367

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DEVELOPED AND POTENTIAL WATER POWER OF THE UNITED STATES AND OTHER COUNTRIES OF THE WORLD DECEMBER 1954

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DEVELOPED AND POTENTIAL WATERPOWER OF THE UNITED STATES AND OTHER COUNTRIES OF THE WORLD, DECEMBER 1954

By Loyd L. Young

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CONTENTS

ILLUSTRATION

TABLES

ABSTRACT

According to the estimates presented in this paper the installed capacity of the waterpower plants of the world was 130 million horsepower on December 31, 1954. The United States had an installed capacity of about 35 million horsepower, or 27 percent of the world total. Since 1920 worldwide waterpower installations have increased 564 percent. Based on the ordinary minimum flow of streams in their present stage of development the world waterpower potential is estimated at 649 million horsepower of which the United States possesses 36.5 million horsepower. The mean flow of the world's streams, it is estimated, would produce about 3 billion horsepower of energy if all

physically feasible sites were developed. In the United States the corresponding figure for mean flow is 116 million horsepower. Mean-flow waterpower potential amounts to 38 horsepower per square mile in the United States. For the countries of the world as a whole the per-square-mile potential for mean flow ranges between lows of near nothing to a high estimated at 531 horsepower per square mile in Switzerland.

By utilizing the gross head at known sites but without further regulation than now exists the low flow of streams in the United States could produce 36.5 million horsepower. However, by regulating streams at reservoir sites where construction is physically feasible it is estimated that this low flow potential could be almost doubled. The three Pacific Coast States possess about 42 percent of the Nation's waterpower resources and these States with the 8 States of the Rocky Mountain area possess nearly 65 percent of the potential waterpower of the United States.

INTRODUCTION

Classification of lands for waterpower purposes has been a function of the Geological Survey since the enactment on March 3, 1879, of the statute creating the office of the Director. The act of October 2, 1888, specifically authorized investigations and reservations of sites for reservoirs and other hydraulic works. Insofar as they relate to the United States the tables that follow are a byproduct of the waterpower classification work.

The potential waterpower of the United States was first estimated by the Geological Survey in 1908. These estimates have been revised at intervals since that time and were last released for 1952 as Circular 329. The compilation of potential and developed waterpower for the entire world was first made in 1918 when engineers of the U. S. Geological Survey prepared an estimate of the potential and developed waterpower of the world, by countries, for use at the Versailles Peace Conference. This estimate was published in 1921 by the Department of the Interior in World Atlas of Commercial Geology, Part II, Water Power of the World. Since that time the estimates, entitled Developed and Potential Water Power of the World, have been kept up to date and released at intervals of 2 to 3 years. Circular 329 was the first formal publication of the estimates since 1921.

Tables 1 and 2 and figure 1 relate to developed and potential waterpower of the world as a whole and tables 3 and 4 to the waterpower of the United States.

DEFINITIONS

Installed waterpower--the total of the capacities shown by the name plate ratings, where known, or the estimated total capacities of the generating units.

Mean flow--the average rate of discharge (estimated in all cases).

Ordinary minimum flow--flow available 95 percent of the time with existing stream regulation.

Plant factor--the ratio of the average load to the aggregate installed capacity.

Potential power--the aggregate horsepower estimated technically capable of being developed, economic infeasibility notwithstanding.

Table 1.--Installed capacity of waterpower plants of the world and of the United States compared, 1920-54

Year [1] (December)	Total capacity of waterpower plants (1,000 horsepower)		United States as percent of total	Comparison with 1920 (percent increase)	
	World	United States		World	United States
1920	23,000	7,500	32.6	100	100
1923	29,000	9,087	31.3	126	121
1926	33,000	11,177	33.9	143	149
1930	46,000	14,885	32.4	200	198
1934	55,000	16,075	29.2	239	214
1936	60,000	17,120	28.5	261	228
1938	63,900	17,949	28.1	278	239
1940	69,400	19,000	27.4	302	253
1941	71,600	19,816	27.7	311	264
1945	77,800	24,223	31.1	338	323
1947	86,900	24,500	28.2	378	327
1950	101,000	27,500	27.2	439	367
1952	115,800	31,000	26.8	502	413
1954	129,718	34,700	26.8	564	463

1 Years when estimates were made by the U. S. Geological Survey.

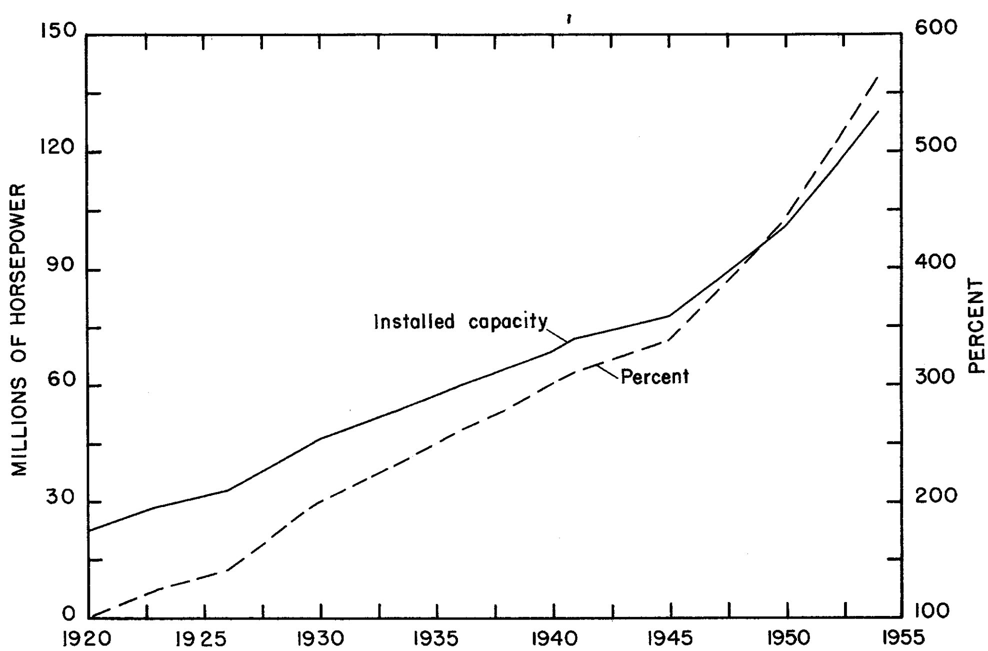

Figure 1. Increase in waterpower installations of the world, 1920-54.

Table 2.--Summary, by countries, of capacity of waterpower plants of the world, plant factor, potential waterpower at ordinary minimum flow and mean flow at 100 percent efficiency at end of 1954

Continent and country	Installed waterpower (1,000 hp)	Plant factor (percent)	Potential waterpower: Based on ordinary minimum flow (1,000 hp)	Potential waterpower: Based on mean flow (1,000 hp)	Potential waterpower: Based on mean flow (hp/sq mi)
Africa	1,249.1		250,990	856,050	
Asia	14,948.8		155,700	865,200	
Europe	54,793.0		63,780	220,300	
North America	52,628.2		92,100	330,000	
Oceani	1,951.5		23,350	182,400	
South America	4,147.5		62,700	625,000	
World	129,718.1		648,620	3,078,950	
Africa:					
Algeria	278.0	15	300	8,000	9
Anglo-Egyptian Sudan	-	-	1,000	26,000	27
Angola	14.0	21	5,700	105,000	216
Bechuanaland	-	-	30	5,000	18
Belgian Congo and Mandate	355.0	63	130,000	240,000	260
British Somaliland	-	-	-	100	3
Dahomey	-	-	800	3,000	75
Egypt	20.0	-	500	1,200	3
Eritrea	8.6	-	-	300	7
Ethiopia	9.0	50	5,700	47,000	115
French Cameroons	40.0	-	7,000	10,000	294
French Equatorial Africa	-	-	40,000	115,000	126
French Guinea	12.0	-	3,000	15,000	169
French Mandate in Togo	-	-	400	2,000	140
French Sudan and Senegal	-	-	1,400	2,500	6
Gambia	-	-	-	(a)	(a)
Gold Coast and British Mandate in Togo	10.0	-	2,000	10,000	109
Ivory Coast	-	-	3,000	15,000	83
Kenya	20.0	46	2,000	22,500	100
Liberia	7.5	16	5,700	10,000	233
Libya	-	-	-	200	.3
Madagascar	14.0	25	7,000	55,000	241
Mauritius and Reunion	10.0	35	-	250	148
Morocco	193.0	25	350	2,000	12
Mozambique	14.0	-	5,000	20,000	66
Nigeria and British Cameroons	22.0	51	13,000	30,000	80
Nyasaland	-	-	1,000	5,000	133
Portuguese Guinea	-	-	-	150	11
Rhodesia	40.5	42	3,500	25,000	57
Rio de Oro, Saguia Hamra, South Morocco and Ifni	-	-	350	1,000	9
Sierra Leone	-	-	2,500	5,000	179
Somaliland	-	-	-	200	.5
Southwest Africa	-	-	200	2,000	6
Spanish Guinea (Rio Muni)	-	-	1,000	4,000	444
Spanish Morocco	15.0	28	70	150	14
Tanganyika	28.5	18	4,000	35,000	102
Tangier	-	-	-	(a)	(a)
Tunisia	10.0	-	40	500	10
Uganda	126.0	-	4,000	20,000	212
Union of South Africa	2.0	45	450	13,000	28
Total	1,249.1		250,990	856,050	

a Small

Table 2.--Summary, by countries, of capacity of waterpower plants of the world, plant factor, potential waterpower at ordinary minimum flow and mean flow at 100 percent efficiency at end of 1954--Continued

Continent and country	Installed waterpower (1,000 hp)	Plant factor (percent)	Potential waterpower: Based on ordinary minimum flow (1,000 hp)	Potential waterpower: Based on mean flow (1,000 hp)	Potential waterpower: Based on mean flow (hp/sq mi)
Asia:					
Afghanistan	40.0	27	700	10,000	41
Burma	10.0	68	5,000	125,000	473
Ceylon	45.0	-	500	1,500	59
Chinese Republic	3.5	-	22,000	100,000	26
Formoso	470.0	44	1,000	3,000	216
French Indo China	.2	-	6,000	90,000	330
India	1,000.0	48	27,000	115,000	94
Iran (Persia)	1.1	-	300	4,000	6
Iraq and Saudi Arabia	-	-	(a)	1,500	3
Israeli, Lebanon, Syria and Trans-Jordan	50.0	-	(a)	200	2
Japan	10,000.0	65	12,000	25,000	173
Korea	1,800.0	53	3,000	5,000	94
Manchukuo	208.0	-	1,000	8,000	20
Pakistan	84.0	35	7,000	20,000	53
Siam and Malay States	80.0	53	5,700	25,000	100
Turkey	32.0	30	500	7,000	23
Union of Soviet Socialist Republics	1,125.0	40	64,000	[b] 325,000	45
Total	14,948.8		155,700	865,200	
Europe:					
Albania	8.0	-	200	2,000	188
Austria	2,500.0	40	2,600	9,000	278
Belgium and Luxembourg	38.0	35	75	300	24
Bulgaria	80.0	59	300	1,000	23
Czechoslovakia	300.0	62	700	1,700	34
Denmark	16.0	30	30	100	6
Eire	250.0	35	500	1,500	55
Estonia	22.0	-	100	200	11
Finland	1,150.0	60	1,000	2,500	19
France	9,400.0	38	6,000	20,000	94
Germany	4,000.0	44	2,000	5,000	37
Great Britain and North Ireland	1,100.0	30	750	2,500	27
Greece	15.0	20	350	3,000	59
Hungary	30.0	59	200	1,000	28
Iceland	83.0	62	700	3,000	76
Italy	9,500.0	42	6,000	20,000	172
Latvia and Lithuania	100.0	-	150	400	9
Netherlands	1.0	-	25	100	8
Norway	5,250.0	62	10,000	27,000	222
Poland	200.0	42	1,000	1,500	12
Portugal	875.0	28	600	2,000	56
Rumania	125.0	27	2,000	8,000	81
Spain	3,000.0	38	3,500	16,000	82
Sweden	5,800.0	60	4,000	21,000	121
Switzerland	4,550.0	45	3,000	8,500	531
Union of Soviet Socialist Republics	6,000.0	40	14,000	[b] 50,000	43
Yugoslavia	400.0	40	4,000	13,000	131
Total	54,793.0		63,780	220,300	

a Small.
b Available 50 percent of the time.

Table 2.--Summary, by country, of capacity of waterpower plants of the world, plant factor, potential waterpower at ordinary minimum flow and mean flow at 100 percent efficiency at end of 1954--Continued

Continent and country	Installed waterpower (1,000 hp)	Plant factor (percent)	Potential Waterpower		
			Based on ordinary minimum flow (1,000 hp)	Based on mean flow (1,000 hp)	Based on mean flow (hp/sq mi)
North America:					
Alaska	68.0	-	2,000	15,000	26
British Honduras	-	-	100	500	56
Canada	16,684.0	60	36,600	95,000	25
Costa Rica	31.0	55	1,400	8,000	407
Greenland	-	-	1,000	15,000	18
Guatemala	35.0	34	2,100	12,000	285
Honduras	7.5	45	1,400	8,000	135
Mexico	900.0	40	8,500	45,000	59
Nicaragua	.7	48	1,100	6,000	105
Panama (including Canal Zone	70.0	62	700	4,000	140
Salvador	26.0	32	300	1,500	114
United States	34,700.0	60	36,500	116,000	38
West Indies	106.0	-	500	4,000	48
Total	52,628.2		92,100	330,000	
Oceani:					
Australia and Tasmania	440.0	57	1,000	38,000	13
Borneo, including New Guinea and Papua	5.0	-	10,500	70,000	117
Celebes	.5	-	1,400	9,000	124
Hawaii	25.0	-	150	400	100
Java	140.0	32	1,100	10,000	205
New Zealand	1,193.0	54	5,000	11,000	106
Philippine Islands	110.0	-	2,000	17,000	147
Sumatra	20.0	32	2,000	26,000	152
Other Islands	18.0	-	200	1,000	125
Total	1,951.5		23,350	182,400	
South America:					
Argentina	140.0	24	5,400	40,000	37
Bolivia	65.0	49	3,600	30,000	73
Brazil	2,585.0	32	20,000	240,000	73
British Guiana	-	-	3,600	20,000	224
Chile	550.0	43	7,000	25,000	87
Columbia	200.0	38	5,400	100,000	227
Dutch Guiana	-	-	1,100	10,000	184
Ecuador	22.0	38	2,000	35,000	348
French Guiana	-	-	700	7,000	201
Paraguay	.5	-	2,800	10,000	64
Peru	325.0	26	6,400	55,000	114
Uruguay	180.0	50	400	3,000	42
Venezuela	80.0	53	4,300	50,000	141
Total	4,147.5		62,700	625,000	

Table 3.--Potential waterpower, in horsepower, of the United States, existing flow, 100 percent efficiency, and gross head

State and division	Available 95 percent of the time	Available 50 percent of the time	Based on mean flow
New England	1,052,000	2,455,000	3,669,000
Middle Atlantic	4,465,000	7,864,000	9,862,000
East North Central	1,013,000	2,296,000	3,480,000
West North Central	1,667,000	3,238,000	4,947,000
South Atlantic	2,067,000	5,176,000	7,663,000
East South Central	2,660,000	5,035,000	7,473,000
West South Central	667,000	1,256,000	2,769,000
Mountain	7,904,000	14,709,000	25,698,000
Pacific	14,965,000	33,149,000	50,000,000
United States	36,460,000	75,178,000	115,561,000
New England:			
Maine	463,000	1,108,000	1,515,000
New Hampshire	295,000	552,000	917,000
Vermont	107,000	276,000	429,000
Massachusetts	134,000	322,000	502,000
Rhode Island	7,000	19,000	28,000
Connecticut	46,000	178,000	278,000
Middle Atlantic:			
New York	4,183,000	6,452,000	7,677,000
New Jersey	12,000	86,000	125,000
Pennsylvania	270,000	1,326,000	2,060,000
East North Central:			
Ohio	25,000	109,000	209,000
Indiana	54,000	186,000	327,000
Illinois	284,000	711,000	1,136,000
Michigan	319,000	571,000	842,000
Wisconsin	331,000	719,000	966,000
West North Central:			
Minnesota	215,000	528,000	857,000
Iowa	109,000	331,000	546,000
Missouri	418,000	939,000	1,408,000
North Dakota	232,000	323,000	443,000
South Dakota	519,000	763,000	1,139,000
Nebraska	123,000	217,000	343,000
Kansas	51,000	137,000	211,000
South Atlantic:			
Delaware	2,000	7,000	11,000
Maryland and the District of Columbia	80,000	334,000	550,000
Virginia	253,000	762,000	1,219,000
West Virginia	245,000	1,054,000	1,601,000
North Carolina	461,000	1,133,000	1,455,000
South Carolina	579,000	1,027,000	1,226,000
Georgia	439,000	823,000	1,519,000
Florida	8,000	43,000	82,000

Table 3.--Potential waterpower, in horsepower, of the United States, existing flow, 100 percent efficiency, and gross head--Continued

State and division	Available 95 percent of the time	Available 50 percent of the time	Based on mean flow
East South Central:			
Kentucky	316,000	617,000	1,168,000
Tennessee	1,328,000	2,380,000	3,243,000
Alabama	966,000	1,904,000	2,687,000
Mississippi	50,000	134,000	375,000
West South Central:			
Arkansas	135,000	333,000	888,000
Louisiana	51,000	97,000	330,000
Oklahoma	181,000	416,000	791,000
Texas	300,000	410,000	760,000
Mountain:			
Montana	1,494,000	2,454,000	4,291,000
Idaho	2,750,000	5,381,000	9,264,000
Wyoming	282,000	554,000	1,324,000
Colorado	385,000	1,184,000	2,323,000
New Mexico	91,000	182,000	322,000
Arizona	1,548,000	2,642,000	4,184,000
Utah	791,000	1,743,000	3,420,000
Nevada	563,000	569,000	570,000
Pacific:			
Washington	6,651,000	15,824,000	25,000,000
Oregon	4,492,000	9,172,000	12,500,000
California	3,822,000	8,153,000	12,500,000

Table 4.--Potential waterpower, in horsepower, of the United States, existing storage and assumed development of known storage sites, 100 percent efficiency, and gross head

State and division	Available 90 percent of the time		Available 50 percent of the time	
	Horsepower	Percent	Horsepower	Percent
New England	1,538,000	2.35	2,545,000	2.94
Middle Atlantic	6,505,000	9.95	8,415,000	9.82
East North Central	1,241,000	1.90	2,342,000	2.75
West North Central	2,701,000	4.13	3,646,000	4.27
South Atlantic	4,200,000	6.43	5,801,000	6.79
East South Central	3,976,000	6.08	5,670,000	6.62
West South Central	1,407,000	2.15	1,830,000	2.14
Mountain	16,939,000	25.91	19,530,000	22.78
Pacific	26,867,000	41.10	35,876,000	41.89
United States	65,374,000	100.00	85,655,000	100.00
New England:				
Maine	749,000	1.15	1,151,000	1.30
New Hampshire	397,000	.61	596,000	.70
Vermont	134,000	.20	277,000	.32
Massachusetts	177,00	.27	323,000	.38
Rhode Island	7,000	.01	19,000	.02
Connecticut	74,000	.11	179,000	.22
Middle Atlantic:				
New York	5,649,000	8.64	6,903,000	8.06
New Jersey	46,000	.07	86,000	.10
Pennsylvania	810,000	1.24	1,426,000	1.66
East North Central:				
Ohio	44,000	.07	110,000	.13
Indiana	85,000	.13	227,000	.27
Illinois	306,000	.47	710,000	.83
Michigan	386,000	.59	571,000	.67
Wisconsin	420,000	.64	724,000	.85
West North Central:				
Minnesota	300,000	.46	554,000	.65
Iowa	137,000	.21	331,000	.39
Missouri	696,000	1.06	1,061,000	1.24
North Dakota	374,000	.57	386,000	.45
South Dakota	827,000	1.27	854,000	1.00
Nebraska	263,000	.40	313,000	.37
Kansas	104,000	.16	147,000	.17
South Atlantic:				
Delaware	3,000	.00	7,000	.01
Maryland and the District of Columbia	286,000	.44	409,000	.48
Virginia	667,000	1.02	930,000	1.09
West Virginia	804,000	1.23	1,121,000	1.31
North Carolina	831,000	1.27	1,170,000	1.37
South Carolina	681,000	1.04	1,074,000	1.25
Georgia	889,000	1.36	1,041,000	1.22
Florida	39,000	.06	49,000	.06

Table 4.--Potential waterpower, in horsepower, of the United States, existing storage and assumed development of known storage sites, 100 percent efficiency, and gross head--Continued

State and division	Available 90 percent of the time		Available 50 percent of the time	
	Horsepower	Percent	Horsepower	Percent
East South Central:				
Kentucky	557,000	0.85	780,000	0.91
Tennessee	1,829,000	2.80	2,571,000	3.00
Alabama	1,400,000	2.14	2,100,000	2.45
Mississippi	190,000	.29	219,000	.26
West South Central:				
Arkansas	554,000	.84	740,000	.86
Louisiana	77,000	.12	99,000	.12
Oklahoma	326,000	.50	477,000	.56
Texas	450,000	.69	514,000	.60
Mountain:				
Montana	2,770,000	4.24	3,359,000	3.92
Idaho	4,530,000	6.93	5,870,000	6.85
Wyoming	573,000	.88	757,000	.88
Colorado	1,360,000	2.08	1,636,000	1.90
New Mexico	223,000	.34	291,000	.34
Arizona	4,588,000	7.02	4,613,000	5.39
Utah	2,205,000	3.37	2,308,000	2.69
Nevada	690,000	1.05	696,000	.81
Pacific:				
Washington	12,711,000	19.44	17,414,000	20.33
Oregon	6,753,000	10.33	8,999,000	10.51
California	7,403,000	11.33	9,463,000	11.05
Outlying possessions:				
Alaska	7,143,000	-	9,286,000	-
Puerto Rico	27,000	-	40,000	-
Hawaii	103,000	-	250,000	-

DISCUSSION

In preparing the original estimates of the developed and potential waterpower of the world the estimates published by the various countries were used wherever available. However, there were many areas where studies of potential power had not been made. For these areas the probable potential was determined from existing data on rainfall and topography. In cases where these data were later supplanted by estimates prepared in the countries themselves the two were in reasonable agreement.

To keep the estimates of developed waterpower up to date all available sources have been used. In recent years this has been done almost entirely by following the waterpower developments of the various countries from reports and articles in yearbooks; from publications of the Department of Commerce, the Federal Power Commission, the World Power Conference, the United Nations, the International Union of Producers and Distributors of Electric Energy; and from various engineering and scientific journals appearing in the United States and abroad. Statistical information on waterpower development is never strictly up to date and recent development must be estimated for many countries. Nevertheless, the world total of 129.7 million horsepower of installed capacity is reasonably correct.

Figure 1 shows the increase of waterpower installations since the first estimates were released. Table 1 shows the total installed capacity as determined for the various releases since 1920 and the percentage of increase over 1920. During the period studied installations estimated at 23 million horsepower in 1920 were increased 564 percent to 129.7 million horsepower in 1954. The current situation is shown in table 2 where installed capacity, plant factor, and potential waterpower available with existing low and mean flow are given by country and continent. The mean-flow potential is also shown on a per-square-mile basis.

Developed power by countries is based on the installed capacity of water wheels at constructed plants; it averages two to four times and may be as many as ten times the potential power at low flow at the same sites. This fact should be considered in comparing the potential power with the developed power and also in evaluating the percentage of the utilized waterpower resources of a nation. For any country a rough estimate of the ultimate installed capacity of water wheels can be obtained by assuming it will equal the power available at mean flow and 100 percent efficiency. Mean flow is the constant flow required to equal the average annual volume. For the United States mean flow is roughly equal to the flow available 25 percent of the time. The sites already utilized are presumably the best sites in a country except where development is regulated for the purpose of preserving the scenic values, as at Niagara Falls, or in large countries where otherwise attractive sites are at long distances from populated areas.

Table 1 shows an increase in installed capacity of water wheels of nearly 107 million horsepower in the 34 years since 1920, yet the increase is continuing throughout the world. The shortage of fuel, both oil and coal, and the increase in fuel prices makes waterpower seem more desirable than ever. The trend toward multiple-purpose projects and basin-wide conservation and development of resources has accelerated the rate of waterpower installation. New interest, with the resultant increased activity in the development of waterpower resources, is almost universal.

At one time there was a question as to where to find a market for power from large projects such as Grand Coulee. Now, with wide interconnection, the market has outstripped the supply. Because of ease and speed of communication, travel, and transportation workmen are willing to live near remote waterpower sites. This accounts for a considerable proportion of present new waterpower developments and for development plans.

The Union of Soviet Socialist Republics reportedly has many plants under construction but specific information on developments in that country is lacking. All the countries of Western Europe, Australia, New Zealand, and Japan, as well as many South American countries, are constructing waterpower plants and conducting water-resources studies at an unprecedented rate. In Africa waterpower sites are being studied with increasing interest, several large projects have been undertaken, and some plants of considerable size are actually producing electric current. Everywhere the power can be used as soon as it becomes available.

The figures for installed capacity of water wheels, although fairly exact in themselves, do not present a complete picture of the utilized waterpower. In some countries with abundant resources of waterpower only the better sites are developed, and therefore the machinery installed can be operated to capacity a considerable part of the year. In other countries the installation is such that it can be used to full capacity for perhaps only 25 percent of the year. At other times it can be used to carry the peak load but not continuously.

A stream can rarely, if ever, be made to flow constantly at an average rate and even if this were possible the demand for power rises and falls with the season and time of day. For these reasons installations invariably are larger than the average output of any powerplant would require if it operated continuously at full capacity. The plant factor indicates the amount by which the installation exceeds the capabilities of the plant, and, if fully developed, the power site itself. A plant factor of 50 percent indicates that an installation half the size would produce the same number of unit hours during a given period if it operated at full capacity the entire time.

For Algeria the plant factor is extremely low, but it is based on reliable figures. This low plant factor is probably caused by the extreme variations in flow of streams in the area. The plant factor given for Canada seems high, yet it may be underestimated as it does not take into account the industrial plants, some of which have a very high plant factor. For Argentina the plant factor seems low, but it may be that the waterpower plants there carry mostly peak loads. For Peru it is possible that the reported output does not include some industrial plants and thus gives a corresponding low plant factor.

In Europe the high plant factors for Bulgaria, Czechoslovakia, and Hungary may be due to the estimate of installed capacity being low because firsthand information on these countries is not available. Germany has large pumped storage plants for peaking purposes, and some of the power for pumping is supplied by steam plants. If the reported output includes power from pumped storage, which is not strictly comparable to the waterpower produced in other countries, the plant factor for Germany would be proportionately higher. For the Union of Soviet Socialist Republics the combined capacity of plants in Europe and Asia was used to obtain the plant factor. Information on the distribution of plants between eastern and western Russia is very limited, and the estimated values are only rough approximations.

The plant factor for Korea is based on the output for 1943, which indicates that the figure for the installed capacity is reasonably reliable for that time. Although some of the plants were damaged by war, it is assumed that they can be restored. The plants in Australia are located mainly in Tasmania where the nature of the streams makes a high plant factor possible. Australia is now building new plants with an ultimate capacity of over 1 million horsepower, but, owing to the regimen of the streams being developed, the new plants may not have the high plant factors of those now in operation.

Japan and Italy illustrate the importance of the plant factor. Japan not only has a large total installed capacity but a very high plant factor. Italy, with approximately the same total installations, has a rather low plant factor. Using the average for the years 1950-54, Japan produced roughly 50 percent more energy, operating at a plant factor of about 65 percent, than did Italy where the plant factor was 42 percent. Likewise, the installed capacity of Europe is greater than for North America, but the plant factors for the United States and Canada show that the output rate per installed horsepower is greater in North America.

The estimates of potential waterpower by countries used in table 2 include developed and undeveloped sites and are computed at 100 percent efficiency. Estimates previous to 1937 were based on an assumed efficiency of 70 percent, and the change to 100 percent efficiency was made to put the estimates on the same basis as those for the World Power Conference. For the same reason the effect of storage has been disregarded except for constructed reservoir sites, the potential power being based on the existing flow. In the United States the existing minimum flow is sufficient to produce 365 million firm horsepower, but construction of reservoirs at known sites would increase the minimum flow sufficiently to double the present minimum-flow power. Such possibility for increase is doubtless true of most other countries. Estimates of the potential power based on the mean flow are considered quite reliable for the United States, Canada, and most countries of western Europe. They represent the amount of horsepower which is physically developable assuming mean flow of streams, gross head of sites, and 100 percent efficiency of plants. Except in instances where they may be too low because of lack of basic data, the estimates are considerably above the economically feasible power possibilities of a given country. The per-square-mile concentration of the mean-flow potential is an index to the relative position of an area insofar as waterpower resources are concerned. Comparison of the ratio of power at ordinary minimum flow to power at mean flow usually reveals the degree of variation in streamflow.

It should be pointed out that the estimates of potential power for the United States, Canada, and many countries of Europe are based on known sites. For other countries, particularly in Asia (except Japan), Africa, and South America (except Brazil), the estimates are based principally on rainfall and topography and consequently are not as dependable. It is difficult to present in figures any exact estimate of the potential waterpower resources of a country. The flow of streams varies from year to year, and the storage required to equalize given flows varies with climate and other factors. However, in all countries the estimated potentials tend to approximate minimum and maximum power technically possible of development. The economic feasibility limit of power development will invariably be lower for a given flow rate than the estimate presented here.

The largest unsurveyed areas as well as those with the greatest waterpower resources are central Africa and northern Asia. Central Africa, because of the heavy rainfall, undoubtedly has immense resources of waterpower and the need for cheap power in large amounts for metallurgical purposes will undoubtedly lead to the utilization of some of the sites, especially those within transmission distance of the Coast. In northern Asia there are large rivers, but, except at the headwaters, the precipitation is low and probably not well distributed throughout the year. The feasibility of utilizing these resources, therefore, is dependent upon the existence of good dam and reservoir sites. Another disadvantage to this area is the distance from ocean transportation.

Lake Nyasa in Africa is an interesting example of a large waterpower resource with enormous obstacles to overcome before practical use can be made of it. The 2300-foot-deep lake lies on a plateau about 1600 feet above sea level. It has an area of 11,600 square miles and claims an additional 38,660-square-mile catchment area. Thirteen hundred feet of the total drop to the sea is concentrated in a 40-mile reach of the outlet stream, the Murchison Cataract of the Shire River. However, the fall does not occur until the Shire River has meandered 75 miles across flat and swamplike terrain. The country around the lake and its outlet is so flat that debris brought down tributary streams will consolidate into obstructing bars upon which vegetation grows rapidly and floating weeds accumulate, thus seriously impeding the flow of the Shire. From 1914 to 1934 such a barrier damned the outlet to Lake Nyasa and prevented outflow even though the lake was storing water at a rate of 6,000 cfs. If some economical method of controlling the level of the water in the lake and conducting the water through the 75-mile section to the head of the Murchison Cataract can be found at least 1 million horsepower of firm power could be produced.

In China a project has been proposed that would involve a dam 750 feet high on the Yangtze River, creating a reservoir with a storage capacity of 50 million acre-feet and having a powerplant of 14 million horsepower capacity. Such a dam and plant appear physically possible but smaller sites are probably of greater value at present because they do not require such large outlays of capital.

The potential waterpower of the United States, in horsepower, at 100 percent efficiency and gross head--for water available 95 and 50 percent of the time and for the arithmetical mean flow under existing conditions--is shown in table 3. The effects of constructed reservoirs are reflected in this table, but no allowance is made for possible future storage. Where the center of a larger stream forms the boundary between States, the power has been divided between the States. Where a dam in one State backs water into a neighboring State the power has been divided on the basis of the length of the reservoir in each State.

Though estimates on the basis of existing conditions for different areas are comparable, they usually fall short of completely reporting the waterpower resources of many streams. This is because of the omission of the effect of possible future storage. On the Colorado River, for example, primary power without storage will be multiplied several times by reservoirs which are reasonably sure to be constructed. Table 4 shows the potential waterpower of the United States with storage at known, large reservoir sites, both developed and undeveloped. However, it does not include many small sites which undoubtedly will be developed at some future time but would not individually add materially to the potential of the stream or the country as a whole. Development of sites now unused would double the waterpower obtainable from our streams.

Estimates of potential waterpower in the United States made by the Federal Power Commission are in essential agreement with the estimates presented here. The potential power estimates in tables 3 and 4 are sums of the estimated power available at the various sites, whereas those of the Federal Power Commission are estimates of the power installations which are likely to be made at these sites. By adding the Federal Power Commission estimates of average annual output in kilowatt hours for developed and potential power and converting that total to a continuous horsepower equivalent it will be seen that their estimate of the total waterpower resources of the United States is near the 75 million horsepower shown in table 3 as being available 50 percent of the time and that it is at the midpoint between the potential power estimated to be available 90 percent of the time and 50 percent of the time with development of known storage sites in table 4.

Estimates of tidal power are not included in this report.

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