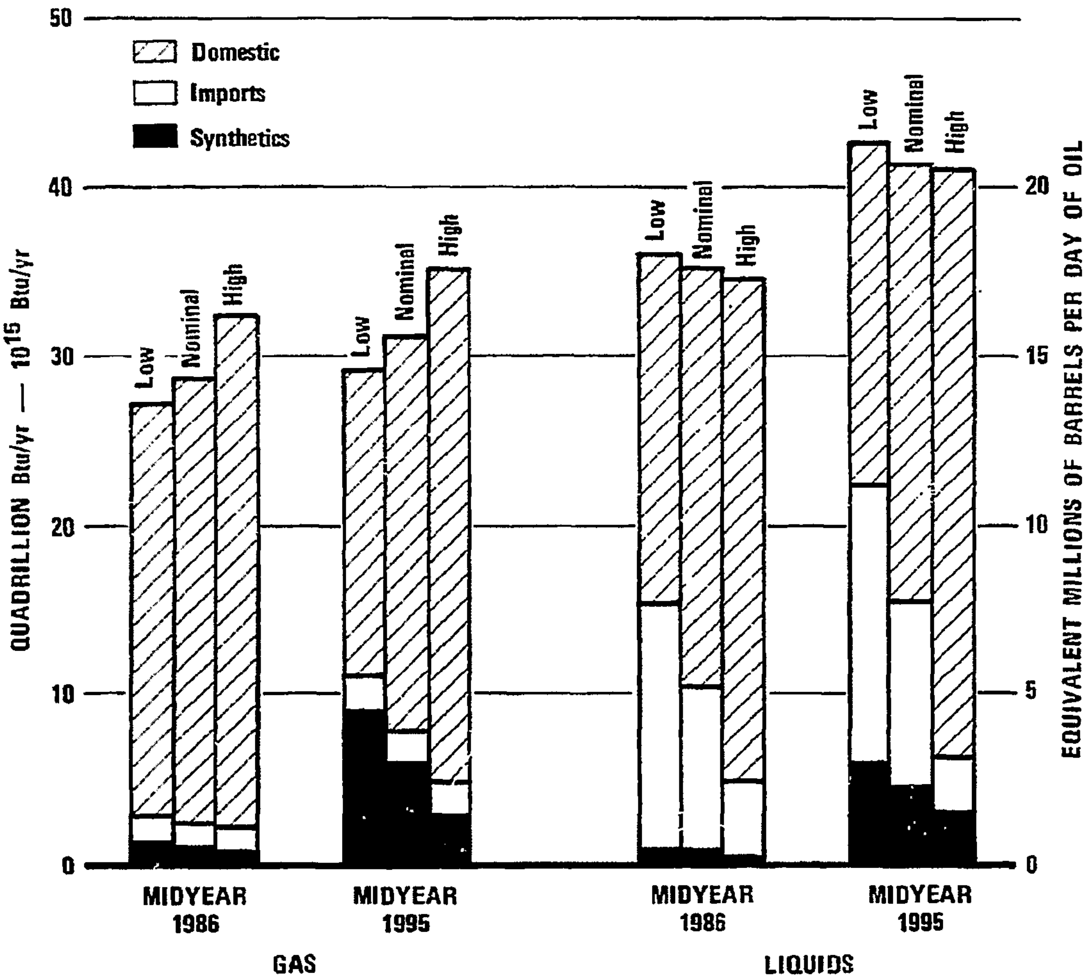
To test the effect of oil and gas availability on synthetic fuels production, the marginal cost curves (pictured in Figure 12 and 13 in Chapter II of the main text) were constructed to bound the range of uncertainty in resource estimates.

The results are pictured in Figure H-III-5 & Table H-III-4 for both the gaseous and liquid fuels markets. From the point of view of synthetic fuels commercialization, liquid and gaseous fuels react similarly to the availability of domestic resources. If more domestic resources are available at a given price, the need for synthetics and imports is delayed, and the vulnerability of the U.S. market to cartel pressure is lessened. If more gas is found, the U.S. market will substitute gas for oil, and our liquid fuels market will be less dependent on imports. If more crude oil is found, our liquid fuels market will be less dependent on imports, and our gaseous fuels market will still depend on coal gasification. The supply-demand balance at the primary resource level is shown in Figures H-III-6, H-III-7, and H-III-8.

The important insights are:

- Lower availability of domestic oil and gas increases imports.
- Lower availability of domestic oil and gas accelerates the need for synthetics.
- Higher availability of domestic oil and gas induces a substitution of gas for oil; gas can be produced more cheaply and requires no conversion.
- Most of the difference between demand and domestic production of crude will be made up by crude imports, regardless of domestic availability.
- Most of the difference between demand and domestic production of gas will be made up by synthetic gas, regardless of domestic availability.

- High availability of domestic oil and gas can make a 50 percent difference in the size of the synthetic fuels industry in 1995, but it cannot eliminate the eventual need for synthetics.
- Subsidies for synthetics plants will be unattractive if oil and gas are plentiful:
- Domestic oil and gas will satisfy half or more of the liquid and gas demand through 1995, even in the low availability case.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO DOMESTIC GAS AND OIL AVAILABILITY

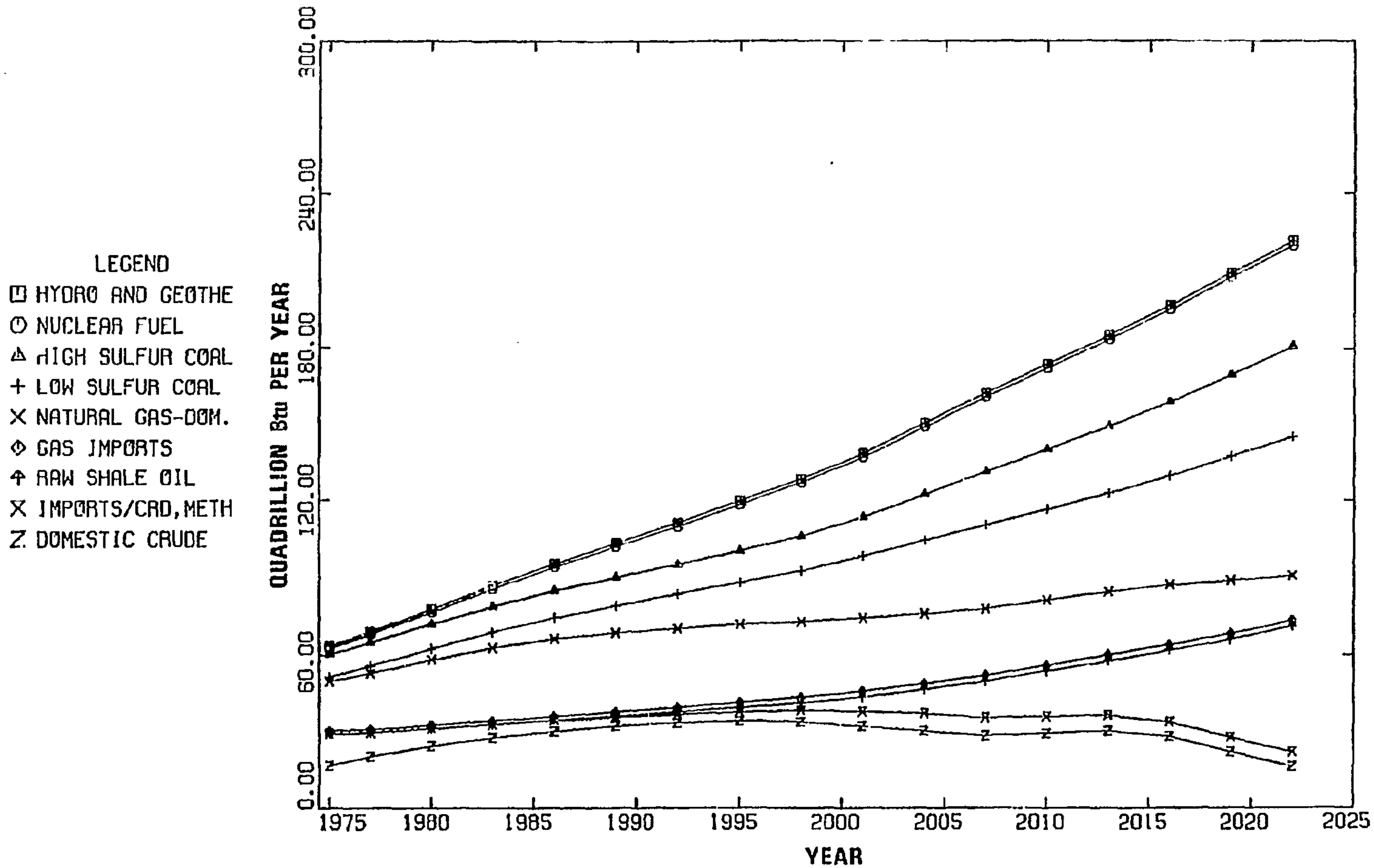
FIGURE H-III-5

Table H-III-4

FUTURE DEMAND FOR GAS AND OIL—
SENSITIVITY TO DOMESTIC GAS AND OIL AVAILABILITY

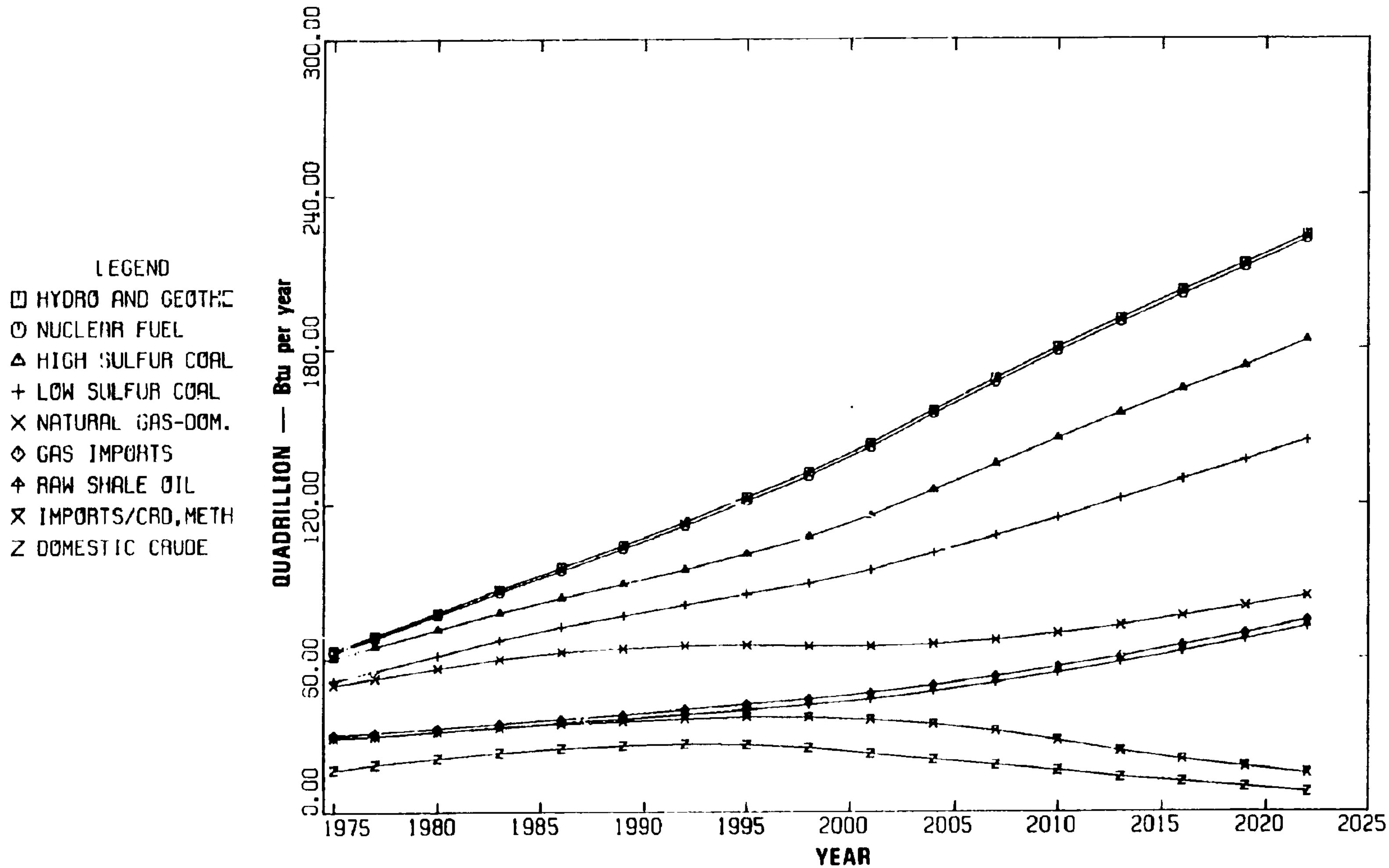
Quadrillion Btu/year (10^{15} Btu/year)

	1986			1995		
	Low Oil & Gas Availability	Nominal	High Oil & Gas Availability	Low Oil & Gas Availability	Nominal	High Oil & Gas Availability
Synthetic Gas	1.4	1.1	.8	9.0	6.1	3.0
Imported Gas	1.6	1.5	1.5	2.2	2.0	1.9
Domestic Natural Gas	24.2	26.4	30.1	18.1	23.3	30.3
Synthetic Liquids	.9	.8	.5	5.9	4.7	3.0
Imported Crude	14.6	9.8	4.3	16.4	10.9	3.6
Domestic Crude	20.6	24.8	30.1	20.5	26.5	34.5



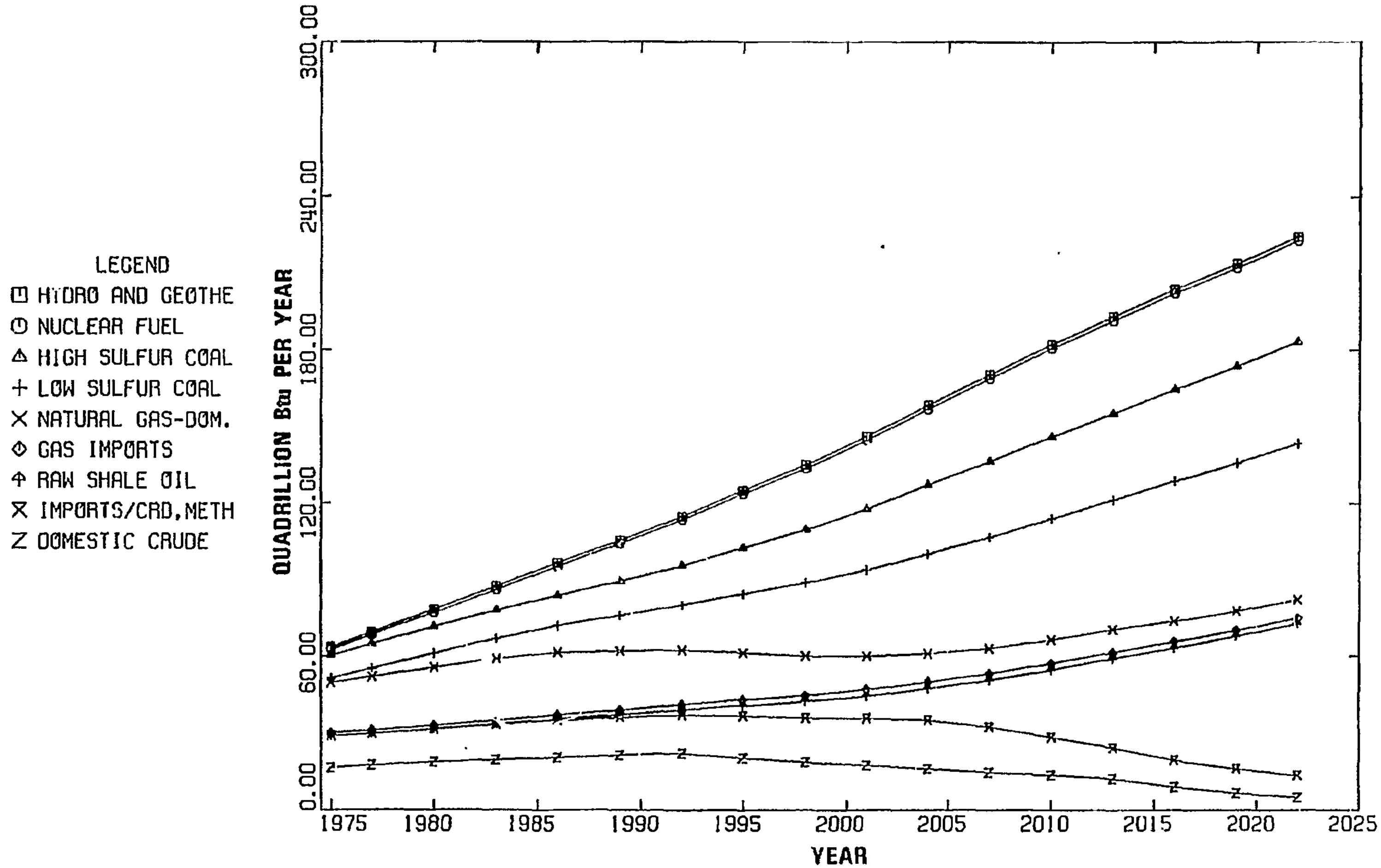
HIGH OIL AND GAS AVAILABILITY

Figure H-III-6



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE H-III-7



LOW OIL AND GAS AVAILABILITY

FIGURE H-III-8

3. Cost of Synthetic Fuels

The cost of synthetic fuels is a major factor in determining their competitive postion relative to imports and domestic production. Synthetics production represents a significant change in the energy production industry--shifting from technologies low in capital cost, where product prices are set principally by the cost of feedstocks, to technologies high in capital cost, where product prices are set principally by the cost of new plants. The combination of large front-end capital cost and the early stage of development of many of the synthetic fuel technologies causes a great deal of uncertainty about the ultimate cost of synthetic fuels.

To deal with this uncertainty, a high synthetics cost case (the nominal case capital and operating costs were increased by 50%) and a low synthetics cost case (the nominal case capital and operating costs were decreased by 20%) were examined. The nominal case synthetics data were presented in Table H-I-5 of this Appendix. To compute the approximate price of a synthetic fuel using Table H-I-5, define the capital charge rate (CCR) to be:

$$CCR = \begin{cases} 0.2276 & \text{for utilities} \\ 0.3087 & \text{for industries} \end{cases}$$

The approximate price of a given synthetic fuel is

$$P = CCR \times \text{Specific Capital Cost} + \text{Specific Operating Cost} + \frac{\text{Feedstock Price}}{\text{Efficiency}}$$

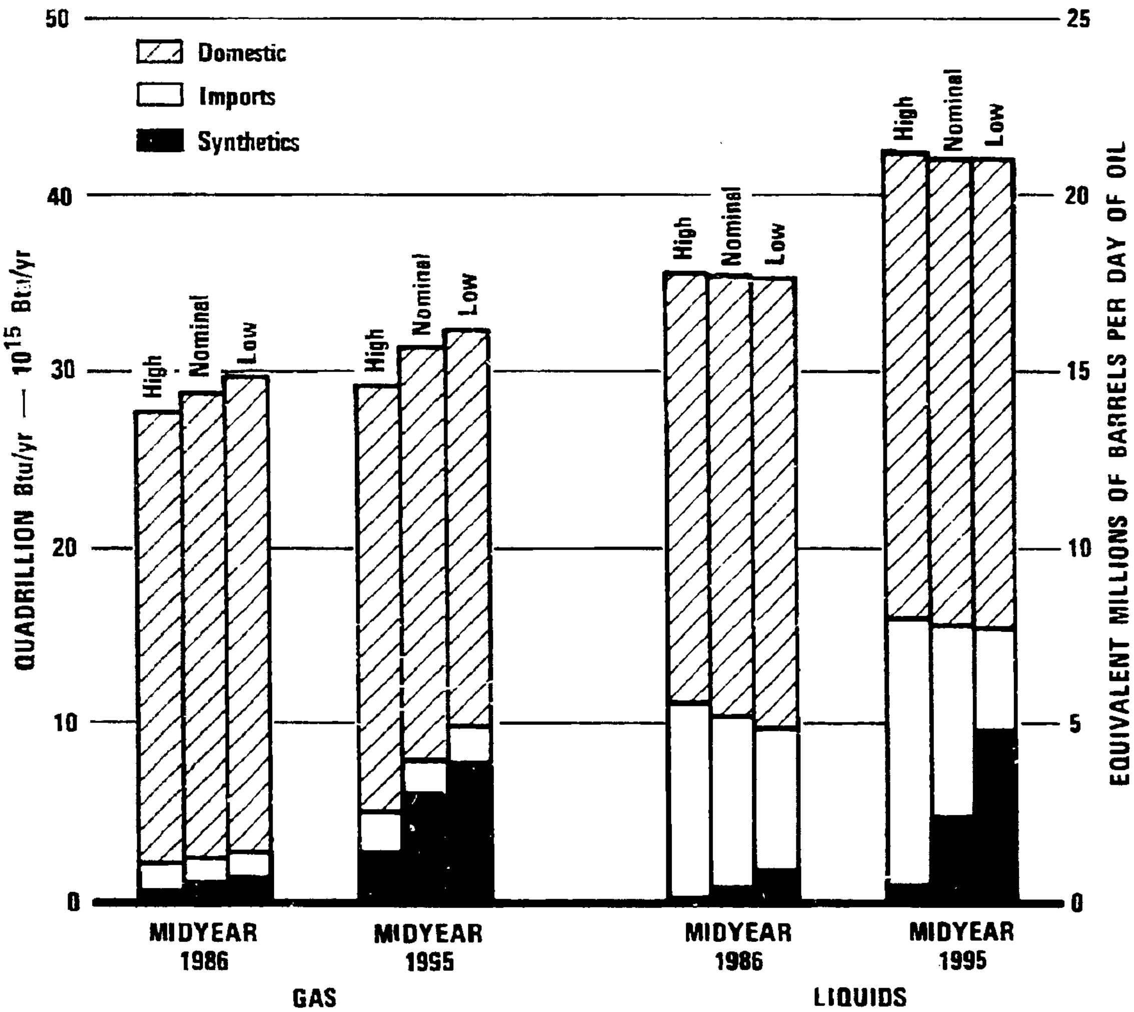
where the specific capital cost, specific operating cost, and efficiency are taken from Table H-I-5. These capital charge rates assume a 7% investment tax credit, a 52% income tax rate, a book life of 25 years, a tax life of 20 years, double declining balance depreciation, and 2.5% property tax and insurance rate.

Figure H-III-9 and Table H-III-5 illustrates the sensitivity of the liquid and gaseous fuel markets to the cost of synthetic fuels. The influence of synthetic fuels costs is shown at the primary resource level in Figures H-III-10, H-III-11, and H-III-12. In the low cost case, imports are driven steadily downward over the 48-year horizon, being replaced mostly by shale oil. In the high cost case, the reverse is true; imports expand their market share beginning in 1995 as conventional domestic sources are depleted.

The important insights are:

- High synthetic fuels costs delay the use of synthetic fuels significantly.
- High synthetic fuels costs result in a higher level of imports.

- Higher synthetic fuels costs have a relatively minor effect on domestic gas and oil production.
- The sum of synthetic liquids and crude imports is relatively constant; synthetic liquids and crude imports compete principally against each other.
- The difference between the demand for gas and domestic gas production is satisfied principally by synthetic gas.
- The difference between demand and domestic crude production is satisfied by synthetic liquids or imports, depending on their relative prices.
- Crude imports are eliminated by 2000 in the low synthetic fuels cost case.
- High synthetic fuels cost virtually eliminates synthetic liquids production between 1975 and 2000.
- High synthetic fuels costs decrease the consumption of gaseous fuels but have little effect on liquid fuels. This is because coal and nuclear fuel become more competitive with the higher priced gases but not with liquids, whose prices are set by imports.



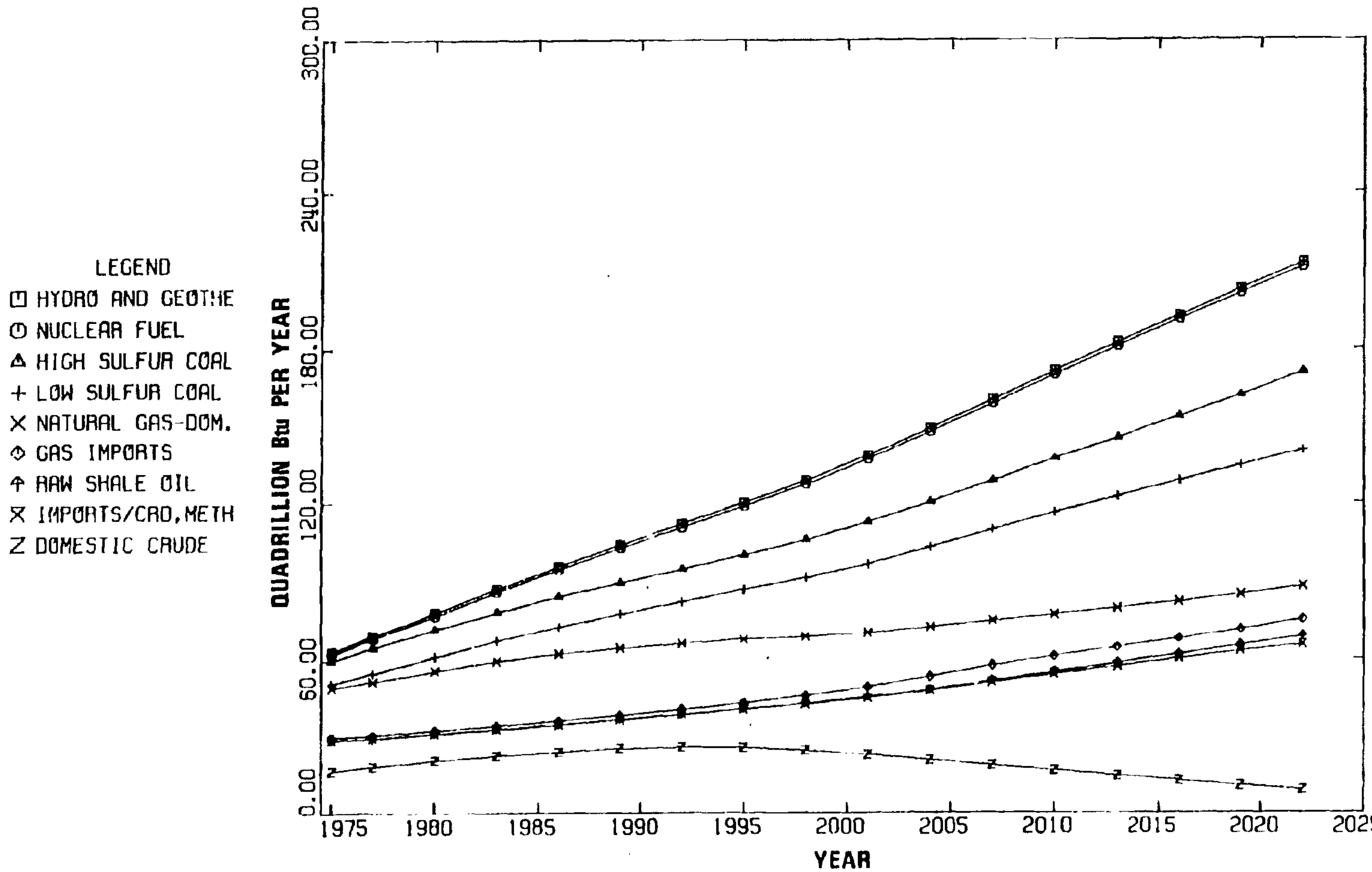
FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO SYNTHETIC FUELS COST

FIGURE H-III-9

Table H-III-5

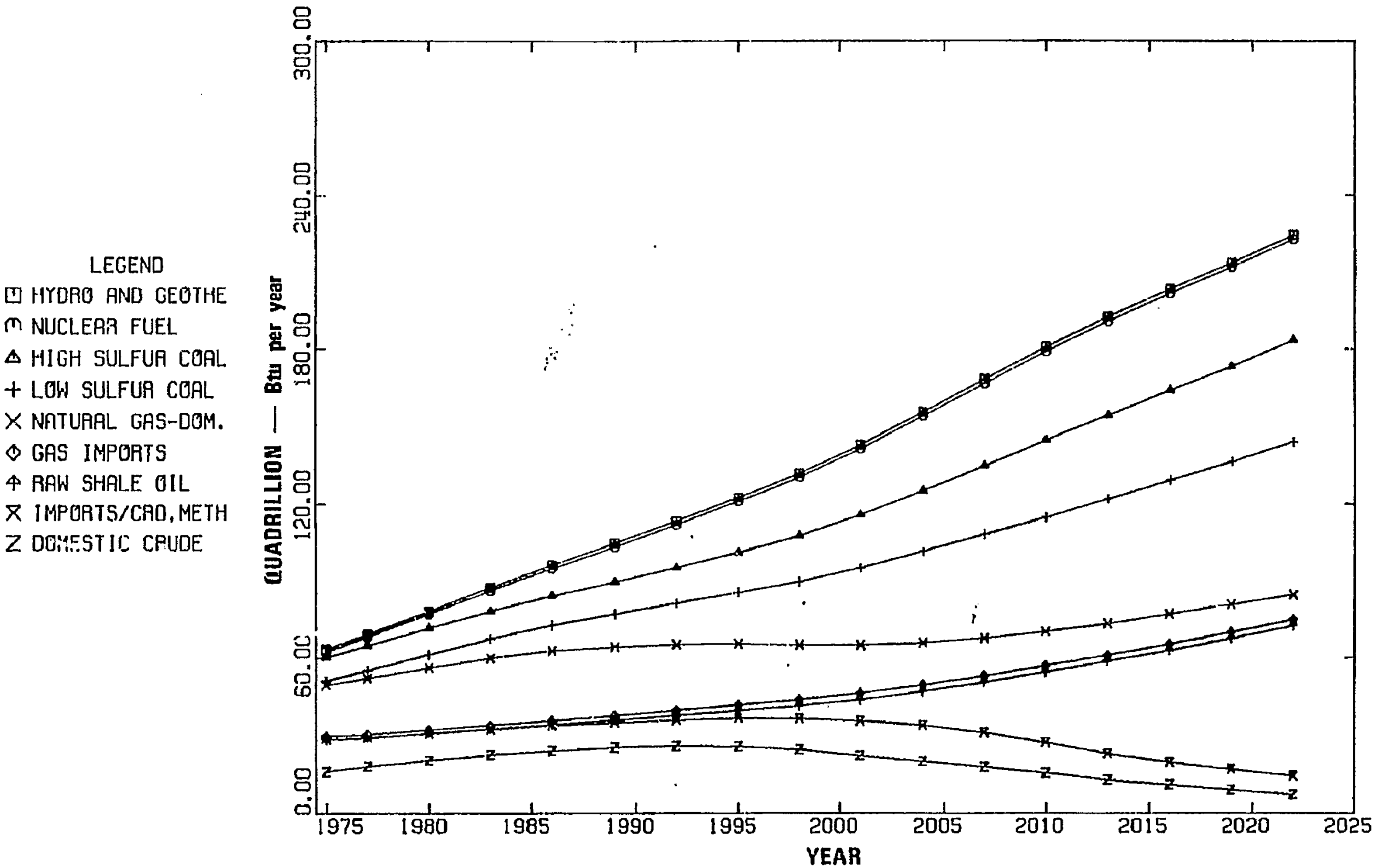
FUTURE DEMAND FOR GAS AND OIL--
SENSITIVITY TO SYNTHETIC FUELS COST
Quadrillion Btu/year (10^{15} Btu/year)

	1986			1995		
	High Synfuels Cost	Nominal	Low Synfuels Cost	High Synfuels Cost	Nominal	Low Synfuels Cost
Synthetic Gas	.6	1.1	1.3	2.8	6.1	7.9
Imported Gas	1.5	1.5	1.5	2.3	2.0	1.9
Domestic Natural Gas	25.8	26.4	26.9	24.3	23.3	22.6
Synthetic Liquids	.2	.8	1.6	1.0	4.7	9.7
Imported Crude	10.8	9.8	8.2	15.0	10.9	5.8
Domestic Crude	24.5	24.8	25.4	26.2	26.5	26.6



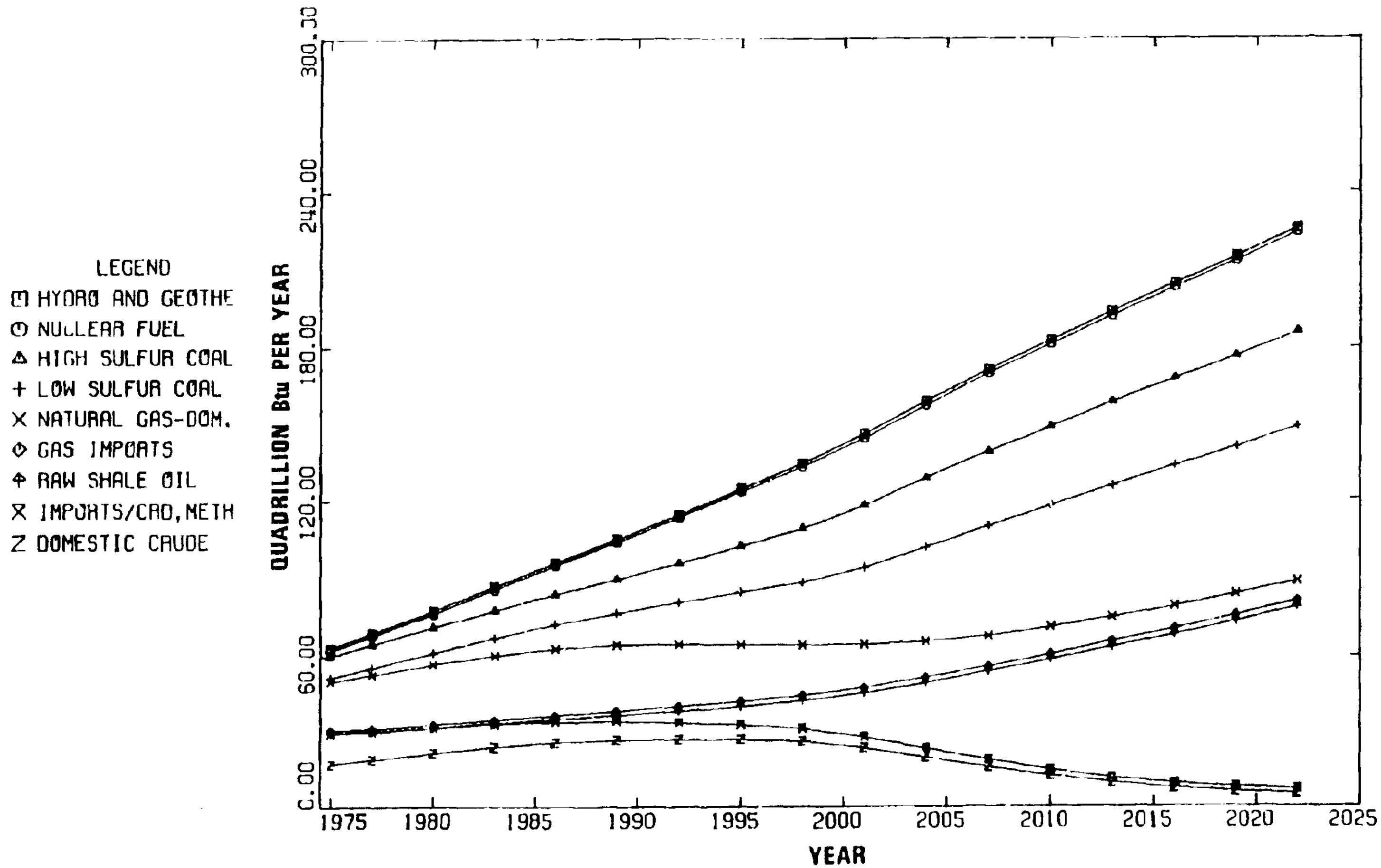
HIGH SYNFUELS COST

FIGURE H-III-10



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE H-III-11



LOW SYNFUELS COST

FIGURE H-III-12

4. Demand

The total energy demand determines the size of the U.S. energy system in future years. Energy conservation measures and the influence of higher energy prices may restrain the growth of energy demand in the future or low energy prices may persist so that demand continues to grow. Demand, as with many other variables, is uncertain, and the uncertainty increases over time.

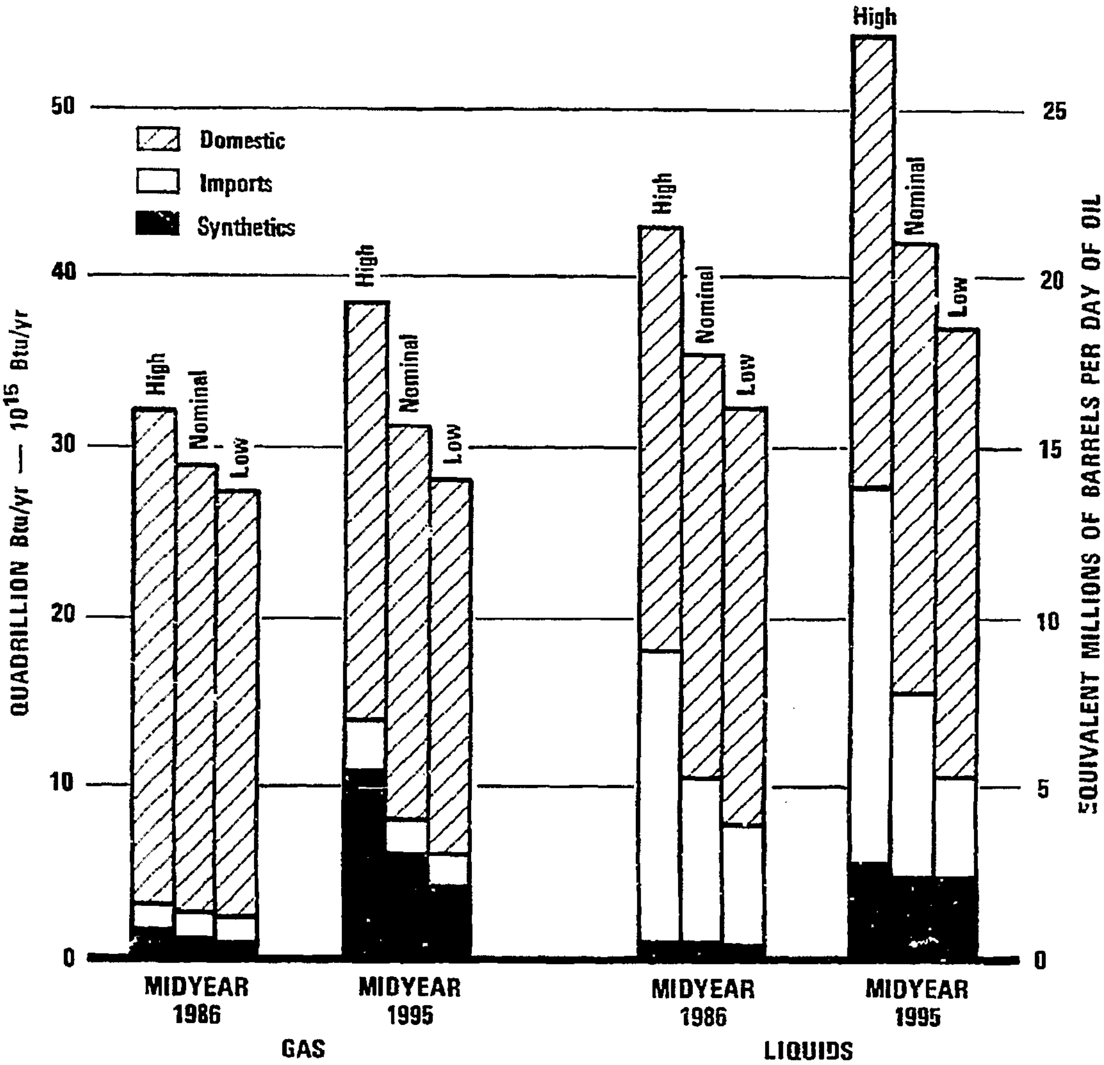
A low demand case was constructed to examining the effects of a successful conservation program which is quite similar to the Ford Foundation's Technological Fix case. The underlying assumption is that the per capita growth in energy is constant with the additional assumption that measures will be taken to increase the efficiency of energy use, resulting in a lower energy demand growth rate. In a similar manner, a high demand case was constructed to examine the effects of no energy conservation program which is quite similar to the Ford Foundation's Historical Growth case. The underlying assumption is that energy growth will not slow, it is an extrapolation of past energy growth. In effect, the high demand case assumes that growth will occur at about the same rate as during 1950-1970, when energy prices were lower. It is important to note that the nominal case was not estimated directly; it is a weighted average of the high and low case, equal to the low case plus 30% of the difference between the high and low cases. The high and low demand cases are given in detail in Tables H-I-1, H-I-2, and H-I-3. The high and low cases were generated by adjusting the Ford Foundation's Historical Growth and Technological Fix scenarios.

The results of the demand sensitivity runs are shown in Fig. H-III-13 and Table H-III-6 for the liquid and gaseous fuels market.

The effects of high and low demand are most easily seen at the primary resource level which is shown in Figures H-III-14, H-III-15, and H-III-16. In the low demand case, the market simply requires a little less of everything; no fuel that is attractive in the nominal or high demand case is eliminated as a result of energy conservation. An important insight is that the U.S. will eventually need coal, nuclear power, shale, synthetics, gas, and oil; when they will be needed, however, depends on demand.

The important results are:

- Imports fill most of the gap between demand and conventional domestic production unless demand is low; thus demand changes have a major effect on imports.
- Domestic production is higher in the near term if demand is higher, but by 1995, the price and production of domestic gas and oil are set by the prices of synthetic gas and world oil, respectively.
- Higher demand accelerates the introduction of synthetic fuels as well as increasing the use of imports.
- Higher demand means that the price of gas and oil rises faster toward the price of synthetic gas and imported crude.
- Synthetic gas production responds strongly to high demand.
- Synthetic liquids production responds weakly to high demand; the liquid fuels market is driven by the price of imports.



FUTURE DEMAND FOR OIL AND GAS — SENSITIVITY TO TOTAL ENERGY DEMAND

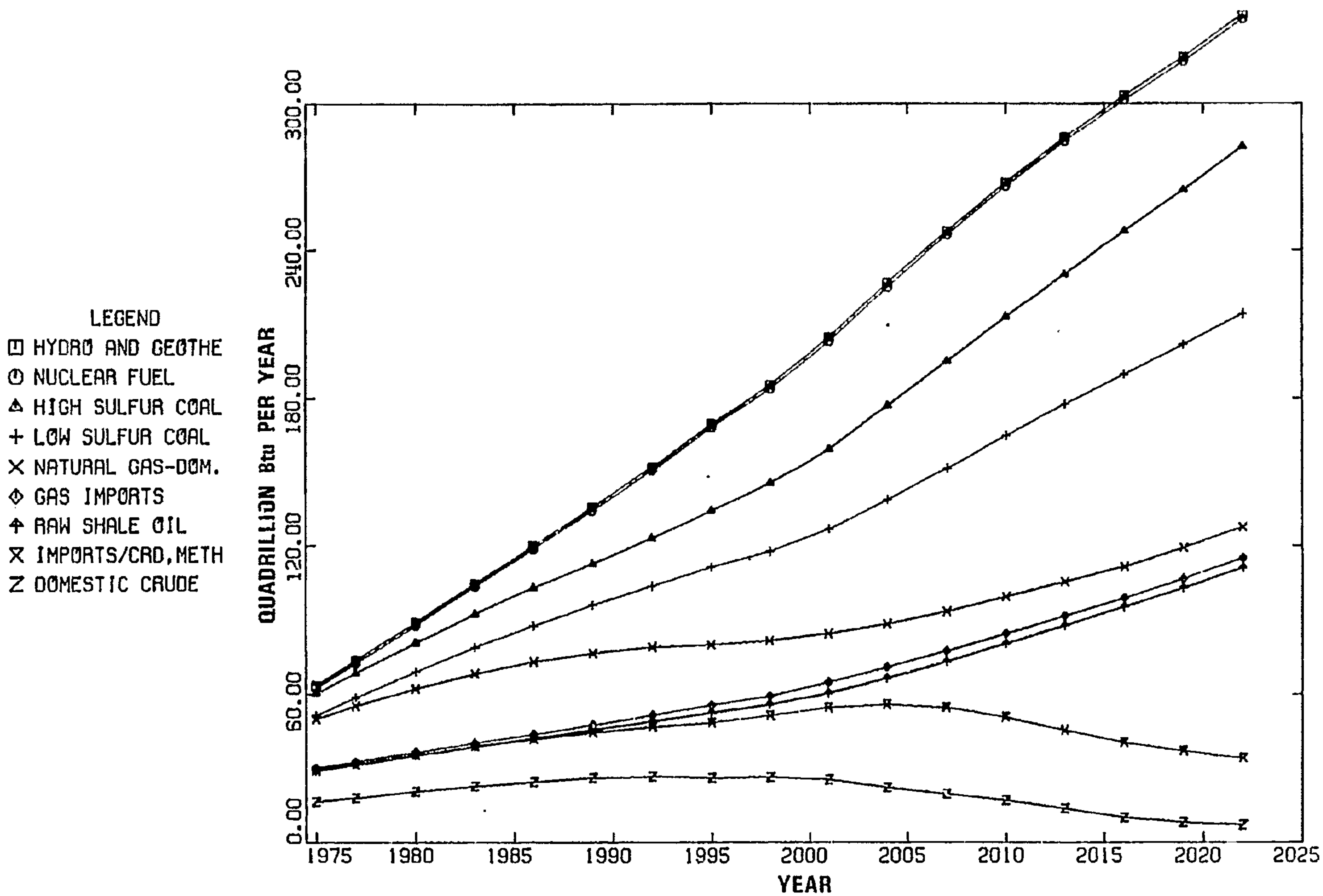
FIGURE H-III-13

Table H-III-6

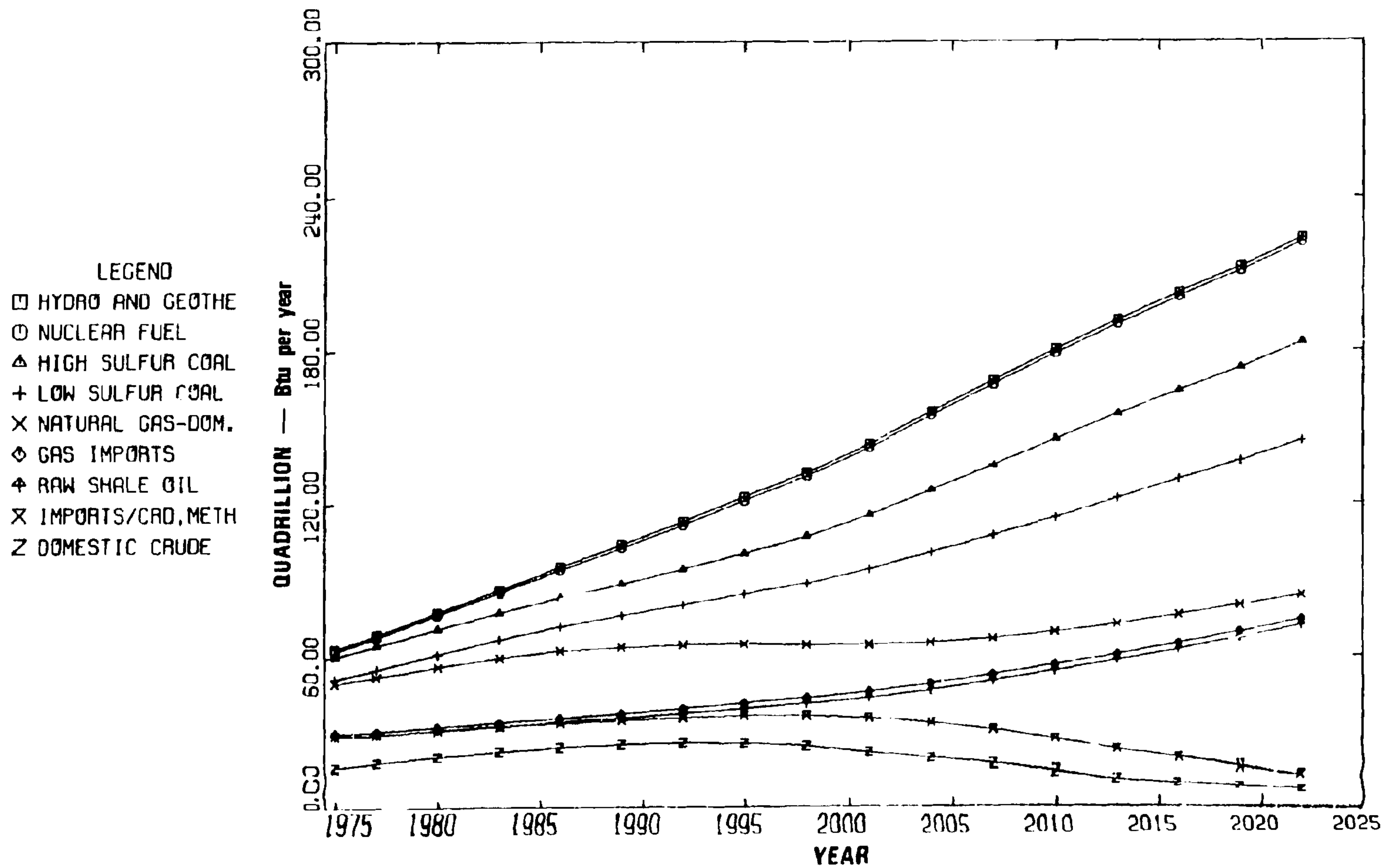
FUTURE DEMAND FOR GAS AND OIL—
SENSITIVITY TO TOTAL ENERGY DEMAND

Quadrillion Btu/year (10^{15} Btu/year)

	1986			1995		
	High Demand	Nominal	Low Demand	High Demand	Nominal	Low Demand
Synthetic Gas	1.6	1.1	.9	11.1	6.1	4.3
Imported Gas	1.6	1.5	1.5	2.9	2.0	1.9
Domestic Natural Gas	29.0	26.4	25.2	24.5	23.3	22.0
Synthetic Liquids	.8	.8	.7	5.5	4.7	4.6
Imported Crude	17.3	9.8	7.1	22.2	10.9	7.0
Domestic Crude	24.8	24.8	24.5	26.5	26.5	25.5

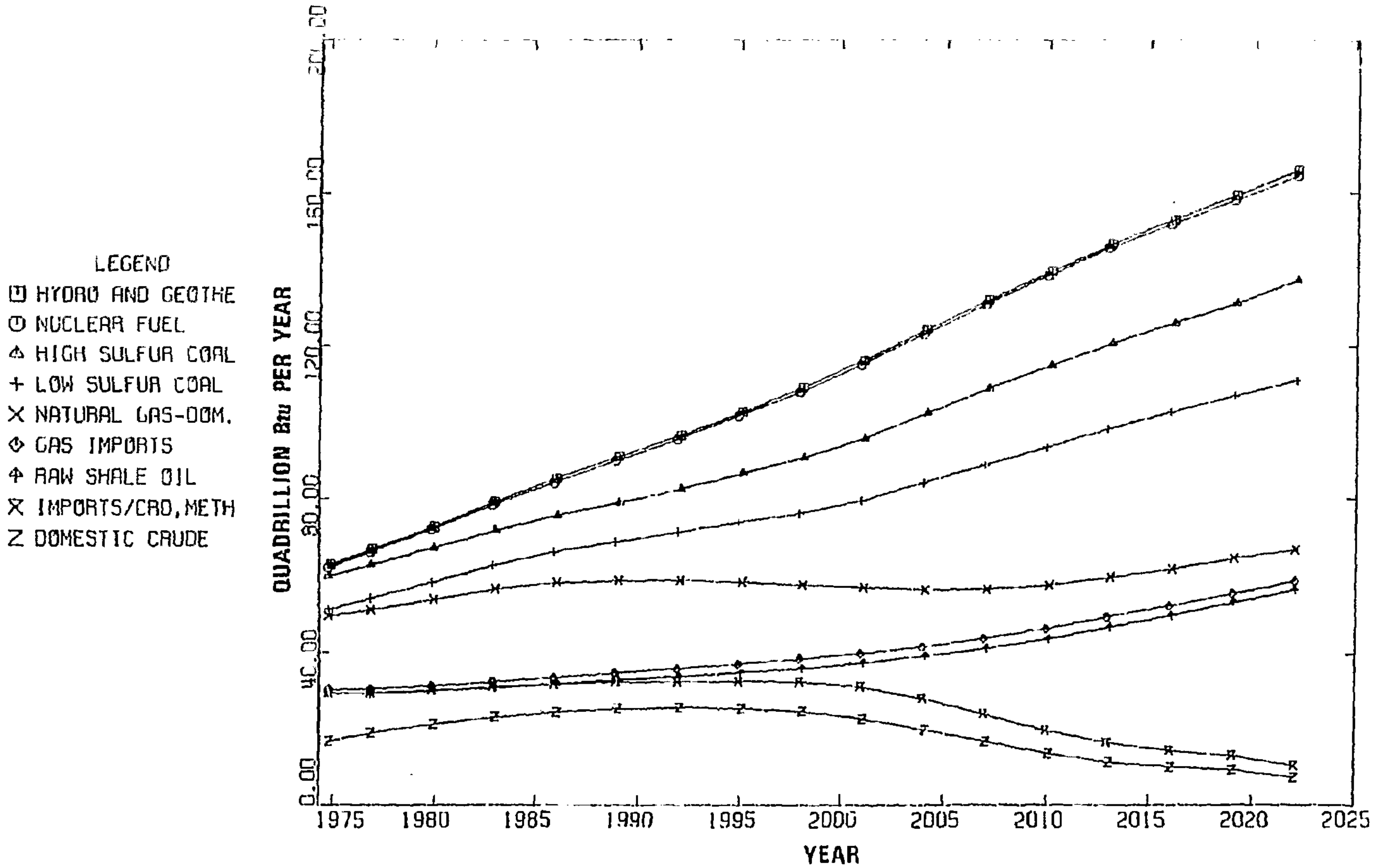


HIGH DEMAND
FIGURE H-III-14



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE H-III-15



LOW DEMAND

FIGURE H-III-16

5. Nuclear Availability

Nuclear availability has less effect on synthetics than some of the earlier variables examined; it is important because of its lack of effect on synthetics. Nuclear fuel competes directly with other fuels only in a limited market, the electric utility market; indirectly, however, it competes with all other fuels at the end-use site. Thus, this sensitivity case is dependent upon how well the effects of competition among all fuel types are modeled.

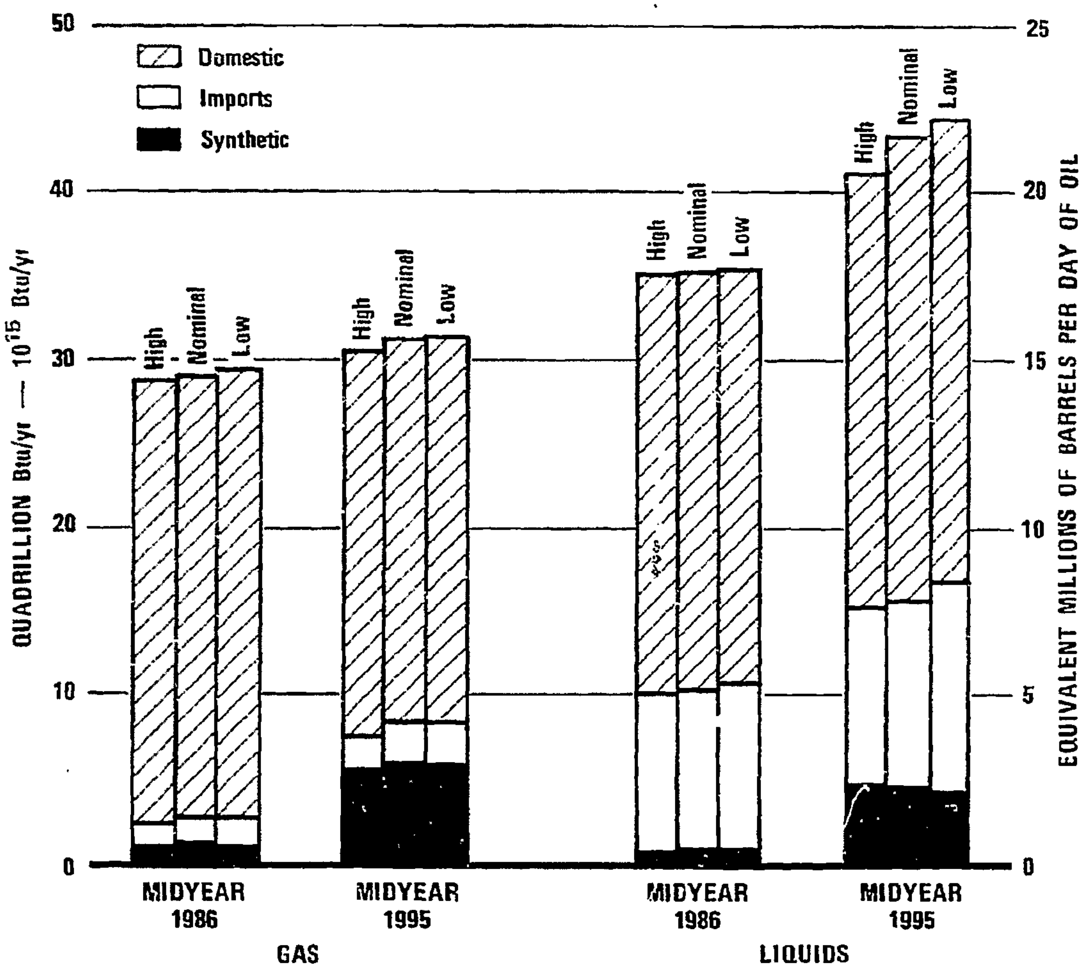
The nominal case assumes the capital cost of the light water reactor power plant to be $550/kw excluding interest during construction. In the nominal case, nuclear power generates virtually all base load power except for some coal generation near coal mines. In the low nuclear availability case, the assumption is that no new nuclear plants will be constructed, but that existing plants will continue to operate until they wear out.

In the high nuclear availability case, the capital cost of the light water reactor plant is assumed to be $400/kw, excluding interest during construction.

The effect of nuclear availability on gaseous and liquid fuels markets is shown in Figure H-III-17 and Table H-III-7 . The key insight is that nuclear availability has relatively little effect on synthetic fuel production. The primary resource balance is pictured in Figures H-III-18, H-III-19, and H-III-20 for the nominal, low, and high nuclear availability cases. Note that, in the low nuclear availability case, nuclear fuel is completely replaced by coal, and that the effect on oil and gas is small. In the high nuclear availability case, little change in primary resource consumption is seen.

The important results are:

- Base load nuclear power is replaced by coal in the event of a nuclear ban.
- In the case of low nuclear availability, synthetic fuels production drops. The reason is high cost of coal due to increased demand for coal; with a higher cost of coal, synthetics are less attractive.
- In the case of high nuclear availability, the price of nuclear power is low enough to capture some of the liquids and gases market resulting in lower demand for synthetics.
- Domestic oil and gas production are virtually unaffected by nuclear availability.
- The volume of imported crude is up slightly in the low nuclear availability case.
- The liquid fuels market responds more strongly to nuclear availability; as nuclear power becomes less attractive, the demand for liquid fuels increases because liquid fuels are used to generate intermediate and peak power in this case.
- The gaseous fuels market is insensitive to nuclear availability.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO AVAILABILITY OF NUCLEAR ENERGY

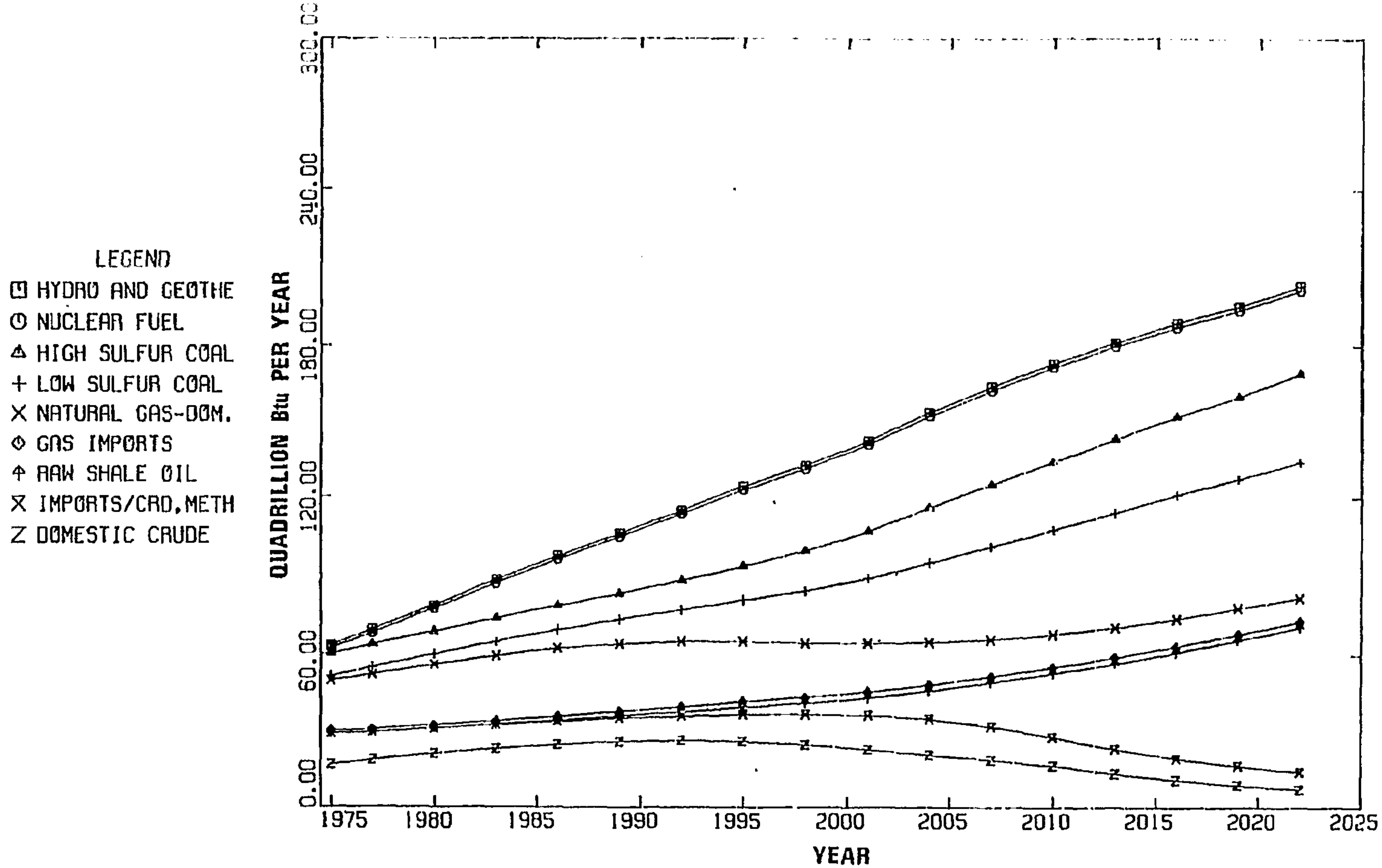
FIGURE H-III-17

Table H-III-7

FUTURE DEMAND FOR GAS AND OIL--
SENSITIVITY TO AVAILABILITY OF NUCLEAR ENERGY

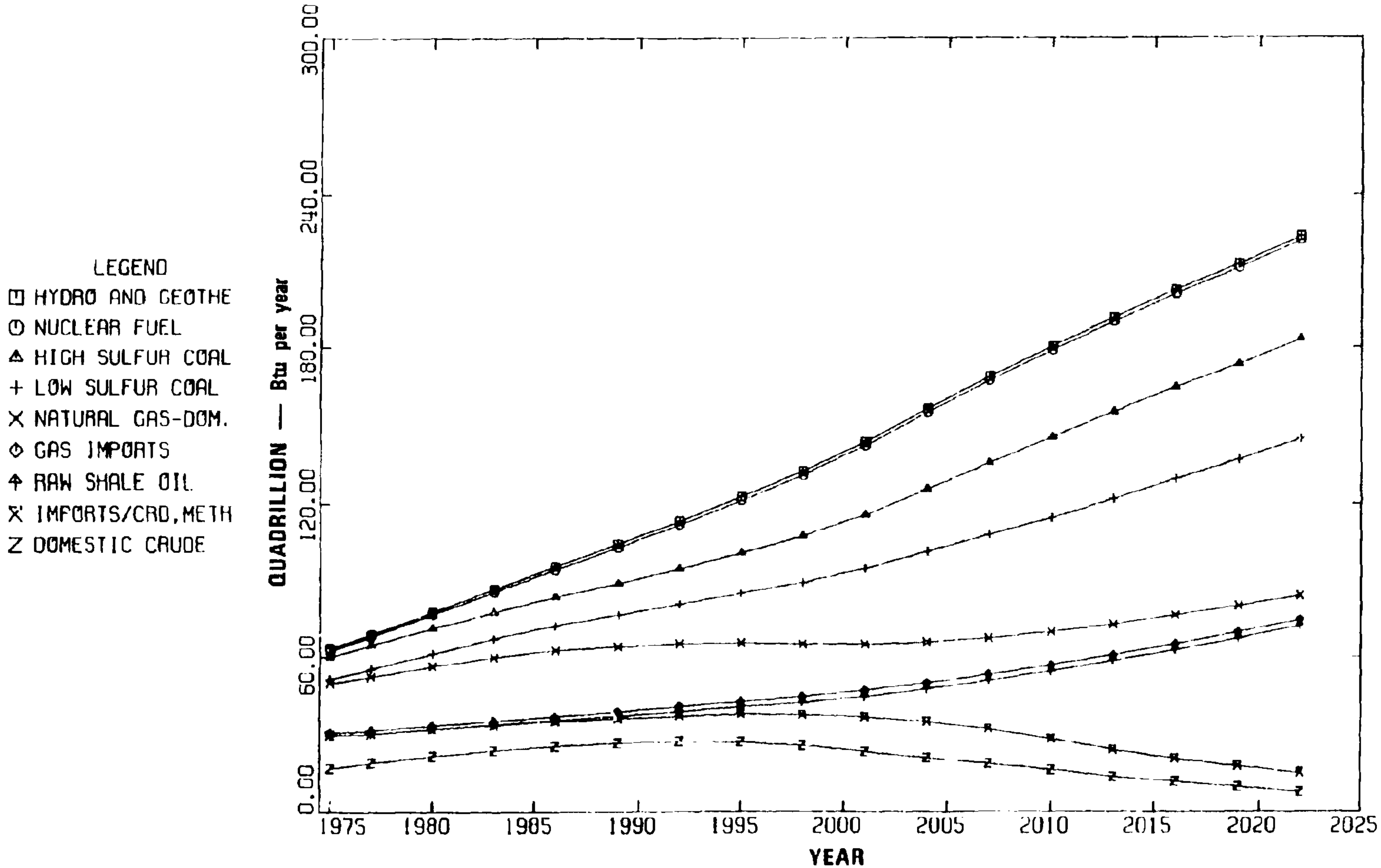
Quadrillion Btu/year (10^{15} Btu/year)

	1986			1995		
	High Nuclear Availability	Nominal	Low Nuclear Availability	High Nuclear Availability	Nominal	Low Nuclear Availability
Synthetic Gas	1.0	1.1	1.1	5.5	6.1	6.0
Imported Gas	1.5	1.5	1.5	2.0	2.0	2.1
Domestic Natural Gas	26.2	26.4	27.0	23.3	23.3	23.6
Synthetic Liquids	.7	.7	.7	4.6	4.7	4.4
Oil Imports	9.6	9.8	10.2	10.8	10.9	11.6
Domestic Crude	24.8	24.8	24.8	26.2	26.5	26.6



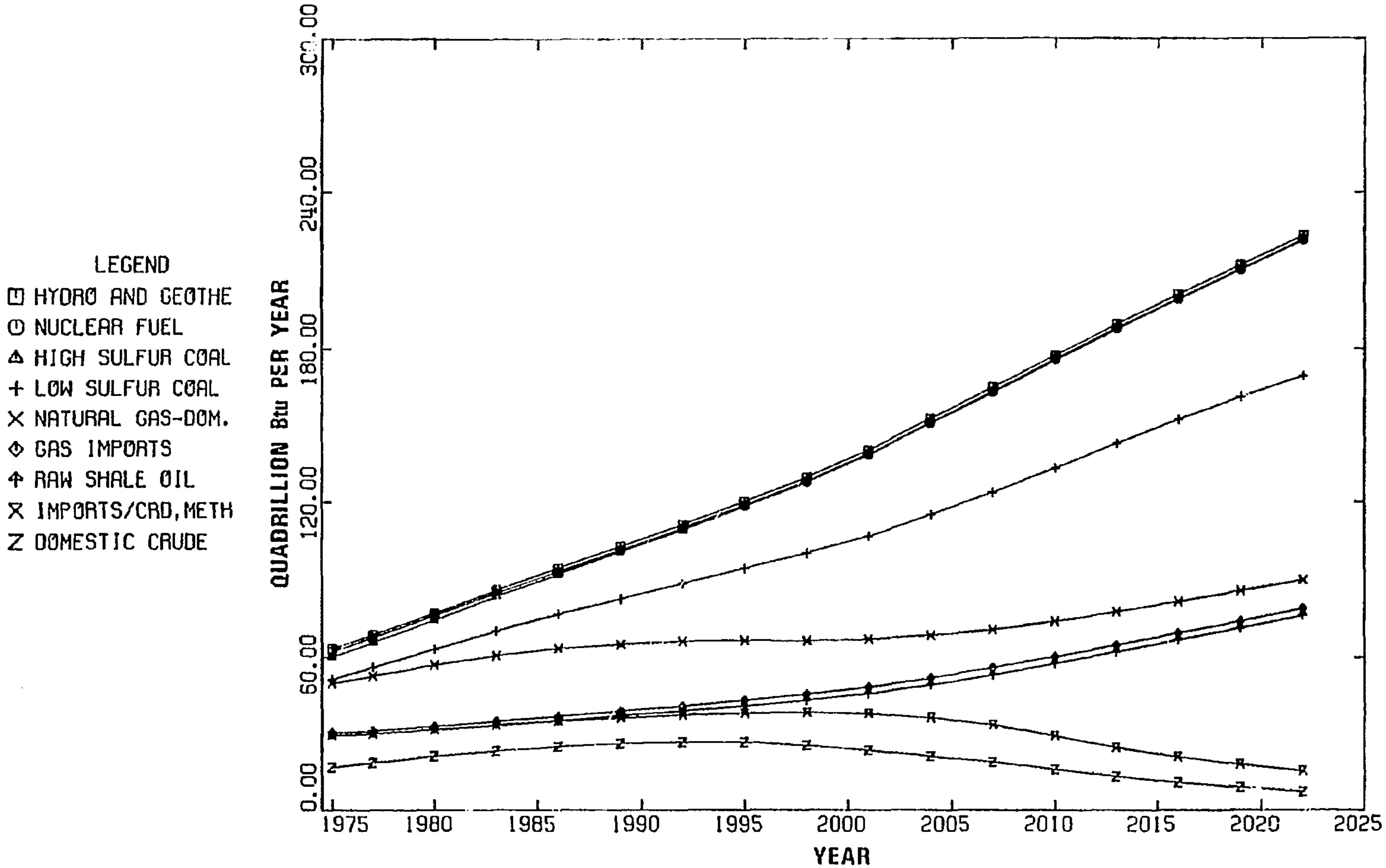
HIGH NUCLEAR AVAILABILITY

FIGURE H-III-18



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE H-III-19



LOW NUCLEAR AVAILABILITY

Figure H-III-20

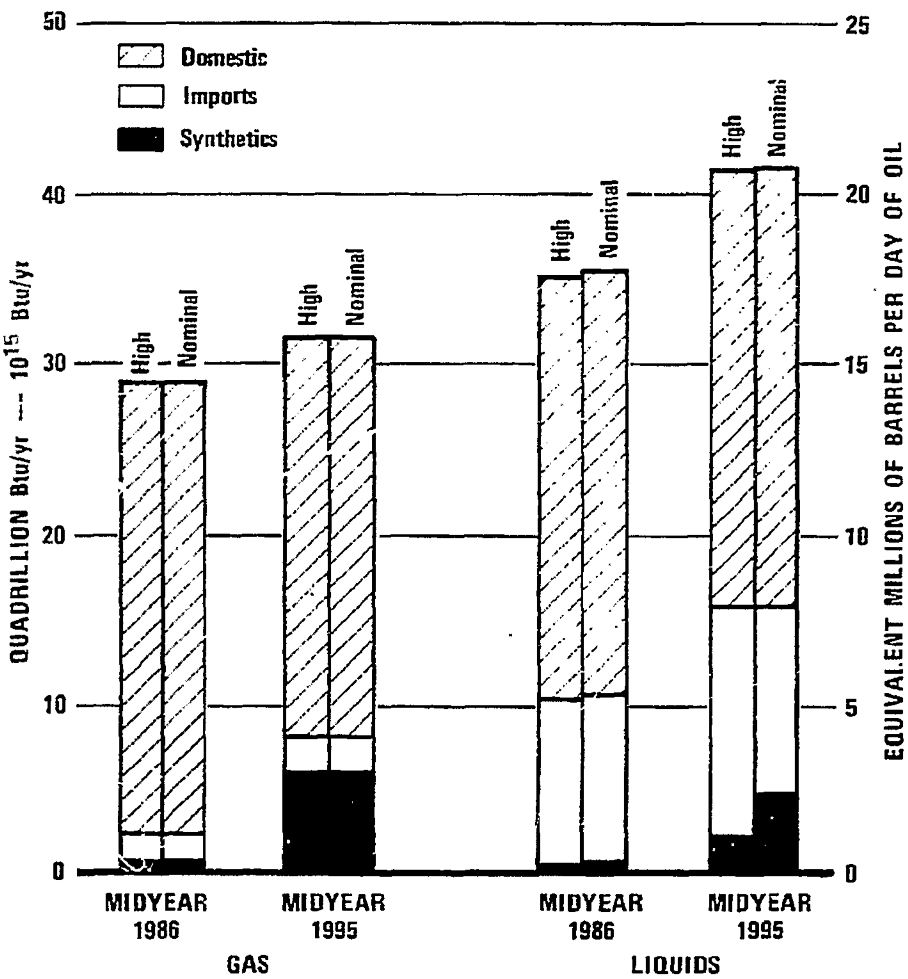
6. High Shale Cost

In the nominal case, shale oil is the most attractive synthetic liquid fuel. The nominal case data implies a shale syncrude cost of roughly $15/bbl. (Shale syncrude is equivalent to domestic crude oil.) Shale oil feasibility has been questioned on the basis of excessive environmental costs, therefore the price of shale syncrude is increased by 65% -- to about $24.75/bbl -- to pay these costs. This increase eliminates shale oil from the U.S. energy picture.

The effect of high shale oil cost for the liquid and gaseous fuel markets is shown in Figure H-III-21 and Table H-III-8. The results are best illustrated at the primary resource level which is shown in Figures H-III-22 and H-III-23. Note that shale syncrude is no longer competitive in the liquid fuels market; all the previous demand for shale oil is filled by imported crude.

The important insights are:

- Shale oil is replaced by imported crude.
- The gas market is unaffected.
- Shale oil competes with imported crude; the difference between demand and domestic crude production is filled by imported crude or shale syncrude, depending on relative costs.
- The production of fuels other than shale oil are weakly affected by shale price.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO HIGH OIL SHALE COST

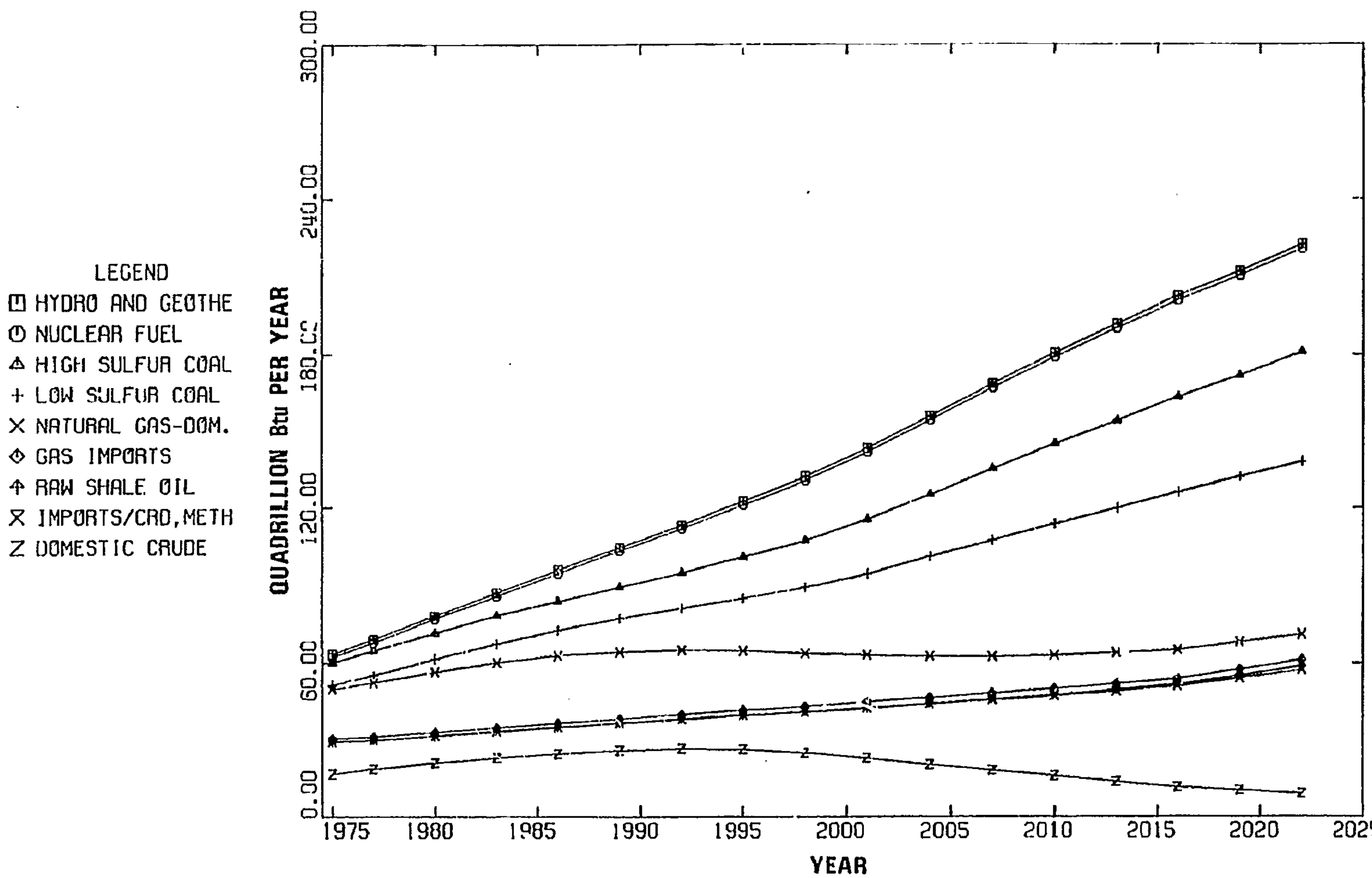
FIGURE H-III-21

Table H-III-8

FUTURE DEMAND FOR GAS AND OIL—
SENSITIVITY TO HIGH OIL SHALE COST

Quadrillion Btu/year (10^{15} Btu/year)

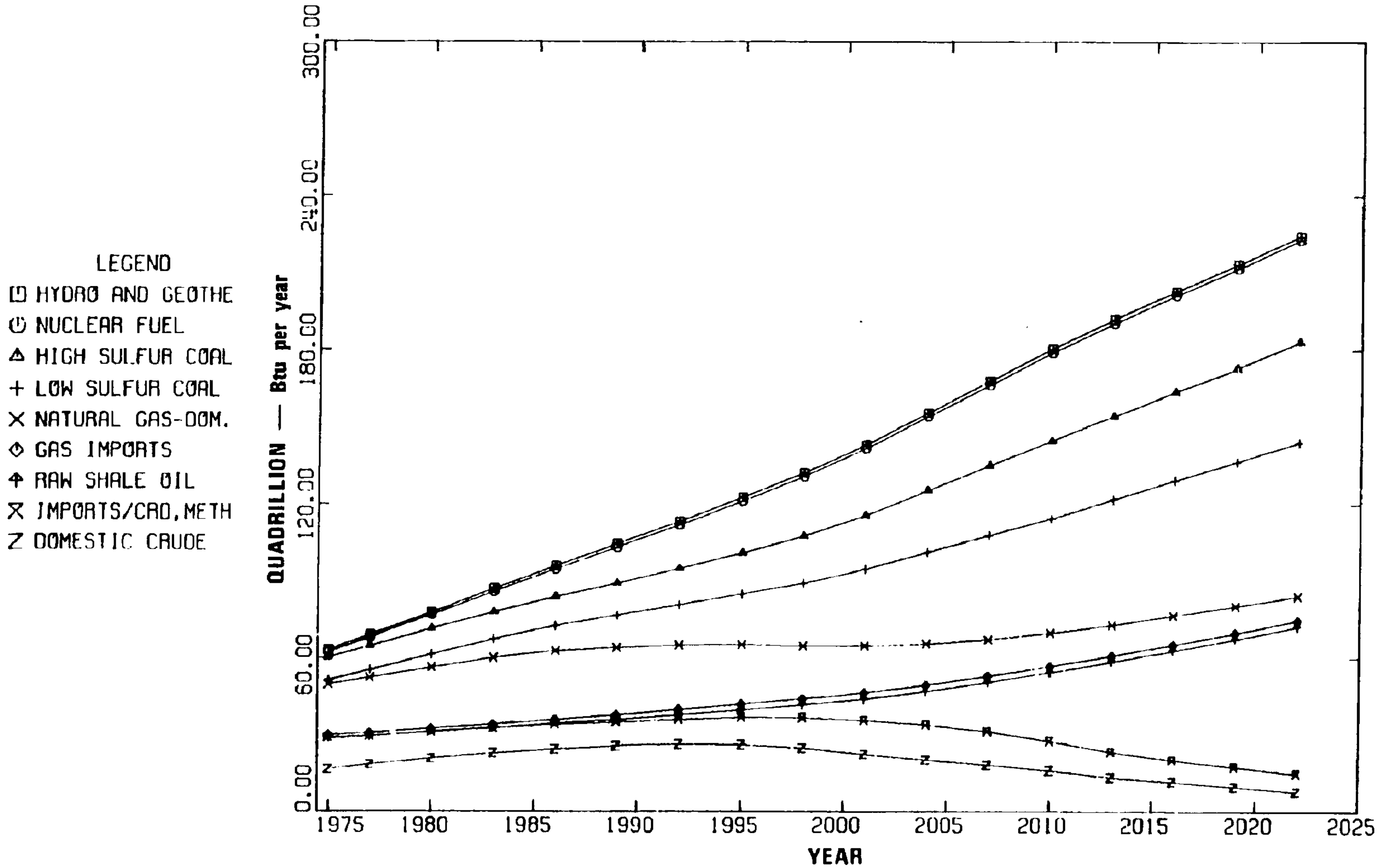
	1986		1995	
	High Shale Cost	Nominal	High Shale Cost	Nominal
Synthetic Gas	1.1	1.1	6.1	6.1
Imported Gas	1.5	1.5	2.0	2.0
Domestic Natural Gas	26.5	26.4	23.3	23.3
Synthetic Liquids	.4	.7	2.3	4.7
Oil Imports	10.3	9.8	13.2	10.9
Domestic Crude	24.6	24.8	26.4	26.5



HIGH SHALE COST

FIGURE H-III-22

H87



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE H-III-23

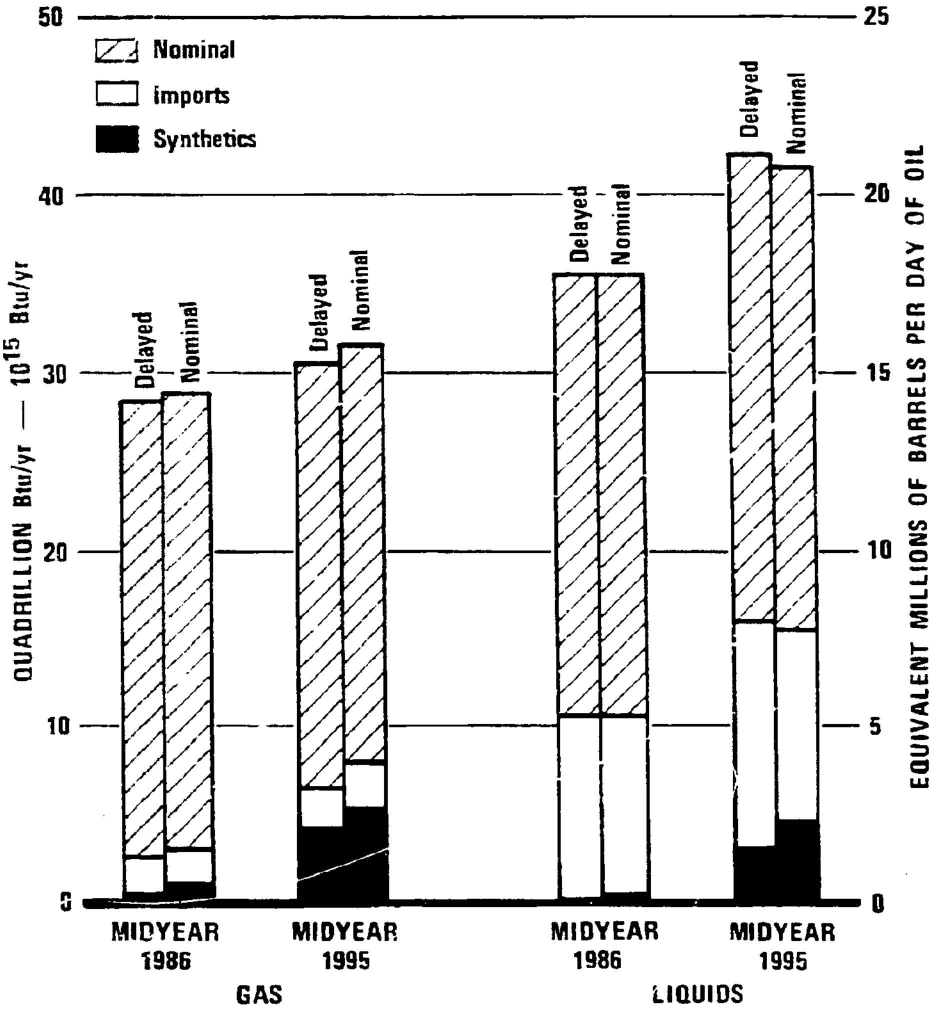
7. Synethtic Fuels Delayed Five Years

An important question from the standpoint of this program is what is the effect of a delay on the introduction of commercial production of synthetic fuels. As discussed in Chapter II of the main text, the primary aim of the Synthetic Fuels Commercialization Program is to increase the probability of early availability of synthetic fuels.

This sensitivity run assumes that synthetic fuels introduction is delayed five years. (See Table H-I-5 in this appendix.) The results are presented in Figure H-III-24 and Table H-III-9. In terms of primary resources, the effect of a five-year delay in synthetics is not major. Shale oil production is delayed, but it grows faster once it begins; eastern and western coal growth is slower in the near term but faster in the longer term. Therefore the primary resource volumes are not shown.

The important insights are:

- The five-year delay in synthetics in 1985 becomes only a two-year delay in 2000. Synthetics production increases faster in the delayed synthetics case.
- The reduced synthetics production due to the delay is made up principally by crude imports and, to a lesser extent, by domestic gas production.
- Synthetic fuels production is down 500,000 bbl/day in 1985 and 1.5 million bbl/day in 1995.
- Imports are up 335,000 bbl/day in 1985 and 850,000 bbl/day in 1995.
- The effect of the five-year delay is not large on imports but is relatively large on synthetics.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO SYNFUELS TIMING

FIGURE H-III-24

TABLE H-III-9

FUTURE DEMAND FOR GAS AND OIL--
SENSITIVITY TO SYNFUELS TIMING

Quadrillion Btu/year (10^{15} Btu/year)

	1986		1995	
	Delayed Synfuels	Nominal	Delayed Synfuels	Nominal
Synthetic Gas	.5	1.1	4.4	6.1
Imported Gas	1.5	1.5	2.0	2.0
Domestic Natural Gas	26.3	26.4	24.2	23.3
Synthetic Liquids	0.2	.7	3.2	4.7
Oil Imports	10.5	9.8	12.7	10.9
Domestic Crude	24.7	24.8	26.2	26.5

8. Synthetic Gas Cost

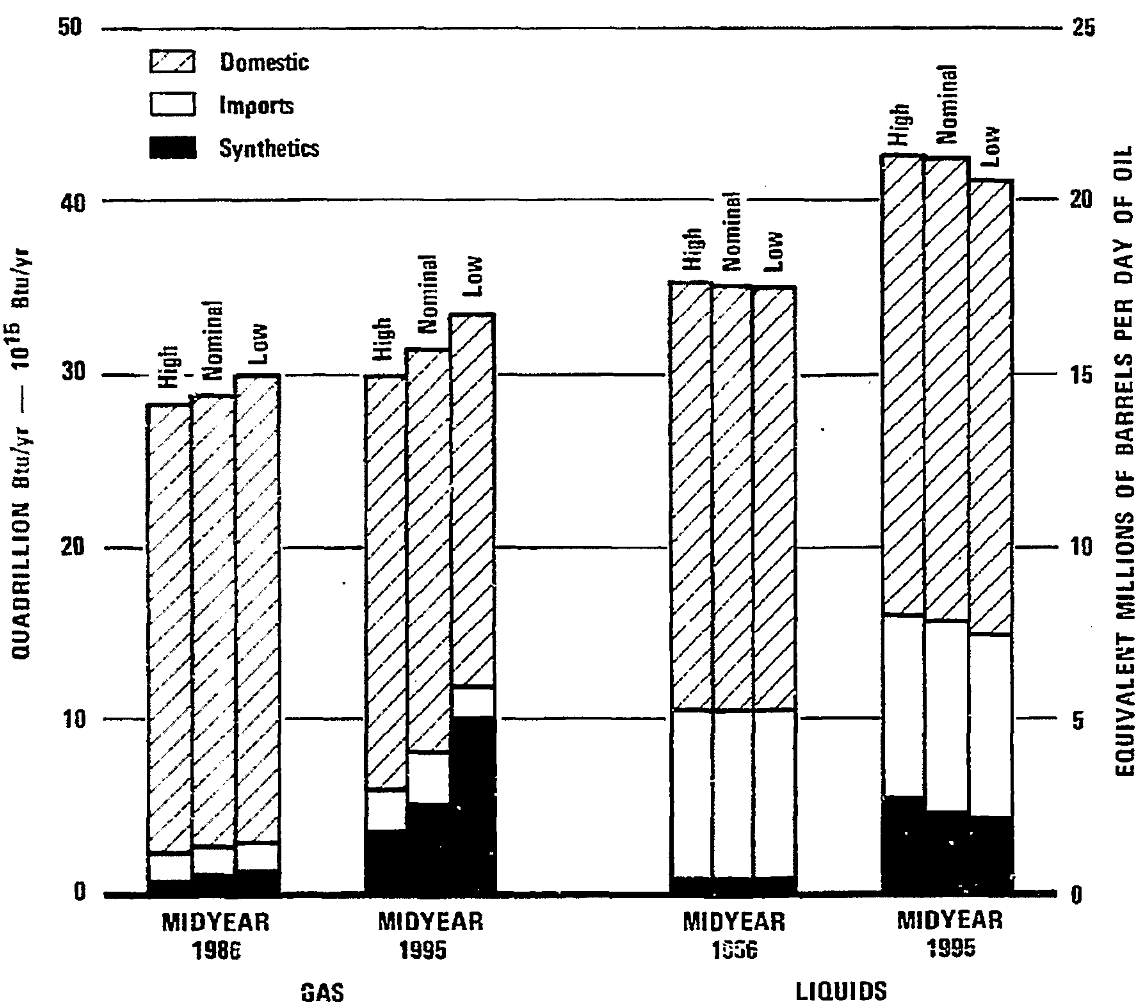
The cost of synthetic gas is also quite important because synthetic high Btu gas ultimately sets the price of U.S. gas in the nominal case, thus the effect of the cost of synthetic high Btu gas was also examined.

In the low SNG (synthetic natural gas or high Btu gas) cost case, the price of synthetic high Btu gas is decreased by $.50/MMBtu; in the high SNG cost case, the price of synthetic high Btu gas is increased by $.50/MMBtu. These changes apply both to first generation Lurgi technology and to second generation technology for producing methane from coal.

The results of this sensitivity analysis are summarized in Figure H-III-25 for the gaseous and liquid fuels markets and Table H-III-10. The primary resource projections are not shown because the effect of SNG cost on primary resources is small.

The important insights are:

- Synthetic gas production is quite sensitive to cost. In the low SNG price case, synthetic gas production is up 66% over the nominal case in 1995. In the high SNG price case, synthetic gas production is down 62%.
- Gas demand is satisfied by either domestic natural gas or synthetic gas; imported LNG is not price competitive.
- As SNG price drops, gas substitutes for liquids, reflecting that gas is a premium fuel.
- Imports are relatively unaffected by SNG cost.
- Domestic production of natural gas is stimulated by high SNG price.
- The liquid fuels market is relatively insensitive to synthetic gas costs.
- If synthetic gas becomes more expensive, gas demand declines and is replaced by liquid fuels and coal.
- Low SNG cost stimulates coal production to make gas, resulting in slightly higher short-term coal costs. This tends to retard direct durning of coal. Thus, low SNG cost retards the substitution of coal for gas.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO SUBSTITUTE NATURAL GAS COST

FIGURE H-III-25

Table H-III-10

FUTURE DEMAND FOR GAS AND OIL--

SENSITIVITY TO SUBSTITUTE NATURAL GAS COST

Quadrillion Btu/year (10^{15} Btu/year)

	1986			1995		
	High SNG Price	Nominal	Low SNG Price	High SNG Price	Nominal	Low SNG Price
Synthetic Gas	0.9	1.1	1.5	3.8	6.1	10.1
Imported Gas	1.5	1.5	1.5	2.2	2.0	1.9
Domestic Natural Gas	25.9	26.4	27.2	24.1	23.3	21.4
Synthetic Liquids	.8	.7	.7	5.3	4.7	4.3
Oil Imports	9.8	9.8	9.6	10.9	10.9	10.6
Domestic Crude	24.9	24.8	24.7	26.4	26.5	26.2

9. Penalty on Industrial Burning of Coal

An important question with respect to synthetic fuels production is whether industrial end users can burn coal directly. In the nominal case, the assumption is that western low sulfur coal can be burned directly and eastern high sulfur coal burning requires stack gas cleanup. The possibility that industrial burning of coal may be expensive must be considered because stack gas cleanup is not entirely proven and because emissions standards could be tightened. In this sensitivity case, it is assumed that industrial direct heaters and boilers are assessed a $1/MMBtu penalty to burn low sulfur coal and a $1.50/MMBtu penalty to burn high sulfur coal. Electric power generation based on coal is not changed; it is assumed that stack gas scrubbing is capable of meeting emissions standards.

The results of a high penalty on industrial coal burning are presented in Figure H-III-26 and Table H-III-11. Since this sensitivity has little effect on the primary resource balance, the primary resource plots are omitted.

The important insights are:

- Synthetic liquid production increases 8.5% in 1995 over the nominal case; synthetic gases production increases 10% in 1995.
- Imports are unchanged.
- Domestic oil and gas production is unchanged.
- There is a slight substitution of gas for liquid as a penalty is assessed against coal.

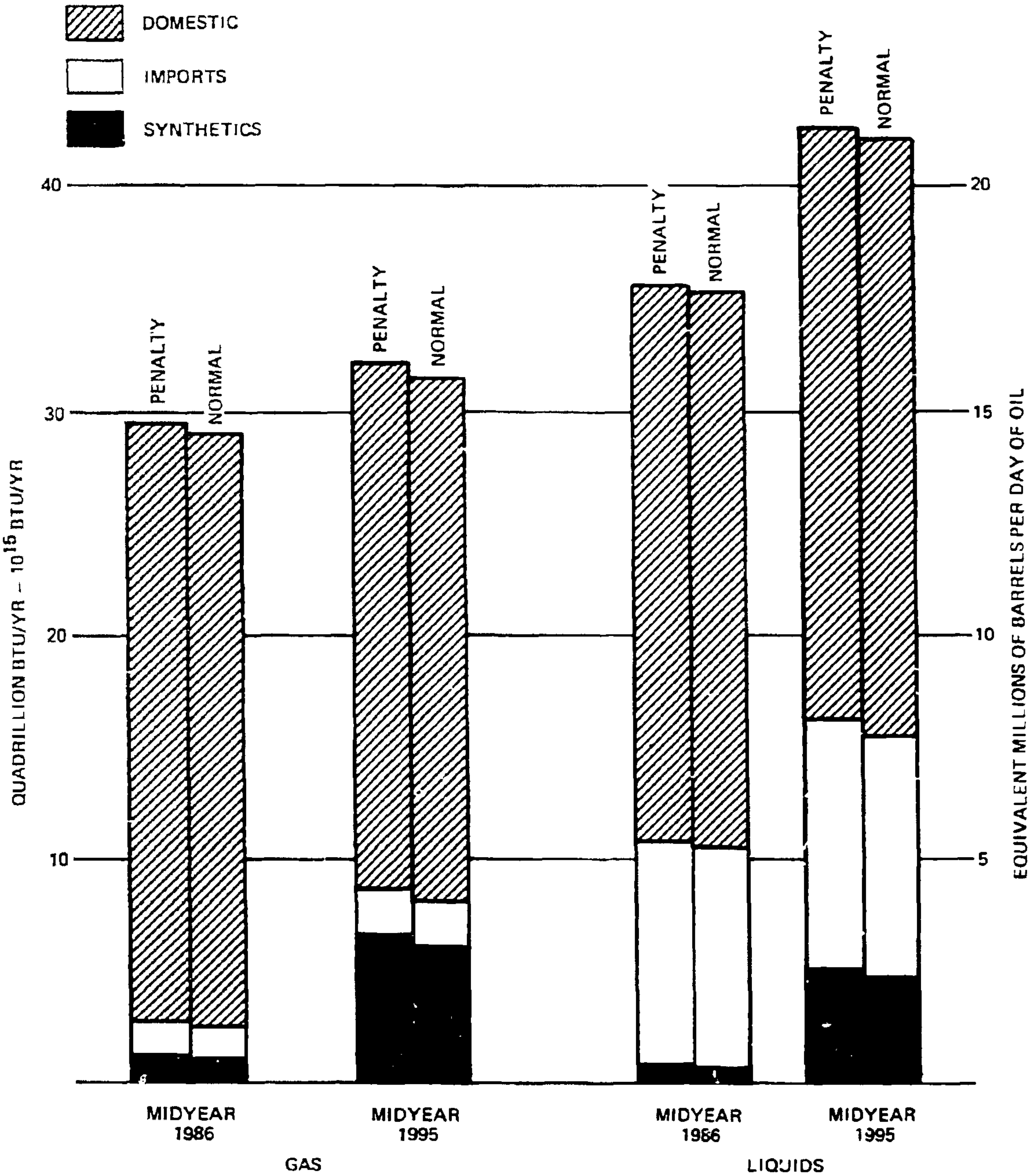


FIGURE H-III-26 FUTURE DEMAND FOR GAS AND OIL – SENSITIVITY TO PENALTY ON USE OF COAL

TABLE H-III-11

FUTURE DEMAND FOR GAS AND OIL--
SENSITIVITY TO PENALTY ON USE OF COAL

Quadrillion Btu/year (10^{15} Btu)

	1986		1995	
	PENALTY on Industrial Coal	Nominal	PENALTY on Industrial Coal	Nominal
Synthetic Gas	1.2	1.1	6.7	6.1
Imported Gas	1.5	1.5	2.0	2.0
Domestic Natural Gas	26.8	26.4	23.5	23.3
Synthetic Liquids	.8	.7	5.1	4.7
Oil Imports	10.0	9.8	11.2	10.9
Domestic Crude	24.8	24.8	26.5	26.5

10. High Import Price with Low and High Oil and Gas Availability

This sensitivity case examines the effect of high and low oil and gas availability given a strong cartel and high import prices. In the case of high import price and low oil and gas availability, the U.S. is highly dependent on high-priced imports. In the case of high import price and high oil and gas availability, the U.S. has large oil and gas reserves, but imports are priced high, presumably due to world market forces.

These sensitivity cases are constructed as follows: The price of imports is the same as in the high import price case discussed in the first sensitivity analysis in this appendix. The oil and gas resource curves are then shifted to the right by 50% and to the left by 20%, as in the second sensitivity analysis in this appendix. In summary:

- High Import Price, High Oil and Gas Availability -- All import price curves were multiplied by 14/11=1.27, and all oil and gas resource curves were shifted to the right by 50%.

- High Import Price, Low Oil and Gas Availability -- All import price curves were multiplied by 14/11=1.27, and all oil and gas resource curves were shifted to the left by 20%.

The results of this sensitivity analysis are presented in Figure H-III-27 and Table H-III-12. The primary resource balance is pictured in Figures H-III-28, H-III-29, and H-III-30.

The important results are:

- High import price has a more important effect than the availability of oil and gas.

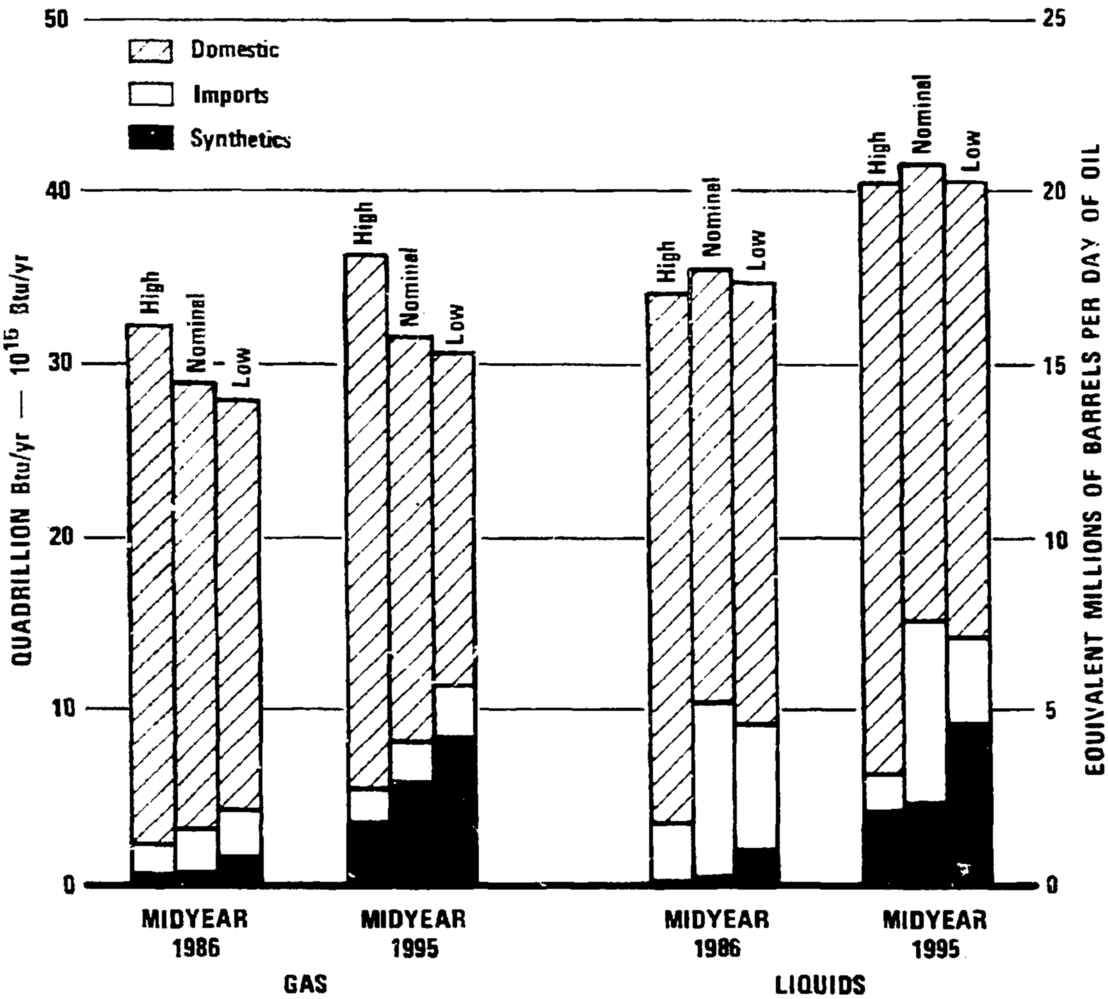
- Oil imports are highest in the nominal case. For low oil and gas availability, crude imports are down 55% in 1995 from the nominal case, but synthetic liquids are up 98%. For high oil and gas availability, crude imports are down 27% in 1995 from the nominal case, but synthetic liquids are down 55% as well.

- When import prices are high and gas and oil are scarce, synthetics are very attractive; their production will reach 18 quads by 1995 (equivalent to 8.5 million bbl/day).

- Oil imports are highest in the nominal case. When gas and oil are scarce and import prices are high, synthetic fuels come in rapidly enough to cut imports. When gas and oil are plentiful and import prices are high, domestic production replaces imports.

- Total gas production in 1995 increases as the availability of gas and oil decrease, due to the increased production of synthetic gas.

- In all three cases, crude imports are not attractive because of their high price, regardless of domestic oil and gas availability because there is a great deal of substitution possible in the \$2.00-\$3.00/MMBtu range.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO DOMESTIC OIL AND GAS AVAILABILITY AND HIGH IMPORT PRICES

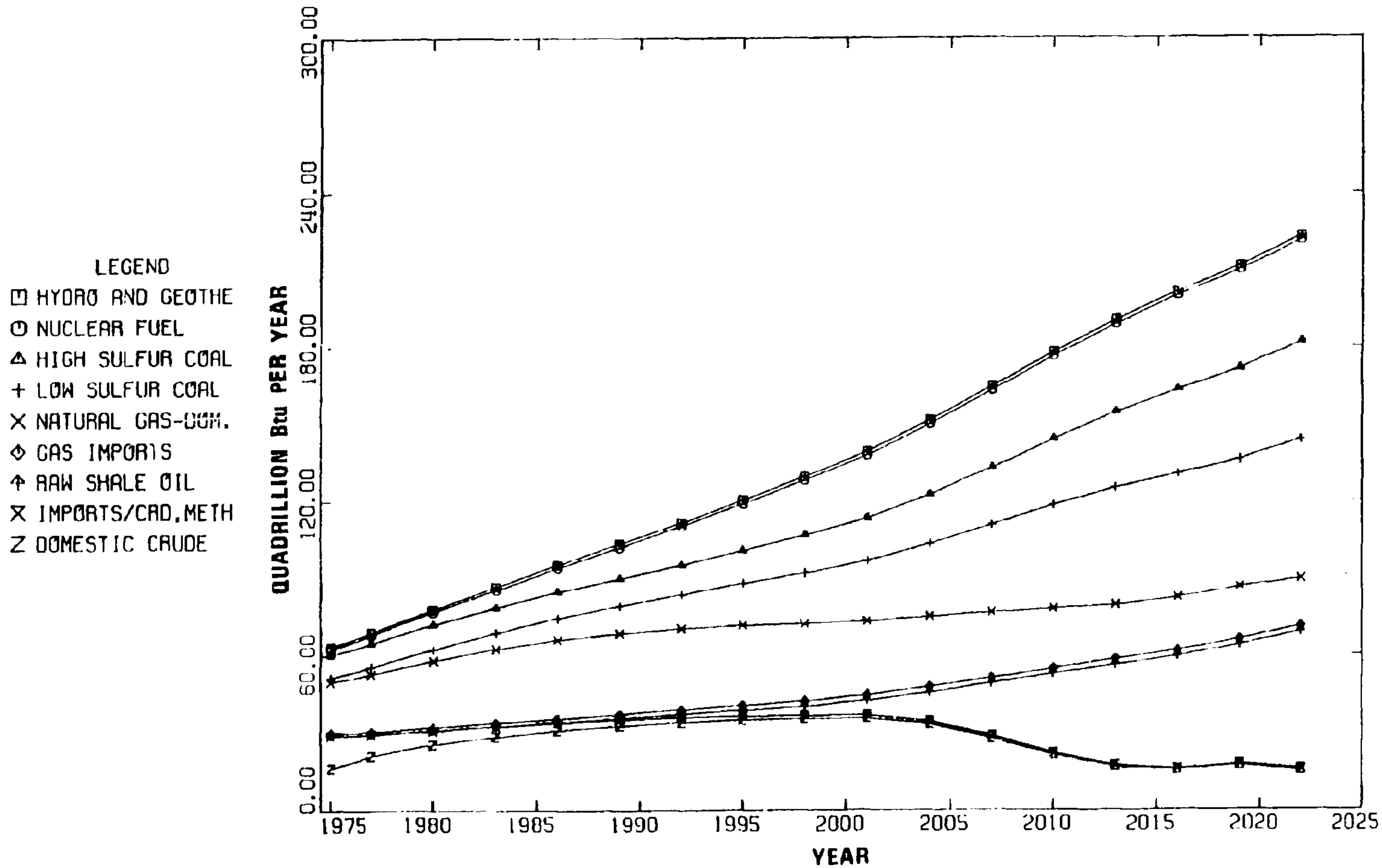
FIGURE H-III-27

TABLE H-III-12

FUTURE DEMAND FOR GAS AND OIL--
SENSITIVITY TO DOMESTIC GAS AND OIL
AVAILABILITY AND HIGH IMPORT PRICES

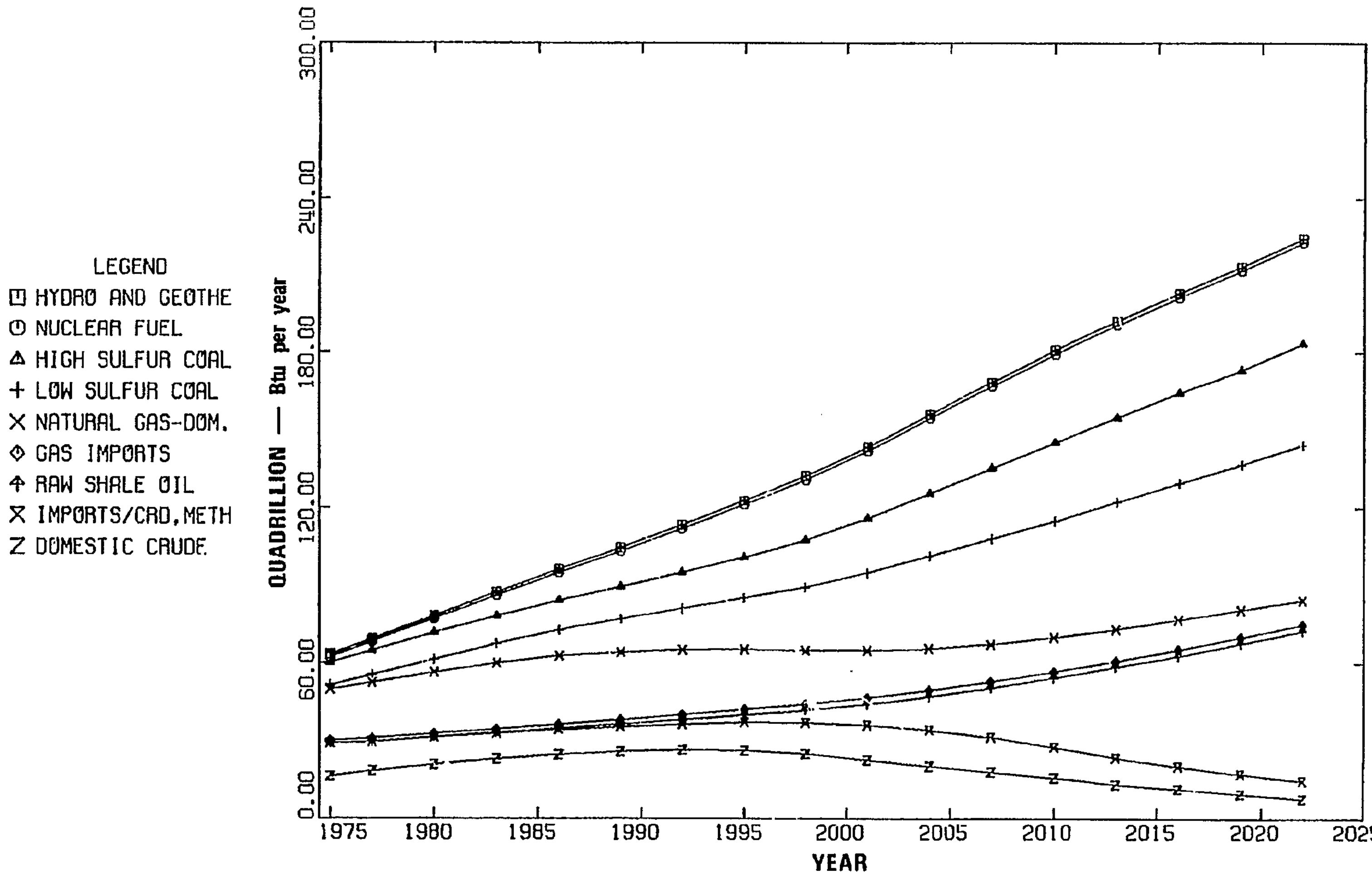
Quadrillion Btu/year (10^{15} Btu/year)

	1986			1995		
	High Oil and Gas, High Import Price	Nominal	Low Oil and Gas, High Import Price	High Oil and Gas, High Import Price	Nominal	Low Oil and Gas, High Import Price
Synthetic Gas	.8	1.1	1.5	3.1	6.1	8.7
Imported Gas	1.5	1.5	1.5	1.9	2.0	2.0
Domestic Natural Gas	30.5	26.4	24.8	30.7	23.3	19.6
Synthetic Liquids	.5	.7	1.9	4.0	4.7	9.3
Oil Imports	3.0	9.8	7.7	1.6	10.9	4.9
Domestic Crude	31.0	24.8	25.2	34.9	26.5	27.0



HIGH OIL AND GAS AVAILABILITY HIGH IMPORT PRICE

FIGURE H-III-28



NOMINAL CASE – TOTAL PRIMARY ENERGY

FIGURE H-III-29

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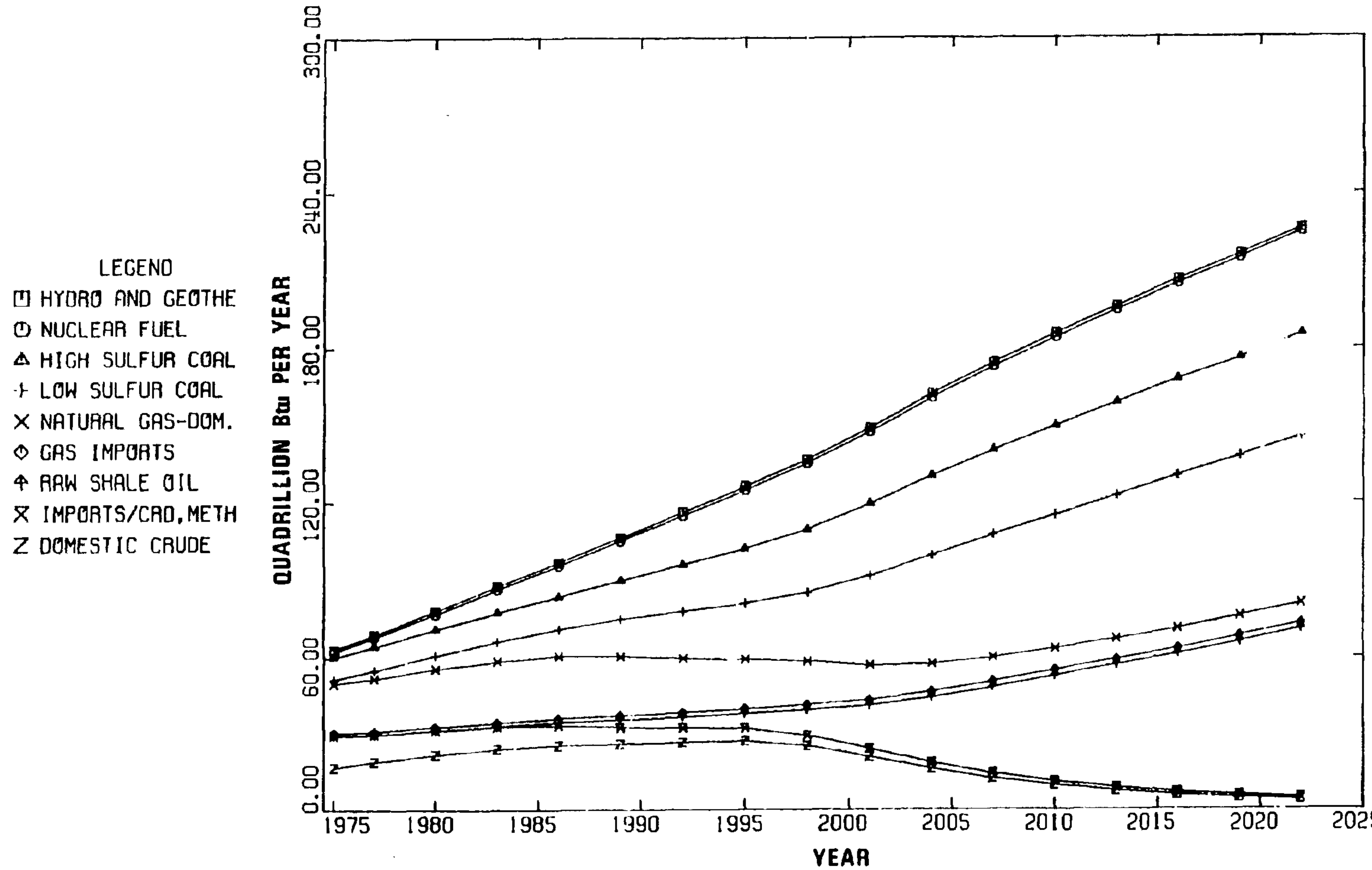


LOW OIL AND GAS AVAILABILITY HIGH IMPORT PRICE

FIGURE H-III-30

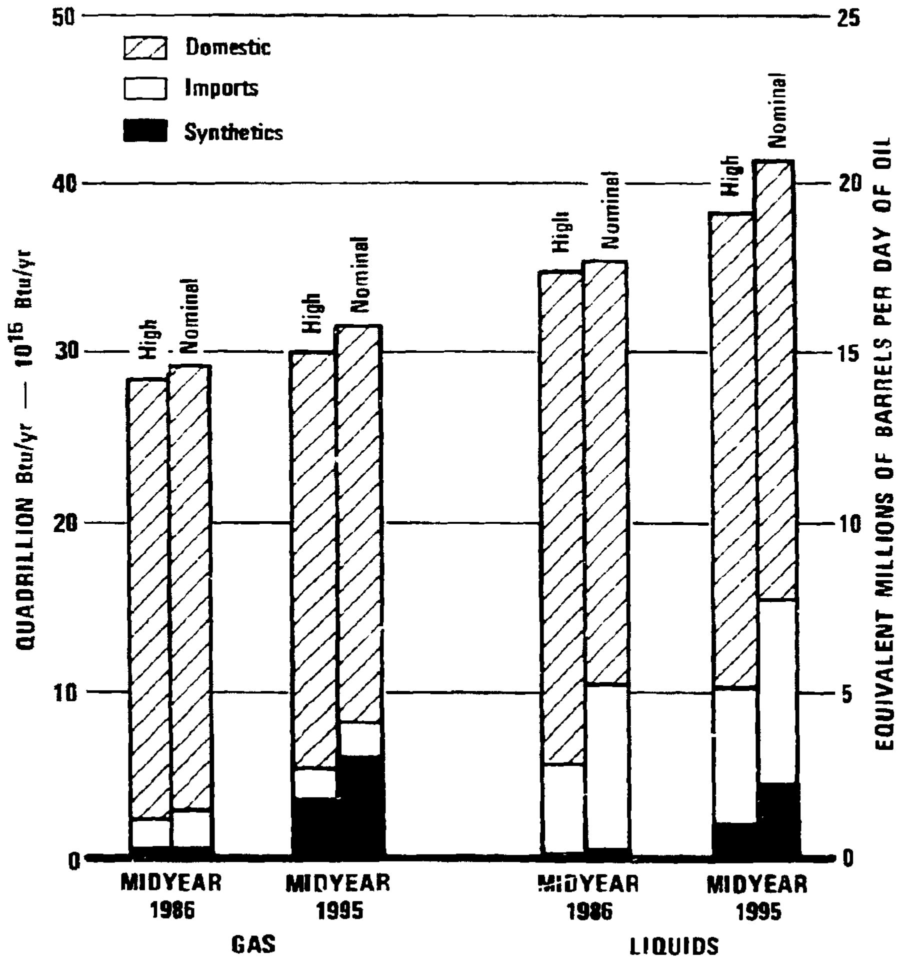
11. High Synthetics Cost and High Import Price

This joint sensitivity analysis examines the case of synthetic fuels being 50% more expensive than planned and the cartel keeping world oil prices high. This case is constructed from the previously discussed high import price case and high synthetics cost cases. The nominal case price of imports is multiplied by 14/11=1.27, and the nominal case capital and operating costs of synthetics shown in Table H-I-5 are increased by 50%. In addition, shale costs are increased by 50%. Thus energy costs are substantially increased for all but domestic sources.

The results are shown in Figure H-III-31 and Table H-III-13. Note that high synthetics costs and high import prices drive down the demand for both liquids and gases because of higher prices. Direct burning of coal and nuclear power substitute for gases and liquids. The primary resource balance is pictured in Figure H-III-32 and H-III-33. Note that the more important variable in the near term is the high import price. Imports are lower than in the nominal case through 1995. However, in 1995, imported crude increases because depletion of domestic oil and gas has driven their prices up to the point where imports are again competitive. Because shale oil is also high-priced, both imports and shale oil production increase to satisfy the demand for liquid fuels.

The important results are:

- Total gas and total oil demand drop as import prices and synfuels costs increase.
- Synthetic gas production is down 43% and synthetic liquids production is down 55% in 1995.
- The volume of crude imports is down 27% in 1995.
- Domestic gas production is up 6% and domestic oil production is up 15% in 1995.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO HIGH SYNTHETICS AND IMPORT PRICES

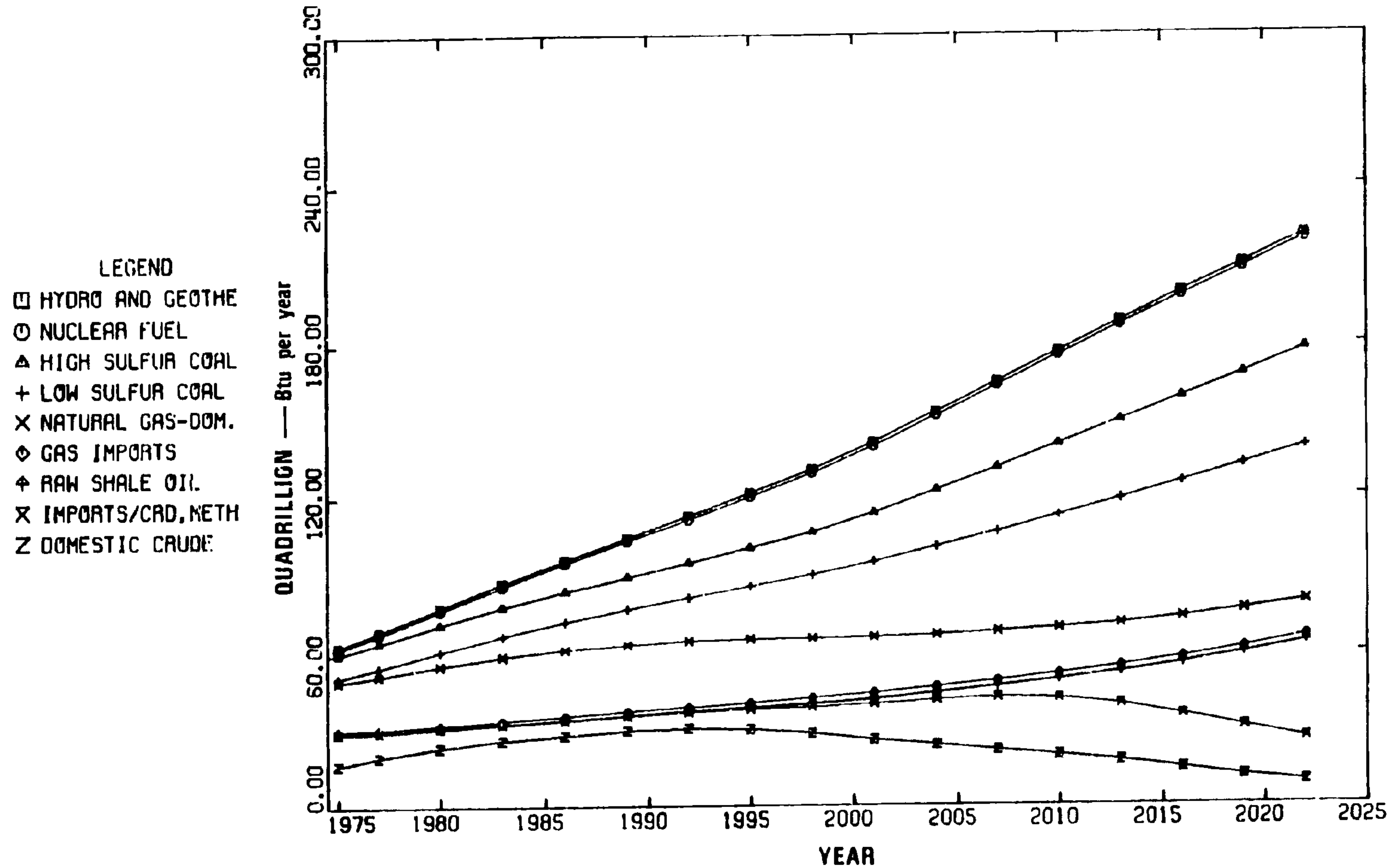
FIGURE H-III-31

TABLE H-III-13

FUTURE DEMAND FOR GAS AND OIL--
SENSITIVITY TO HIGH SYNTHETICS AND IMPORT PRICES

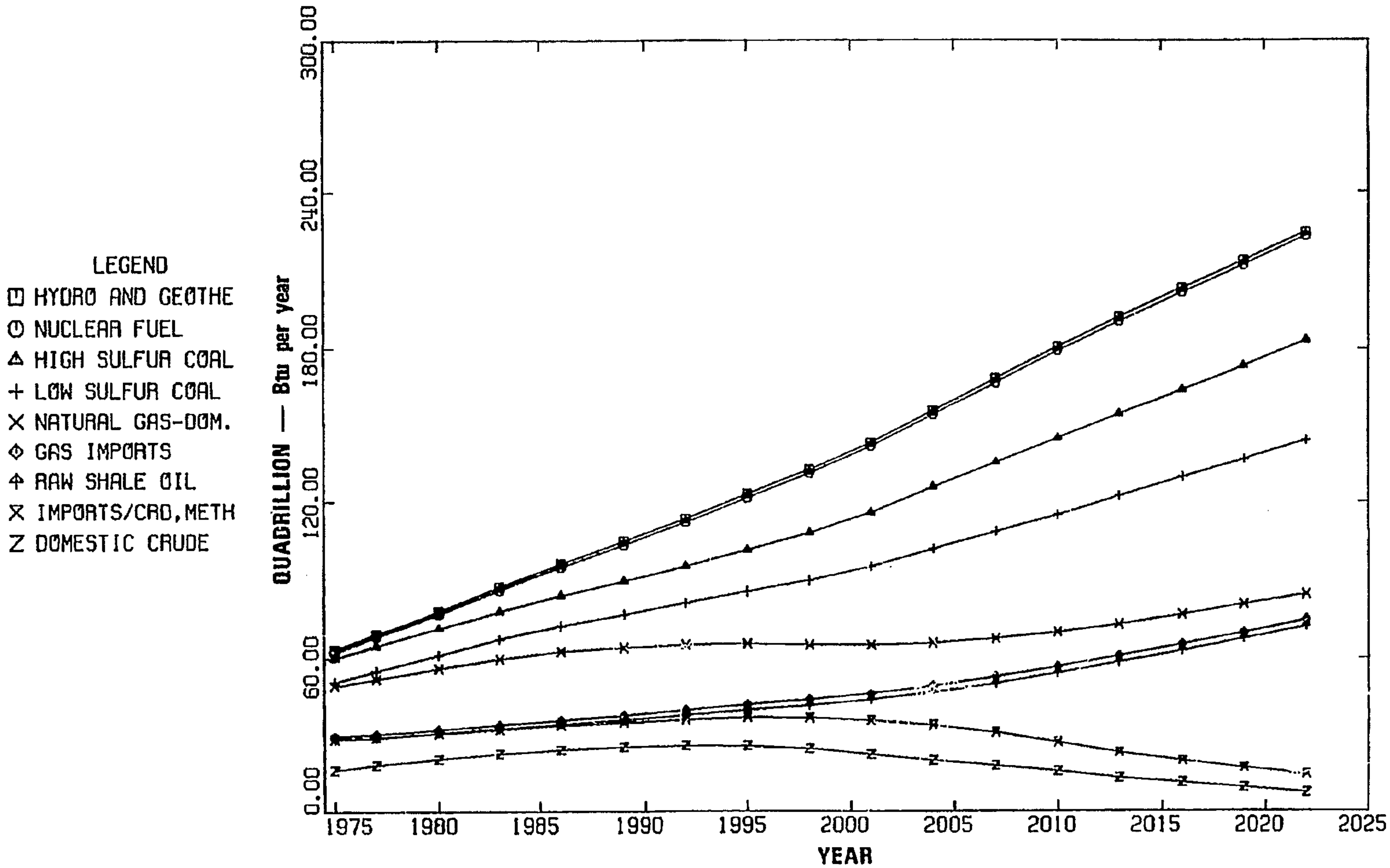
Quadrillion Btu/Year (10^{15}/year)

	1986		1995	
	High Synthetic & Import Prices	Nominal	High Synthetic & Import Prices	Nominal
Synthetic Gas	.7	1.1	3.5	6.1
Imported Gas	1.5	1.5	1.9	2.0
Domestic Natural Gas	26.0	26.4	24.6	23.3
Synthetic Liquids	0.4	.7	2.1	4.7
Oil Imports	6.0	9.8	8.0	10.9
Domestic Crude	28.2	24.8	30.4	26.5



HIGH SYNTHETICS AND HIGH IMPORT PRICE

FIGURE H-III-32



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE H-III-33

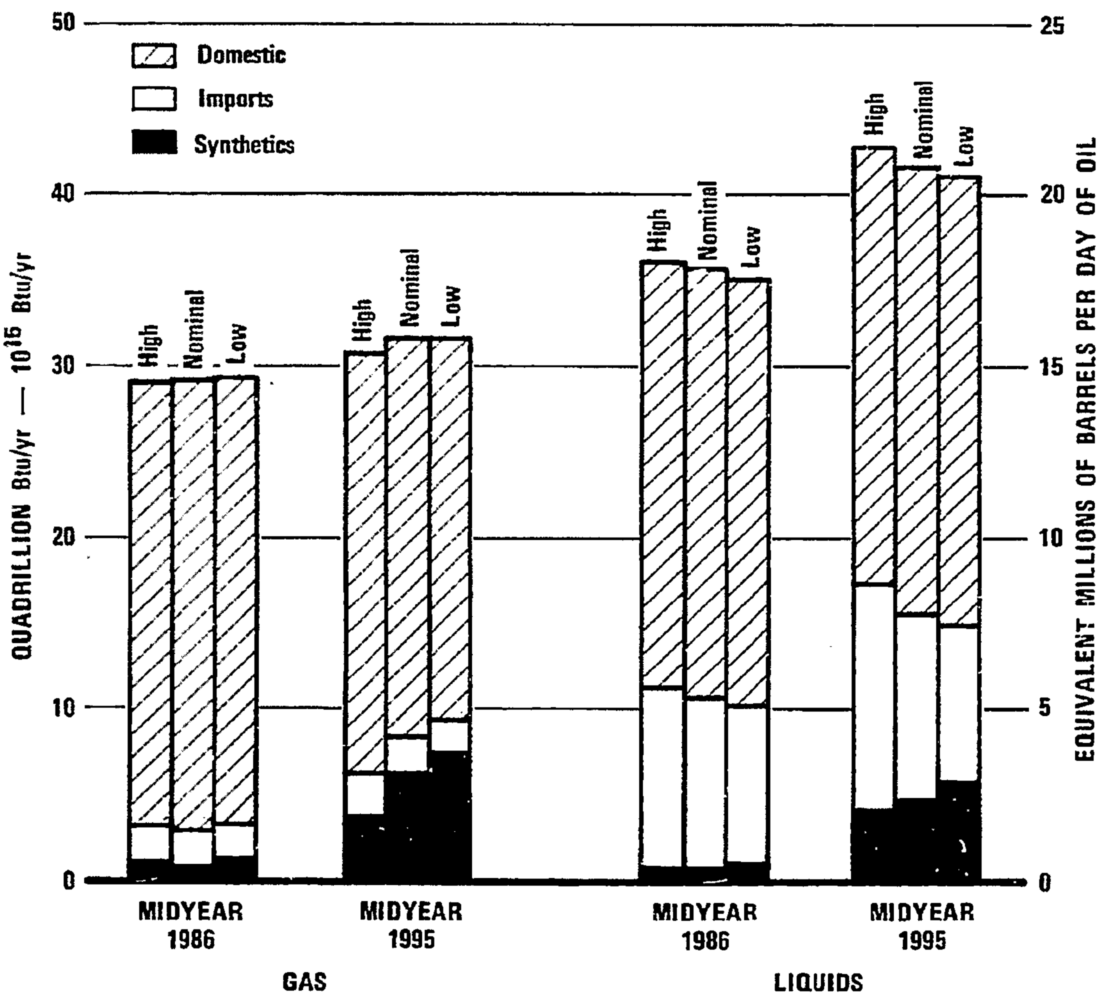
12. Coal Cost

The cost of coal is surprisingly unimportant with respect to synthetic fuels production. In order to test the sensitivity of synthetic fuels production to the cost of coal, a high and low coal cost case were constructed as follows: The high coal cost case was constructed by increasing the nominal case marginal cost by 50%; the low coal cost case was constructed by decreasing the nominal case marginal cost by 20%.

The results of the sensitivity to higher and lower coal costs are shown in Figure H-III-34 and Table H-III-14. The supply-demand balance at the primary resource level is illustrated in Figures H-III-35, H-III-36, and H-III-37.

The important results are:

- Synthetic gases are moderately sensitive to coal costs. In the high coal cost case, synthetic gas production is down 39% in 1995. The reason is that synthetic gases are all based on coal.
- Synthetic liquids are relatively insensitive to coal costs. In the high coal cost case, synthetic liquids production is down 15%. The reason is that the most attractive synthetic liquid, shale syncrude, is not based on coal.
- Higher coal costs result in moderately more imports: gas imports are up 25% and oil imports are up 21% in 1995.
- Domestic gas production is stimulated by high coal cost because synthetic gas is less attractive.
- Higher coal costs have remarkably little effect at the primary resource level. With higher coal prices, total coal production is down only about 16% in 2000 below the nominal case; whereas with low coal prices, total coal production is up 46% in 2000. The implication is that higher coal costs do very little to delay our need for coal; the future U.S. energy picture will depend heavily on coal.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO COAL COST

FIGURE H-III-34

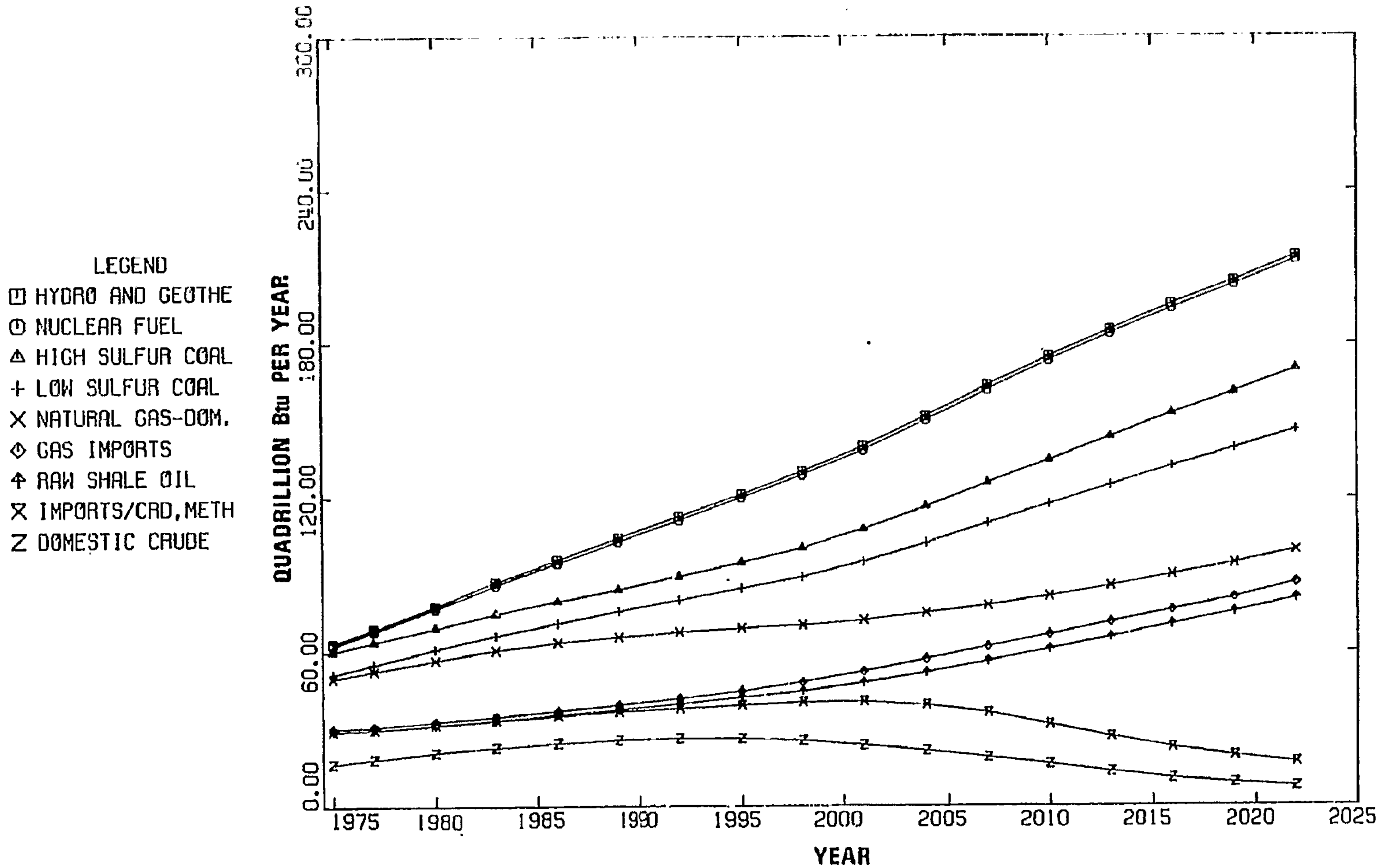
TABLE H-III-14

FUTURE DEMAND FOR GAS AND OIL—
SENSITIVITY TO COAL COST

Quadrillion Btu/year (10^{15} Btu/year)

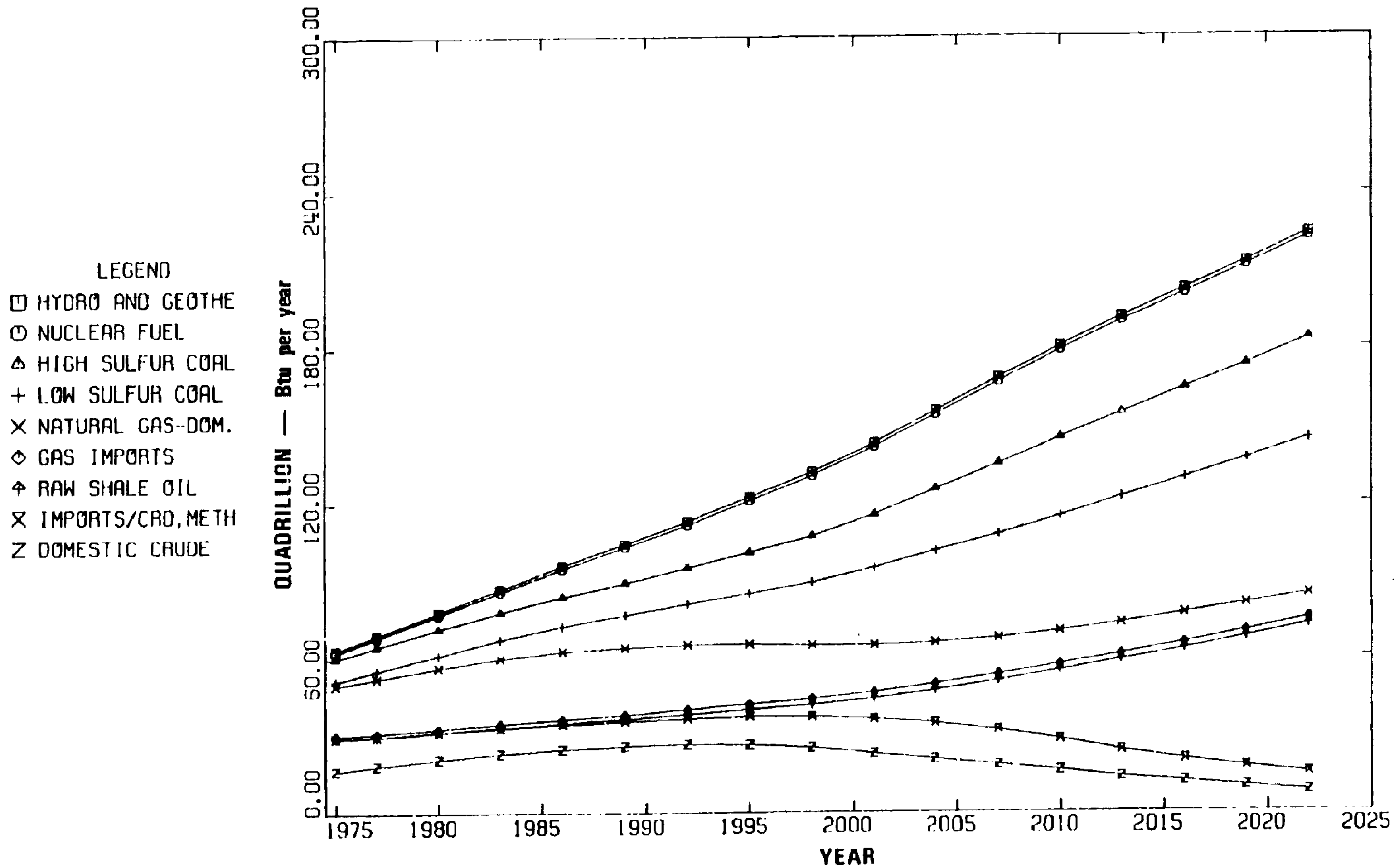
	1986			1995		
	High Coal Cost	Nominal	Low Coal Cost	High Coal Cost	Nominal	Low Coal Cost
Synthetic Gas	.9	1.1	1.2	3.7	6.1	7.2
Imported Gas	1.5	1.5	1.5	2.5	2.0	1.9
Domestic Natural Gas	26.6	26.4	26.4	24.5	23.3	22.6
Synthetic Liquids	.6	.7	.8	3.8	4.7	5.5
Oil Imports	10.7	9.8	9.2	13.2	10.9	9.4
Domestic Crude	24.7	24.8	25.0	26.3	26.5	26.5

H112



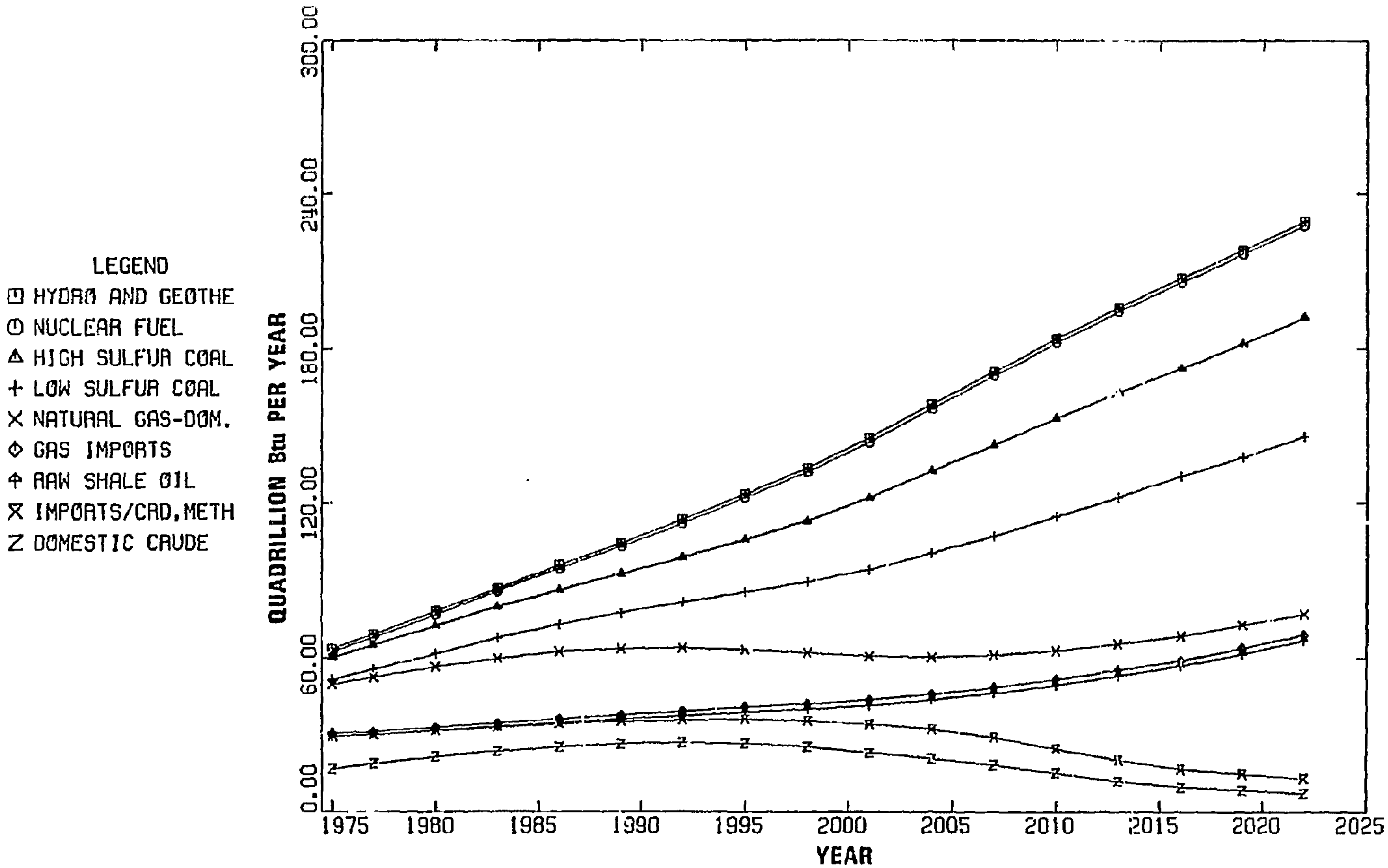
HIGH COAL COST

FIGURE H-III-35



NOMINAL CASE—TOTAL PRIMARY ENERGY

FIGURE II-III-36



LOW COAL COST

FIGURE H-III-37

13. High DCF Rate

The effect of tighter capital markets and higher returns on equity are explored in this sensitivity. The nominal case discount rates are:

Utilities: 13.2%

Industry : 17.8%

expressed in inflated dollars. In terms of constant 1975 dollars assuming a 5% inflation rate, these discount rates are 7.81% and 12.2% respectively. In the high DCF rate case, the discount rates were changed to:

Utilities: 14.9%

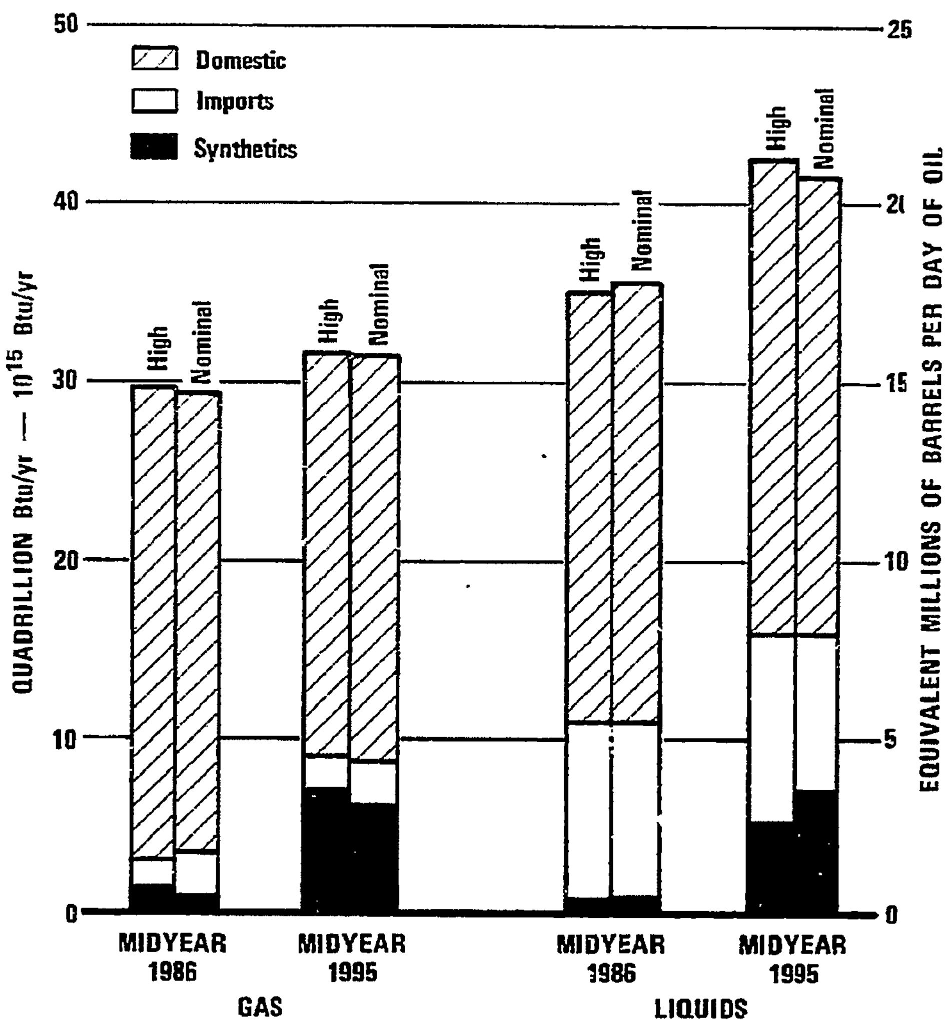
Industry : 25.7%

expressed in inflated dollars. In terms of constant 1975 dollars, these discount rates are 9.43% and 19.7% respectively.

The sensitivity of the gaseous and liquid fuels markets to the high DCF rate is shown in Figure H-III-38 and Table H-III-15. The interesting point to note is that the high DCF rate has small negative effect on synfuels because they are so capital intensive and a small positive effect on imports because they are low in capital cost. Thus the principal effect of high DCF rate is to make the capital-intensive technologies less attractive relative to low capital cost technologies.

The important results are:

- Synthetic gases are up 5% in 1995; synthetic liquids are down 29% in 1995.
- Imported crude is up 13% in 1995.
- Domestic production is unaffected.
- The effect of higher discount rates is relatively minor.
- High returns on equity favor synthetic gas plants over synthetic liquids plants because the gas plants are more highly leveraged.



FUTURE DEMAND FOR GAS AND OIL — SENSITIVITY TO DISCOUNTED CASH FLOW RATE

FIGURE H-III-38

Table H-III-15

FUTURE DEMAND FOR GAS AND OIL—
SENSITIVITY TO DISCOUNTED CASH FLOW RATE

Quadrillion Btu/year (10^{15} Btu/year)

	1986		1995	
	High DCF Rate	Nominal	High DCF Rate	Nominal
Synthetic Gas	1.0	1.1	6.4	6.1
Imported Crude	1.5	1.5	2.1	2.0
Domestic Natural Gas	27.0	26.4	23.3	23.3
Synthetic Liquids	.6	.7	3.4	4.7
Oil Imports	10.0	9.8	12.3	10.9
Domestic Crude	24.7	24.8	26.6	26.5

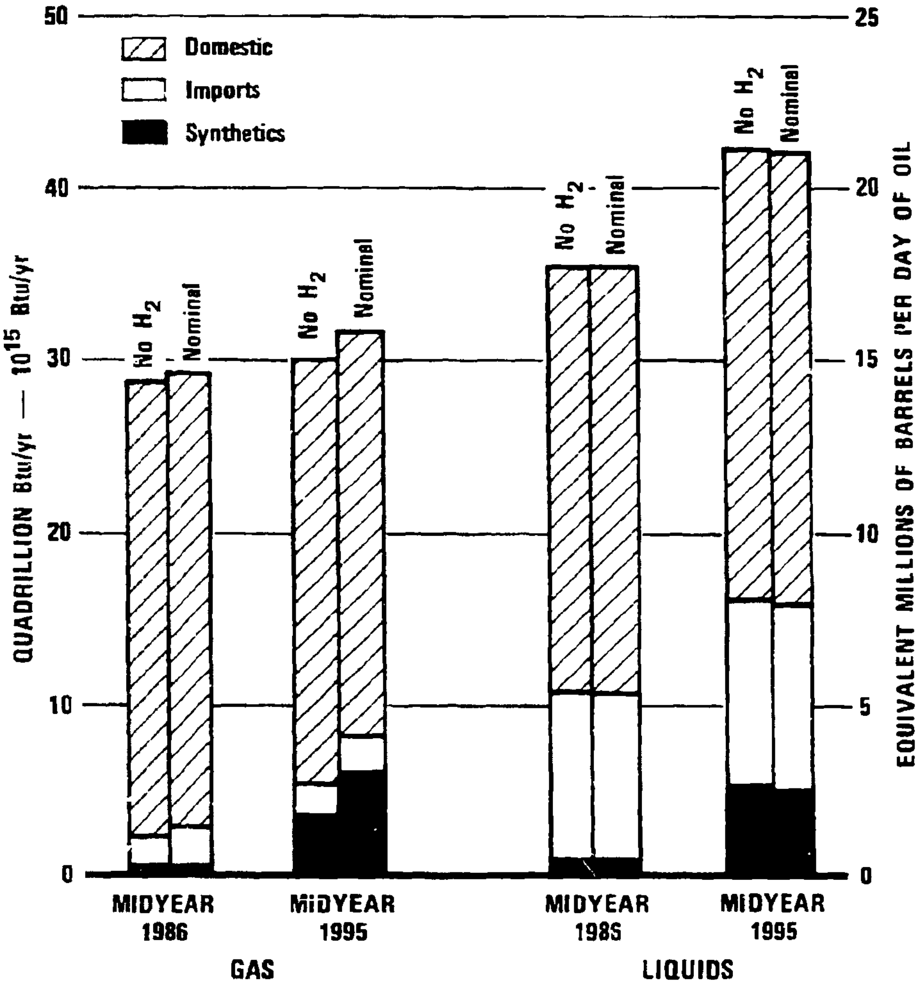
14. Hydrogen Availability

There is some question as to the feasibility of hydrogen because of transportation, distribution, and safety difficulties. In this sensitivity, hydrogen is eliminated from the energy balance altogether, whereas in the nominal case, hydrogen can be generated by partial oxidation of coal or by thermochemical decomposition of water using nuclear heat.

Figure H-III-39 and Table H-III-16 illustrate the sensitivity of the liquid and gaseous fuels markets to hydrogen availability. Since the elimination of hydrogen has virtually no effect on the primary resource balance, it will not be shown.

The effects of removing hydrogen are the following:

- Small reduction in gas production due to elimination of hydrogen.
- Small increase in domestic gas production to account for hydrogen elimination.
- Small increase in electric power generation to account for elimination of industrial fuel cells.
- No effect on imports.
- Small increase in synthetic liquids.



DEMAND FOR GAS AND OIL — SENSITIVITY TO AVAILABILITY OF HYDROGEN

FIGURE H-III-39

Table H-III-16

FUTURE DEMAND FOR GAS AND OIL--
SENSITIVITY TO AVAILABILITY OF HYDROGEN

Quadrillion Btu/year (10^{15} Btu/year)

	1986		1995	
	No H_2	Nominal	No H_2	Nominal
Synthetic Gas	0.5	1.1	4.6	6.1
Imported Gas	1.5	1.5	2.0	2.0
Domestic Natural Gas	26.6	26.4	23.4	23.3
Synthetic Liquids	0.8	0.7	5.0	4.7
Oil Imports	9.8	9.8	10.9	10.9
Domestic Crude	24.8	24.8	26.4	26.5