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Consensus Forecast of U.S. Electricity Supply and Demand to the Year 2000

J. A. Lane

OAK RIDGE NATIONAL LABORATORY
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CONTENTS

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ABSTRACT

Recent forecasts of total electricity generating capacity and energy demand as well as for electricity produced from nuclear energy and hydroelectric power are presented in tables and graphs to the year 2000. A forecast of the distribution of type of fuel and energy source that will supply the future electricity demand is presented.

Use of electricity by each major consuming sector is presented for 1975. Projected demands for electricity in the years 1985 and 2000, as allocated to consuming sectors, are derived and presented.

1. ELECTRICITY DEMAND FORECAST

1.1 Total Electricity

In developing an electricity demand forecast, one might expect that the same conservation-oriented forces that inhibit total energy demand would likewise influence electricity demand. Thus, for purposes of this study, electricity was correlated as a function of the percentage of total energy demand for both the historical growth and conservation-oriented forecasts described in ORNL/TM-5369.[1] The results are plotted in Fig. 1 and show close agreement between the various forecasts.[2-9] Since the average of the four electricity generation forecasts[8] of the Energy Research and Development Administration/Office of Planning and Analysis (ERDA/OPA) appears to represent a consensus of the forecasts plotted, this average was taken for the purpose of this study. These percentages were applied to the previously selected total energy consumption forecast to obtain the electricity generation forecasts shown in Table 1. Installed capacities and corresponding kilowatt-hours generated were calculated next, using system capacity factors given in the ERDA/ORA report. Heat rates were assumed to level off at 10,300 Btu/kWhr to reflect the growing fractions of nuclear light-water reactors, gas turbines, and coal-fired plants with sulfur dioxide removal systems.

1. J. A. Lane, *Consensus Forecast of U.S. Energy Supply and Demand to the Year 2000.* ORNL/TM-5369 (to be published).

2. Associated Universities, Inc., *Reference Energy Systems and Resource Data for Use in the Assessment of Energy Technologies,* PB-221 422 (also AET-8), May 1972.

3. National Petroleum Council, *Guide to NPC Report on U.S. Energy Outlook,* December 1972.

4. W. G. Dupree and J. A. West, *United States Energy Through the Year 2000,* Department of the Interior, U.S. Government Printing Office, December 1972.

5. M. A. Adelman et al., "Energy Self Sufficiency; An Economic Viewpoint," *Technol. Rev.* 76(6), 22 (May 1974).

6. R. C. Seamans, *U.S. Energy Prospects: An Engineering Viewpoint,* National Academy of Engineering, May 1974.

7. Federal Energy Administration, *Project Independence Report,* November 1974.

8. Office of Planning and Analysis, *Total Energy, Electric Energy and Nuclear Power Projections, United States,* Energy Research and Development Administration, February 1975.

9. E. Teller, *Energy – A Plan for Action,* report to the Energy Panel of the Commission on Critical Choices for Americans, April 1975.

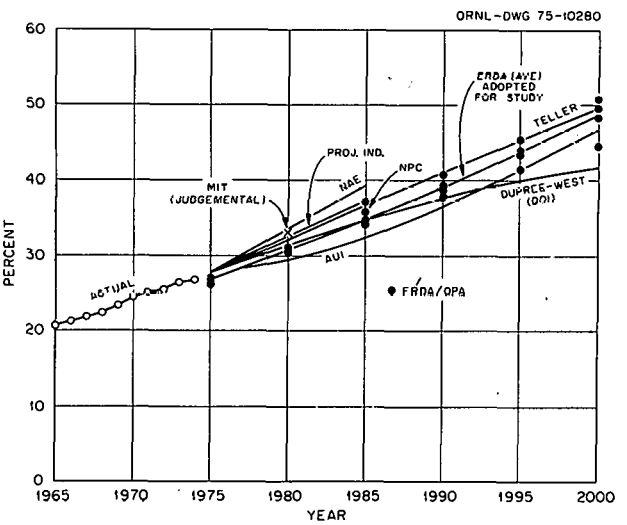

Fig. 1. Electricity as percent of total energy.

Table 1. Electrical generation and capacity forecasts

Year	Total energy (quads)	Utility electricity (percent of total)	Electrical generation (quads)	Heat rate (Btu/kWhr)	Electrical generation (kWhr $\times 10^9$)	System capacity factor (percent)	Yearly average capacity [GW(e)]	Yearend capacity [GW(e)]
1975	71.1	28.3	20.1	10,563	1900	44	493	510
1980	88	30.7	27.0	10,800	2500	45	634	660
1985	100	35.4	35.4	10,500	3200	47	780	800
1990	110	39.2	43.1	10,300	4200	49	970	990
1995	121	43.6	52.8	10,300	5100	51	1150	1180
2000	132	48.4	63.9	10,300	6200	52	1370	1400

Table 2. Nuclear power generation forecasts

Reference No.	Forecaster	Year of forecast	Nuclear power generation (quads)			
			1975	1980	1985	2000
10	U.S. Bureau of Mines	1968	1.8	4.1		
4	Department of the Interior (Dupree–West)	1972	2.6	6.7	11.7	49.2
11	Westinghouse (Ross)	1973	2.0	8.0	16.0	94.0
12	Joint Committee on Atomic Energy	1973				52.0
13	NASA/ASEE TERRASTAR	1973	2.6	6.7	10.9	35.0
14	Environmental Protection Agency					45.0
15	Ford Foundation historical growth	1974			10.7	43.3
15	Ford Foundation technical fix	1974			5.0	3.0
15	Ford Foundation self-sufficiency	1974			8.0	11.0
16	Council on Environmental Quality (Peterson)	1974				35.0
6	National Academy of Envineering	1974			17.6	
17	NASA/ASEE MEGASTAR	1974		3.3	7.0	18.0
7	Federal Energy Administration Independence (BAU)[a] Project	1974		4.8	12.5	
8	ERDA/Office of Planning and Analysis					
	Low	1975	2.2	4.3	9.5	35.5
	Moderate to low	1975	2.3	4.5	11.2	45.5
	Moderate to high	1975	2.4	5.1	12.7	58.2
	High	1975	2.6	5.9	15.4	74.9
9	E. Teller	1975			12.0	60.0

[a]Business as usual.

1.2 Nuclear Power Forecasts

Various nuclear power forecasts for thermal energy generated are listed in Table 2. Unfortunately, because of the wide variation of assumptions used, the spread of data is too great to adopt the consensus approach.

10. W. E. Morrison and C. L. Readling, "An Energy Model for the U.S. Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000," Bureau of Mines Information Circular, IC-8384, July 1968.

11. P. N. Ross, Westinghouse Electric Corporation, "The Nuclear Electric Economy," paper presented at the Conference on the Hydrogen Economy, Miami, Fla., March 1974.

12. Joint Committee on Atomic Energy, *Understanding the National Energy Dilemma*, Joint Committee Print, August 1973.

13. NASA/ASEE–Auburn Unitersity, *Terrestrial Applications of Solar Technology and Research (TERRASTAR)*, NASA/CR-129012, September 1973.

14. Environmental Protection Agency, *Alternative Futures and Environmental Quality*, Office of Research and Development, November 1973.

15. Ford Foundation, *A Time to Choose – America's Energy Future*, final report of the Energy Policy Project, 1974.

16. Council on Environmental Quality, *A National Energy Conservation Program – The Half and Half Plan*, March 1974.

17. NASA/ASEE–Auburn University, *MEGASTAR (The Meaning of Energy Growth: An Assessment of Systems, Technologies and Requirements*, Report NASA/CR-120338, September 1974.

Values for the year 2000 range from a low of 3 quads for the Ford Foundation technical fix (environmental protection) case[15] to a high of 94 quads for the Westinghouse "Nuclear Electric Economy" scenario.[11] For this reason, a forecast slightly below the average of ERDA's low and moderate/low forecasts of installed nuclear capacities for the years 1985 to 2000 was adopted.[8] The estimated installed capacities to 1980 were based on current commitments as shown in Fig. 2. These forecast capacities are given in Table 3, which shows that the estimated installed nuclear capacity would reach 50% of the total electrical capacity by the year 2000. Nuclear capacities were converted into kilowatt-hours of electricity and corresponding thermal generation, using the heat rates and plant factors shown in Table 3. In contrast to ERDA's estimated plant factors for the low and moderate/low cases, which rose to 67% and then leveled off at 65.5%, it was assumed in this case that plant factors would gradually reach 69%. As a result, the nuclear thermal generation forecast came very close to the ERDA moderate/low case.

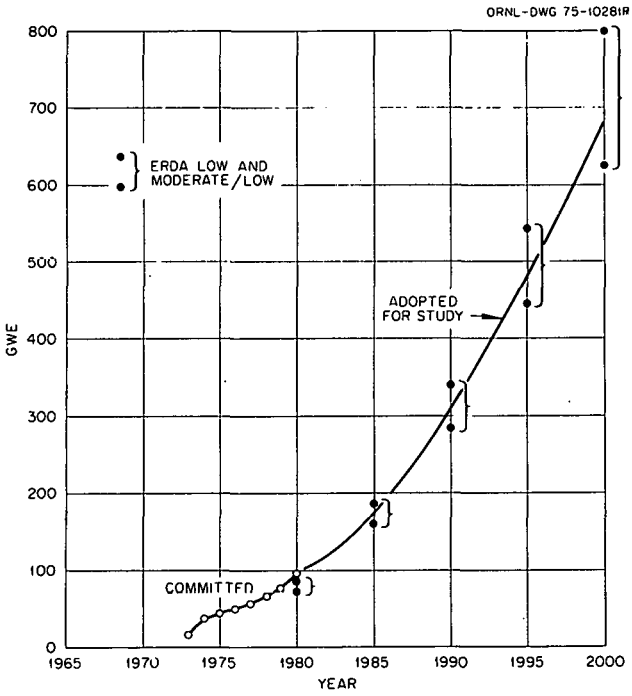

Fig. 2. Nuclear capacity forecasts.

1.3 Hydroelectric Power Forecasts

Forecasts of hydroelectric power generation converted to quads using an equivalent central station heat rate are shown in Table 4 and are plotted in Fig. 3. As Fig. 3 shows, the extrapolation of the 1971 to 1975 trend appears to represent a reasonable forecast of future hydroelectric power supply. Table 4 shows the corresponding hydroelectric power capacities estimated from these data.

2. ELECTRICITY SUPPLY FORECASTS

2.1 Distribution by Source

If the previously derived total electricity demand forecasts and the forecast contributions of nuclear and hydroelectric power are used as a basis for calculation, the contributions of coal, gas turbine, solar, and geothermal energy would amount to 16.1 quads by the year 2000. Allowing 1 quad each for these latter three sources of electricity results in a coal-fired steam-generating contribution of 13.1 quads as shown in Table 5. The corresponding kilowatt-hour contributions are also shown, based on the given plant efficiencies. The amount of electricity delivered to consumers was also calculated, assuming a transmission and distribution efficiency of 0.926.

Table 3. Nuclear capacity and generation forecasts

Year	Yearly average capacity [GW(e)]	Yearend capacity [GW(e)]	Electrical generation (percent of total)	Plant factor (percent)	Nuclear electricity generation (kWhr × 10^9)	Heat rate (Btu/kWhr)	Thermal generation (quads)
1975	35	40	7.1	53.4	164	10,700	1.8
1980	79	86	13.0	60.0	415	10,400	4.3
1985	175	184	23.0	66.0	1075	10,300	11.1
1990	305	320	32.3	67.0	1890	10,300	19.5
1995	485	500	42.4	68.0	2980	10,300	30.7
2000	685	700	50.0	69.0	4240	10,300	43.7

Table 4. Forecasts of hydroelectric power generation

Reference No.	Forecaster	Power generation (quads)					
		1975	1980	1985	1990	1995	2000
4	Department of the Interior (Dupree–West)	3.57	3.99	4.32			5.95
10	U.S. Bureau of Mines		3.0				5.1
15	Ford Foundation			3.0			4.0
8	ERDA/Office of Planning and Analysis						
	Low	2.83	3.02	3.37	3.54	3.93	4.28
	Moderate	2.87	3.10	3.53	3.84	4.38	5.13
	High	2.87	3.22	3.70	4.08	4.69	5.64
7	Federal Energy Administration Project Independence			4.50			
18	Stanford Research Institute			2.97			
9	E. Teller		3.0	3.0			5.0
16	Council on Environmental Quality						4.2
3	National Petroleum Council			3.16			
19	U.S. Atomic Energy Commission (D. L. Ray)						
20	Institute for Energy Analysis			3.2	3.4		3.9
6	National Academy of Engineering			3.18			
21	NASA/ASEE TERRASTAR	3.6	4.0	4.3			5.0
22	ERDA-48			3.38			3.65
	Selected for this study, quads	3.1	3.4	3.7	3.9	4.1	4.2
	Corresponding capacities, GW(e)	55	62	70	78	86	94

Table 5. Electrical supply forecast for the year 2000

Source of electricity	Utility consumption (quads)	Assumed plant efficiency (percent)	Electricity generated		Electricity delivered to consumer (kWhr × 10^9)
			Quads	kWhr × 10^9	
Nuclear	43.7	32	14.2	4160	3849
Coal	13.1[a]	36	4.7	1370	1274
Hydroelectric	4.2	34	1.4	409	380
Gas turbine	1.0	30	0.3	87	80
Solar	1.0	30	0.3	87	80
Geothermal	1.0	30	0.3	87	80
Total	64.0	33	21.2	6200	5743

[a] An additional 0.4 quad was consumed in coal processing before delivery to utilities.

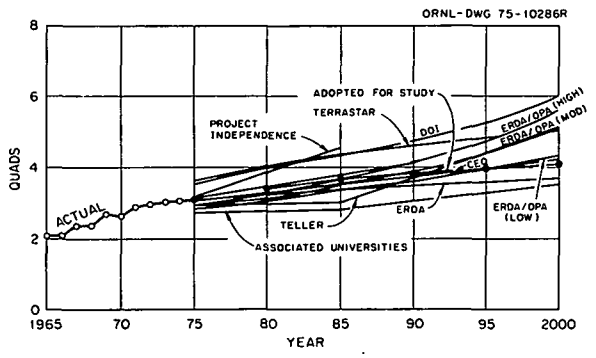

Fig. 3. Hydroelectric power forecasts.

18. S. Field, Stanford Research Institute, "The U.S. Power Puzzle," paper presented at 38th midyear meeting of Division of Refining, Philadelphia, May 1973.

19. D. L. Ray, *The Nation's Energy Future*, WASH-1281, U.S. Atomic Energy Commission, December 1973.

20. C. E. Whittle and D. B. Reister, *The IEA Energy Simulation Model*, Institute for Energy Analysis, January 1975.

21. NASA/ASEE–Auburn University, *Terrestrial Applications of Solar Technology and Research (TERRASTAR)*, NASA/CR-129012, September 1973.

22. Energy Research Development Administration, *A National Plan for Energy Research Development and Demonstration – Creating Energy Choices for the Future*, ERDA-48, June 1975.

2.2 Distribution by Capacity

Data from *Electrical World* were used to determine the existing and near-future distribution of the utility electrical capacities by plant type. These data are shown in Table 6. The breakdown of fossil-fueled capacities by fuel type is not shown in this table; however, it can be calculated from the amount of fuel consumed[23] and the appropriate plant factors. Capacity data for the nuclear and hydroelectric plants have already been derived and are shown in Table 7. Data for solar and geothermal plants, derived using the "most likely" introduction rate of these sources of electricity, are also shown in Table 7. Finally, gas-fired and oil-fired plants were assumed to be phased out after 1995, as shown in the table, leaving the resulting incremental capacity to be assumed by coal-fired plants.

Table 6. Distribution of utility generating capacity by plant type

In GW(e)

Fuel type	Dec. 31, 1974	Planned		
		1975	1976	1977
Hydroelectric	54.3	55.6	57.3	59.2
Pumped storage	8.8	10.1	11.2	11.9
Fossil fuel	336.9	356.8	370.4	388.8
Nuclear	30.3	39.5	49.0	55.9
Internal combustion	5.0	5.1	5.1	5.3
Combustion turbine	39.3	42.8	45.5	46.5
Total	474.6	510.0	538.6	567.7

3. FUEL CONSUMPTION BY ELECTRIC UTILITIES

Historical data on the fuel consumption in utility fossil-fueled plants are shown in Table 8, categorized by fuel type. These data were projected to the year 2000, based on the assumption that oil- and gas-fired steam plants would be phased out, as Table 8 shows, by the year 2000. For this projection gas turbines were treated as a generating sector separate from the oil- and gas-fired steam sectors.

4. ELECTRICITY CONSUMPTION BY CONSUMER CLASS

Electricity consumption data for 1975 from the U.S. Bureau of Mines[24] were corrected for 9% transmission losses and distributed among the various sectors as shown in Table 9. Industrial self-generation amounting to 234×10^9 kWhr was included in the electrical sector of the table, rather than in the fuel sector, as done by the U.S. Bureau of Mines. The actual amount of electricity generated by utilities in 1975 amounted to 1901×10^9 kWhr; however, only 1735×10^9 kWhr actually reached the consuming sectors.

Table 10 shows projected electricity consumption data for 1985 based on the Brookhaven National

23. Ref. 1, Table 13.

24. Personal communication to C. Readling from C. E. Whittle, Institute for Energy Analysis, Feb. 3, 1976.

Table 7. Projected distribution of utility generating capacities by fuel type

In GW(e)

Fuel type	1975	1980	1985	1990	1995	2000
Coal	204	227	252	281	313	348
Oil	76	70	60	34	11	0
Natural gas	73	67	55	39	26	0
Hydroelectric	55	62	70	78	86	94
Nuclear	35	79	175	315	500	685
Gas turbine	41	57	67	75	82	99
Geothermal	0.4	0.6	1	3	6	13
Solar	0	0	0	7	15	37
Pumped sotrage	10	18	30	39	44	46
Total	494	581	710	871	1083	1322

Laboratory energy supply and demand scenario for the year.[25]

Projected electricity consumption data for the year 2000 (Table 11) were derived from the "most likely" energy supply and demand scenario of 132 quads of energy supply in that year as given in ORNL/TM-5369.[1]

25. D. Behling, Brookhaven National Laboratory, memorandum to C. E. Whittle, Feb. 4, 1976.

Table 8. Distribution of fuel consumption in fossil-fueled plants

Year	Percent of total fuel consumption			
	Coal	Oil	Gas	Gas turbine
1964	65.5	7.1	27.4	
1965	66.6	7.6	25.8	
1966	65.0	8.4	26.6	
1967	64.0	9.1	26.9	
1968	62.6	9.5	27.8	
1969	59.9	11.7	28.3	
1970	55.9	14.5	29.5	
1971	54.6	16.7	28.7	
1972	54.2	19.2	26.5	
1973	56.4	20.8	22.6	
1974	57.4	22.2	22.2	
1975 (9 months)	58.6	20.5	20.9	
		Forecast		
1975	57.6	21.6	17.6	3.2
1980	66.5	16.5	13.5	3.5
1985	75.0	11.0	10.2	3.8
1990	83.0	6.0	6.6	4.4
1995	89.0	2.0	3.6	5.4
2000	93.0	0	0	7.0

Table 9. Summary of electricity consumption by consuming sector in 1975

Consuming sector	End use consumption (kWhr × 10^9)	Fuel equivalent (quads)	Energy consumption at source (quads)
Residential/commercial			
Space heating	96	0.33	1.03
Air conditioning	114	0.39	1.22
Water heating and cooking	188	0.64	2.00
Miscellaneous electric	607	2.07	6.45
Subtotal	1005	3.43	10.70
Industrial			
Aluminum	57	0.23	0.72
Iron and steel	38	0.13	0.41
Process heat	234	0.80[a]	2.50
Miscellaneous electric	619	2.11	6.57
Subtotal	958	3.27	10.20
Transportation			
Electric mass transport	6	0.02	0.06
Subtotal	6	0.02	0.06
Total	1969[b]	6.72	20.96

[a] Industrial electricity self-generation.
[b] Excludes transmission losses of 166 × 10^9 kWhr (8.7% of generation).

Table 10. Summary of electricity consumption by consuming sector in 1985

Consuming sector	End use consumption (kWhr × 10^9)	Fuel equivalent (quads)	Energy consumption at source (quads)
Residential/commercial			
Space heating	381	1.3	4.5
Air conditioning	205	0.7	2.4
Water heating and cooking	234	0.8	2.8
Miscellaneous electric	616	2.1	7.2
Subtotal	1436	4.9	16.9
Industrial			
Aluminum	88	0.3	1.0
Iron and steel	59	0.2	0.7
Process heat	467	1.6	5.5
Miscellaneous electric	821	2.8	9.6
Subtotal	1435	4.9	16.8
Transportation			
Electric mass transport	3	0.01	0.03
Battery automotive	6	0.02	0.07
Subtotal	9	0.03	0.10
Total	2880	9.83	33.8

Source: Memorandum to C. E. Whittle from D. Behling, Brookhaven National Laboratory, Feb. 4, 1976.

Table 11. Summary of electricity consumption by consuming sector in the year 2000

Consuming sector	End use consumption (kWhr × 10^9)	Fuel equivalent (quads)	Energy consumption at source (quads)
Residential (99×10^6 units)			
Space heating	440	1.5	4.9
Air conditioning	293	1.0	3.3
Heat pumps	29	0.1	0.3
Water heating and cooking	293	1.0	3.3
Miscellaneous electric	410	1.4	4.6
Subtotal	1465	5.0	16.4
Commercial (42×10^9 ft^2)			
Space heating	264	0.9	3.0
Air conditioning	176	0.6	2.0
Heat pumps	29	0.1	0.3
Water heating and cooking	88	0.3	1.0
Miscellaneous electric	498	1.7	5.6
Subtotal	1055	3.6	11.9
Industrial			
Aluminum (18.9×10^6 tons)	234	0.8	2.6
Iron and steel (302×10^6 tons)	88	0.3	1.0
Process heat	879	3.0	9.9
Miscellaneous electric	1787	6.1	20.0
Subtotal	2988	10.2	33.5
Transportation			
Mass transport	59	0.2	0.6
Electric vehicles	176	0.6	2.0
Subtotal	235	0.8	2.6
Total	5743	19.6	64.4

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