

A comprehensive study on the recent progress and trends in development of Small Hydropower projects

Teegala Srinivasa Kishore ¹, Epari Ritesh Patro ^{2,*}, V.S.K.V. Harish ³ and Ali Torabi Haghighi ²

¹ Electrical & Electronics Engineering, GMR Institute of Technology, Rajam 532127, India; srinivasakishoret@gmail.com or kishore.ts@gmrit.edu.in

² Water, Energy and Environmental Engineering, University of Oulu, 90014 Oulu, Finland; ali.torabihaghighi@oulu.fi

³ Department of Electrical Engineering, School of Technology, Pandit Deendayal Energy University Gandhinagar, Gujarat 382481, India; vskvharish@ieee.org

* Correspondence: ritesh.patro@oulu.fi

Table S1. Global Hydropower and SHP Statistics [1]

Sl. No.	Region	Country	Hydropower Data				Small Hydropower Data				
			Electrical capacity (MW)	Hydropower capacity (MW)	Hydropower generation (GWh/year)	Hydropower capacity %	Capacity Definition (MW)	Installed Capacity (MW)	Potential (MW)	Installed (<=10 MW)	Potential (<=10 MW)
1	Central Asia	Kazakhstan	21902	2699	10300	12.32	35	200	4800	116	2707
2	Central Asia	Kyrgyzstan	3939	3077	14204	78.12	30	47	409	47	275
3	Central Asia	Tajikistan	5757	5039	16900	87.53	30	N/A	N/A	27	30000
4	Central Asia	Turkmenistan	5428	1.2	N/A	0.02	N/A	N/A	N/A	1	1300
5	Central Asia	Uzbekistan	14142	1879	7930	13.29	30	262	1392	76	76
6	Eastern Asia	China	1777030	341190	1189840	19.20	50	79300	128000	41900	63500
7	Eastern Asia	DPRK	10000	5768	13650	57.68	N/A	N/A	N/A	83	83
8	Eastern Asia	Japan	300149	50020	84540	16.67	10	3545	10327	3545	10327
9	Eastern Asia	Mongolia	1240	28	85	2.26	10	5	27	5.22	27
10	Eastern Asia	ROK	116908	6490	5798	5.55	10	190	1500	190	1500

11	Southern Asia	Afghanistan	623	308	930	49.44	10	76	1200	76	1200
12	Southern Asia	Bangladesh	17115	230	982	1.34	N/A	N/A	N/A	0.06	60
13	Southern Asia	Bhutan	1622	1614	7959	99.51	25	32	17792	8.1	8.1
14	Southern Asia	India	344002	49779	135539	14.47	25	4485	21134	N/A	N/A
15	Southern Asia	Iran	74103	11278	14087	15.22	10	20	103	20	103
16	Southern Asia	Nepal	1077	1021	3635	94.80	25	447	4196	236	1960
17	Southern Asia	Pakistan	35372	8689	28562	24.56	50	410	3100	N/A	N/A
18	Southern Asia	Sri Lanka	4018	1726	4221	42.96	10	357	873	357	873
19	South East Asia	Cambodia	1749	1028	2705	58.78	10	1.7	300	1.7	300
20	South East Asia	Indonesia	59656	5321	19888	8.92	10	403	12800	403	12800
21	South East Asia	Lao PDR	6621	4701	7367	71.00	15	148	2287	50	50
22	South East Asia	Malaysia	33764	6144	20342	18.20	N/A	N/A	N/A	40	40
23	South East Asia	Myanmar	5389	3255	9744	60.40	N/A	N/A	N/A	36	231
24	South East Asia	Philippines	22733	3627	9611	15.95	10	147	2021	147	2021
25	South East Asia	Thailand	42209	3573	4687	8.47	6	172	700	172	700
26	South East Asia	Timor-Leste	301	0.35	N/A	0.12	50	0.35	N/A	0.35	220
27	South East Asia	Viet Nam	41422	18004	65722	43.46	30	1666	7200	N/A	N/A
28	Western Asia	Armenia	2850	1318	2269	46.25	30	353	422	328	328
29	Western Asia	Azerbaijan	7869	1105	1959	14.04	10	26	520	26	520
30	Western Asia	Georgia	4106	3161	9813	76.98	13	178	336	142	187
31	Western Asia	Iraq	26680	1500	N/A	5.62	N/A	N/A	N/A	6	26
32	Western Asia	Israel	16682	6	24	0.04	N/A	N/A	N/A	6	6
33	Western Asia	Jordan	4609	12	42	0.26	10	12	58	12	58
34	Western Asia	Lebanon	3035	282	479	9.29	10	31	140	31	140

35	Western Asia	Saudi Arabia	79070	0	0	0.00	N/A	N/A	N/A	0	130
36	Western Asia	Syrian Arab Republic	9122	1572	413	17.23	10	21	21	21	21
37	Western Asia	Turkey	86931	27509	58400	31.64	10	2961	6500	2961	6500
38	Oceania	Australia	67000	9000	15000	13.43	10	173	173	N/A	N/A
39	Oceania	New Zealand	9291	5363	24965	57.72	10	154	622	N/A	N/A
40	PICT	Fiji	316	130	495	41.14	N/A	11	14	N/A	N/A
41	PICT	New Caledonia	959	78	361	8.13	10	9.9	100	N/A	N/A
42	PICT	Papua New Guinea	581	230	799	39.59	10	29	153	N/A	N/A
43	PICT	Solomon Islands	31	0.3	N/A	0.97	10	0.3	11	N/A	N/A
44	PICT	Vanuatu	35	1.3	N/A	3.71	10	1.3	6	N/A	N/A
45	PICT	Federated States of Micronesia	35	0.7	N/A	2.00	N/A	0.7	9	N/A	N/A
46	PICT	French Polynesia	227	48	176	21.15	10	48	98	N/A	N/A
47	PICT	Samoa	55	12	35	21.82	N/A	14	22	N/A	N/A
48	Eastern Africa	Burundi	74	34	100	45.95	1	3.1	30.5	15.8	61
49	Eastern Africa	Ethiopia	4232	3814	N/A	90.12	10	12.9	1500	12.9	1500
50	Eastern Africa	Kenya	2351	705	3341	29.99	10	39.4	3000	39.4	3000
51	Eastern Africa	Madagascar	813	163	N/A	20.05	N/A	N/A	N/A	33	82
52	Eastern Africa	Malawi	508	352	N/A	69.29	5	5.6	150	5.6	150
53	Eastern Africa	Mauritius	826	N/A	90	N/A	N/A	N/A	N/A	19.3	19.7
54	Eastern Africa	Mozambique	2789	2134	8285	76.51	25	19.4	N/A	3.4	1000
55	Eastern Africa	Reunion	843	133	422	15.78	10	11	17	11	17
56	Eastern Africa	Rwanda	218	98	N/A	44.95	5	24.8	111.1	24.8	111.1
57	Eastern Africa	Somalia	103	0	0	0.00	N/A	N/A	N/A	0	4.6

58	Eastern Africa	South Sudan	82	0	0	0.00	N/A	N/A	N/A	0	24.7
59	Eastern Africa	Tanzania	1370	573	N/A	41.82	10	30.4	480	30.4	480
60	Eastern Africa	Uganda	943	712	3457	75.50	20	82.8	258	51.8	200
61	Eastern Africa	Zambia	2827	2566	11025	90.77	20	39.7	138.7	12.9	62
62	Eastern Africa	Zimbabwe	2215	930	4989	41.99	30	30.2	N/A	15.2	120
63	Middle Africa	Angola	3800	2365	5192	62.24	10	13.1	600	N/A	N/A
64	Middle Africa	Cameroon	1665	732	4404	43.96	10	1	970	N/A	N/A
65	Middle Africa	CAR	29	29	170	100.00	10	28.8	41	N/A	N/A
66	Middle Africa	Congo	610	228	N/A	37.38	N/A	0	65	N/A	N/A
67	Middle Africa	DRC	2931	2812	N/A	95.94	10	56	101	N/A	N/A
68	Middle Africa	Equatorial Guinea	390	180	650	46.15	N/A	7.5	7.5	N/A	N/A
69	Middle Africa	Gabon	452	170	821	37.61	N/A	4.6	7.8	N/A	N/A
70	Middle Africa	Sao Tome & Principe	32	3	6	9.38	10	2.7	63.8	N/A	N/A
71	Northern Africa	Algeria	17140	269	1080	1.57	10	42.1	42.1	42.1	42.1
72	Northern Africa	Egypt	32015	2800	13352	8.75	N/A	N/A	N/A	6.8	51.7
73	Northern Africa	Morocco	8253	1770	1662	21.45	10	38.4	306.6	38.4	306.6
74	Northern Africa	Sudan	3400	1593	N/A	46.85	5	7.2	63.2	7.2	63.2
75	Northern Africa	Tunisia	5476	62	45	1.13	N/A	N/A	N/A	17	56
76	Southern Africa	Botswana	893	0	0	0.00	N/A	N/A	N/A	0	1
77	Southern Africa	Eswatini	61	60	119	98.36	N/A	N/A	N/A	8.2	16.2
78	Southern Africa	Lesotho	77	76	N/A	98.70	10	3.8	38.2	3.8	38.2
79	Southern Africa	Namibia	557	347	1593	62.30	N/A	N/A	N/A	0.05	120
80	Southern Africa	South Africa	47043	2184	3717	4.64	40	N/A	N/A	38	247

81	Western Africa	Benin	262	0.6	N/A	0.23	30	0.6	304.9	0.6	69.9
82	Western Africa	Burkina Faso	315	34	139	10.79	N/A	N/A	N/A	2.3	17
83	Western Africa	Cote d'Ivoire	2199	879	2047	39.97	10	5	45.7	5	45.7
84	Western Africa	Gambia	99	0	0	0.00	30	0	N/A	0	12
85	Western Africa	Ghana	3795	1580	5561	41.63	1	0	12.1	0	17.4
86	Western Africa	Guinea	602	367	428	60.96	N/A	N/A	N/A	10.8	198
87	Western Africa	Libreria	131	93	0	70.99	30	4.9	85.9	4.9	56.4
88	Western Africa	Mali	672	316	1102	47.02	30	5.7	61.7	5.7	28.4
89	Western Africa	Mauritania	306	0	229	0.00	N/A	N/A	N/A	0	N/A
90	Western Africa	Niger	173	0	0	0.00	N/A	N/A	N/A	0	8
91	Western Africa	Nigeria	13392	2002	N/A	14.95	30	64.2	735	N/A	N/A
92	Western Africa	Senegal	950	0	332	0.00	10	0	N/A	0	N/A
93	Western Africa	Sierra Leone	163	56	N/A	34.36	30	12.9	639	12.9	12.9
94	Western Africa	Togo	230	67	N/A	29.13	N/A	N/A	N/A	1.6	144
95	Carribean	Cuba	6407	66	64	1.03	N/A	28.9	84.9	N/A	N/A
96	Carribean	Dominica	27	7	36	25.93	10	4.8	4.8	N/A	N/A
97	Carribean	DR	3460	616	1510	17.80	10	59.3	59.3	N/A	N/A
98	Carribean	Grenada	51	0	0	0.00	N/A	0	7	N/A	N/A
99	Carribean	Guadeloupe	573	11	34	1.92	10	11.1	16.1	N/A	N/A
100	Carribean	Haiti	349	61	131	17.48	10	7	20.9	N/A	N/A
101	Carribean	Jamaica	941	30	157	3.19	10	16.6	45.5	N/A	N/A
102	Carribean	Puerto Rico	6161	100	51	1.62	10	41.8	47.9	N/A	N/A
103	Carribean	Saint Lucia	91	0	0	0.00	N/A	0	2.7	N/A	N/A
104	Carribean	SV&G	58	7	37	12.07	10	7	7.4	N/A	N/A

105	Central America	Belize	158	55	261	34.81	N/A	N/A	N/A	10.3	21.7
106	Central America	Costa Rica	3530	2328	8677	65.95	N/A	N/A	N/A	125.5	125.5
107	Central America	El Salvador	1846	575	1339	31.15	20	42	158	22.6	119.8
108	Central America	Guatemala	4072	1438	5765	35.31	5	114.3	201	114.3	201
109	Central America	Honduras	2571	676	3088	26.29	30	301.8	N/A	128	385
110	Central America	Mexico	55889	12125	29138	21.69	30	699.3	N/A	N/A	N/A
111	Central America	Nicaragua	1482	143	468	9.65	10	18.6	85.7	18.6	85.7
112	Central America	Panama	3401	1777	7253	52.25	20	213.5	417	104.8	263.3
113	South America	Argentina	38200	10118	38529	26.49	50	410.2	N/A	97	430
114	South America	Bolivia	1855	483	1715	26.04	5	N/A	N/A	152.8	200
115	South America	Brazil	158260	101289	380900	64.00	30	5670	20506	N/A	N/A
116	South America	Chile	23900	6710	21786	28.08	20	488	10825	236	2113
117	South America	Columbia	17391	11834	57000	68.05	10	214	25000	214	25000
118	South America	Ecuador	7607	4418	15834	58.08	10	98.2	296.6	98.2	296.6
119	South America	French Guiana	300	119	439	39.67	10	6.3	6.3	6.3	6.3
120	South America	Guyana	163	0	0	0.00	5	0	24.2	0	92.1
121	South America	Paraguay	8835	8810	59684	99.72	50	0	116.3	0	86.3
122	South America	Peru	14518	5189	24172	35.74	20	363	3500	N/A	N/A
123	South America	Suriname	501	307	1356	61.28	N/A	N/A	N/A	1	2.7
124	South America	Uruguay	4546	1538	7469	33.83	50	0	232	0	207.8

125	South America	Venezuela	36561	16905	67633	46.24	N/A	N/A	N/A	0.3	48
126	North America	Canada	143000	80800	392647	56.50	50	3400	15000	1113	1113
127	North America	Greenland	140	9	371	6.43	10	8.8	183.1	8.8	183.1
128	North America	USA	1084783	101200	294000	9.33	N/A	N/A	N/A	3612	10583
129	Eastern Europe	Belarus	10069	95	405	0.94	10	18	250	18	250
130	Eastern Europe	Bulgaria	12070	3204	3395	26.55	1	N/A	N/A	486	580.7
131	Eastern Europe	Czech Republic	21989	1090	2001	4.96	10	337	465	337	465
132	Eastern Europe	Hungary	8479	57	259	0.67	5	16.5	55	16.5	55
133	Eastern Europe	Republic of Moldova	3001	64	226	2.13	10	0.4	3	0.4	3
134	Eastern Europe	Poland	41396	988	2399	2.39	N/A	N/A	N/A	294.8	1500
135	Eastern Europe	Romania	23738	6389	14300	26.91	10	404	730	404	730
136	Eastern Europe	Russian Federation	239812	48450	178902	20.20	30	826.5	825845	169.6	169.6
137	Eastern Europe	Slovakia	7721	2539	4677	32.88	10	81.6	241.4	81.6	241.4
138	Eastern Europe	Ukraine	55330	6220	9120	11.24	10	95	375	95	375
139	Northern Europe	Denmark	14247	10	19	0.07	10	9.8	9.8	9.8	9.8
140	Northern Europe	Estonia	2885	7	35	0.24	10	6.5	10	6.5	10
141	Northern Europe	Finland	17175	3159	15634	18.39	10	312	600	312	600
142	Northern Europe	Iceland	2767	1984	14059	71.70	10	54.8	54.8	54.8	54.8
143	Northern Europe	Ireland	10459	530	692	5.07	5	N/A	N/A	41	60
144	Northern Europe	Latvia	3095	1564	4386	50.53	10	28	75	28	75

145	Northern Europe	Lithuania	3665	1028	1147	28.05	10	26.9	51.9	26.9	51.9
146	Northern Europe	Norway	33800	31837	143000	94.19	10	2571	7803	2571	7803
147	Northern Europe	Sweden	39991	16181	61700	40.46	10	961	961	961	961
148	Northern Europe	Great Britain	78300	4400	8400	5.62	10	390	1179	390	1179
149	Southern Europe	Albania	2018	1920	4525	95.14	15	330.2	N/A	240.2	1963
150	Southern Europe	Bosnia & Herzegovina	4352	2173	5843	49.93	10	90	1005	90	1005
151	Southern Europe	Croatia	4794	2175	6556	45.37	10	33	192	33	192
152	Southern Europe	Greece	19624	3408	3500	17.37	15	232	2000	232	600
153	Southern Europe	Italy	114161	22181	43785	19.43	10	3395	7073	3395	7073
154	Southern Europe	Montenegro	893	674	1807	75.48	10	25.3	97.5	25.3	97.5
155	Southern Europe	Noth Macedonia	2057	675	1879	32.81	10	130	260	130	260
156	Southern Europe	Portugal	19519	6838	16909	35.03	10	414	750	414	750
157	Southern Europe	Serbia	7838	2936	9477	37.46	30	87.6	N/A	87.6	467.2
158	Southern Europe	Slovenia	3537	1271	4825	35.93	10	155	180	155	180
159	Southern Europe	Spain	104121	20361	20613	19.56	10	2079	2158	2079	2158

160	Western Europe	Austria	21813	11990	42906	54.97	10	1523	1780	1523	1780
161	Western Europe	Belgium	21066	142	2409	0.67	10	72.8	103.4	72.8	103.4
162	Western Europe	France	130761	25517	53600	19.51	10	2200	2615	2200	2615
163	Western Europe	Germany	207932	13399	28000	6.44	1	N/A	N/A	1731	1830
164	Western Europe	Luxembourg	2023	1330	1530	65.74	10	34	44	34	44
165	Western Europe	The Netherlands	31976	38	94	0.12	10	3	12	3	12
166	Western Europe	Switzerland	20842	14809	36300	71.05	10	950	1250	950	1250

(PICT: Pacific Island Countries)

References

1. Liu, D., Liu, H., Wang, X., Kremere, E. *World Small Hydropower Development Report 2019*; 2019; United Nations Industrial Development Organization; International Center on Small Hydro Power. ([www. smallhydroworld.org](http://www.smallhydroworld.org).)