

903 **A Generation and demand data**

Country	Hydro [GWh]		Solar [GWh]	Wind [GWh]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	22068	4032	0	7228	-
Belgium	245	-	3529	3833	5332
Bulgaria	1003	1656	1422	1315	0
Czechia	875	1116	2261	691	-
Denmark	0	-	963	10456	5694
Estonia	18	-	0	688	0
Finland	12284	-	0	5985	0
France	31111	21952	11044	34180	0
Germany	15014	1366	44895	101185	24563
Greece	0	3617	3961	7278	0
Hungary	101	112	1374	705	-
Ireland	878	-	0	9365	0
Italy	21206	23984	24326	20063	0
Latvia	2096	-	0	152	0
Lithuania	340	-	74	1482	0
Netherlands	0	-	5063	5671	5777
Poland	1780	159	0	14703	0
Portugal	5231	1930	1292	13585	0
Romania	10185	5287	1760	6705	0
Slovakia	3935	318	589	3	-
Slovenia	4338	-	268	6	-
Spain	8087	16623	14326	54625	0
Sweden	-	64623	0	19902	0
Switzerland	17735	17260	1963	140	-
United Kingdom	5603	-	12677	35485	28650
Europe	164133	164034	132689	355432	70015

Table A.1: Annual electricity generation^{38–41} [GWh] by technology used to validate the hourly generation profiles.

Country	Hydro [MW]		Solar [MW]	Wind [MW]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	6610	2833	1431	3085	0
Belgium	181	0	3619	2113	1363
Bulgaria	535	1810	1057	700	0
Czechia	334	753	2049	316	0
Denmark	8	0	1014	4426	1700
Estonia	7	0	33	341	0
Finland	3148	0	134	2080	71
France	10955	8279	10100	15108	7
Germany	3950	1298	47100	52212	6900
Greece	299	2403	2523	2754	0
Hungary	29	28	936	326	0
Ireland	216	0	33	3700	25
Italy	10650	4357	20120	10330	0
Latvia	1539	0	1	70	0
Lithuania	120	0	82	530	0
Netherlands	38	0	4522	3669	957
Poland	435	157	640	5878	0
Portugal	2858	1515	828	5157	0
Romania	2760	3573	1157	2970	0
Slovakia	1208	418	531	4	0
Slovenia	1078	0	275	5	0
Spain	6142	12626	8914	25704	10
Sweden	0	16301	501	7853	177
Switzerland	4162	8224	2246	75	0
United Kingdom	2950	0	13400	13619	10328
Europe	60212	64575	123246	163024	21539

Table A.2: Current installed generation capacities [MW] by country.

Country	Hydro [-]		Solar [-]	Wind [-]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	0.381	0.162	0.097	0.267	-
Belgium	0.155	-	0.111	0.207	0.447
Bulgaria	0.214	0.104	0.154	0.214	0.448
Czechia	0.299	0.169	0.126	0.250	-
Denmark	0.000	-	0.108	0.270	0.382
Estonia	0.298	-	0.097	0.230	0.448
Finland	0.445	-	0.097	0.328	0.448
France	0.324	0.303	0.125	0.258	0.448
Germany	0.434	0.120	0.109	0.221	0.406
Greece	0.000 *	0.172	0.179	0.302	0.448
Hungary	0.397	0.458	0.100	0.247	-
Ireland	0.464	-	0.097	0.289	0.448
Italy	0.227	0.628	0.138	0.222	0.448
Latvia	0.155	-	0.097	0.247	0.448
Lithuania	0.323	-	0.103	0.319	0.448
Netherlands	0.000 *	-	0.100	0.230	0.520
Poland	0.467	0.115	0.097	0.286	0.448
Portugal	0.209	0.145	0.178	0.301	0.448
Romania	0.421	0.169	0.174	0.258	0.448
Slovakia	0.372	0.100	0.127	0.256	-
Slovenia	0.459	-	0.111	0.149	-
Spain	0.150	0.150	0.183	0.243	0.448
Sweden	-	0.453	0.097	0.289	0.448
Switzerland	0.486	0.240	0.100	0.213	-
United Kingdom	0.217	-	0.108	0.297	0.317
Europe	0.288	0.264	0.118	0.230	0.333

* The generation technology is either not installed or not used at all, although the potential is not null.

Table A.3: Yearly average capacity factors [-] of the generation technologies by country. The factors are validated using the published validity ranges.⁶⁶

Country	Hydro [MW]		Solar [MW]	Wind [MW]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	6610 *	43565	163242	62000	0
Belgium	181 *	0	97423	13000	5000
Bulgaria	3019	9990	260162	57000	35000
Czechia	573	1221	187591	96000	0
Denmark	8 *	0	141057	83000	220000
Estonia	7 *	0	52511	46000	54000
Finland	3148 *	0	65068	58000	240000
France	10955 *	40730	1612248	944000	331000
Germany	3950 *	22858	940007	308000	106000
Greece	299 *	11960	270696	172000	114000
Hungary	80	1074	155289	98000	0
Ireland	216 *	0	210046	164000	235000
Italy	26517	19474	928832	226000	146000
Latvia	1539 *	0	93607	85000	83000
Lithuania	258	0	177685	142000	21000
Netherlands	38 *	0	108064	49000	97000
Poland	1247	8566	931507	502000	113000
Portugal	3098	18368	169856	43000	57000
Romania	2760 *	20566	552862	183000	80000
Slovakia	1208 *	7237	107282	34000	0
Slovenia	1078 *	0	19198	3000	0
Spain	6142 *	46331	1184747	731000	128000
Sweden	0	30018	134703	192000	403000
Switzerland	4227	10954	76484	16307	0
United Kingdom	4073	0	613099	436000	1040000
Europe	81230	292911	9253265	4743307	3508000

* All potential capacity already installed.

Table A.4: Potential generation capacities [MW] by country.

Country	Direct electricity [-]		Heating [-]		Demand [GWh]
	Current	Mobility	Households	Services	
Austria	0.672	0.179	0.113	0.036	93914
Belgium	0.678	0.141	0.130	0.051	125371
Bulgaria	0.785	0.159	0.042	0.014	47778
Czechia	0.657	0.161	0.134	0.048	100745
Denmark	0.612	0.160	0.178	0.051	54842
Estonia	0.636	0.143	0.169	0.053	12948
Finland	0.774	0.098	0.086	0.041	107814
France	0.719	0.175	0.069	0.037	650589
Germany	0.602	0.192	0.150	0.056	815345
Greece	0.755	0.186	0.051	0.008	68431
Hungary	0.623	0.164	0.158	0.056	69912
Ireland	0.666	0.159	0.136	0.039	43653
Italy	0.651	0.209	0.107	0.033	451866
Latvia	0.547	0.237	0.150	0.066	13222
Lithuania	0.595	0.236	0.120	0.049	20468
Netherlands	0.688	0.125	0.136	0.050	165497
Poland	0.618	0.169	0.175	0.039	273472
Portugal	0.782	0.173	0.037	0.009	64382
Romania	0.684	0.165	0.115	0.036	87848
Slovakia	0.689	0.134	0.126	0.051	42145
Slovenia	0.704	0.215	0.057	0.024	18767
Spain	0.749	0.173	0.055	0.023	333724
Sweden	0.797	0.114	0.062	0.027	171163
Switzerland	0.668	0.163	0.119	0.051	86454
United Kingdom	0.614	0.183	0.163	0.040	485588
Europe	0.670	0.174	0.116	0.040	4405939

Table A.5: Annual electricity demand [GWh] and shares [-] by contribution.

Country	Cities
Austria	Vienna, Graz, Linz, Innsbruck
Belgium	Gent, Brussels, Bastogne, Antwerpen
Bulgaria	Sofia, Varna, Plovdiv
Czechia	Prague, Pilsen, Brno, Ostrava
Denmark	Copenhagen, Herning, Aalborg
Estonia	Tallinn, Tartu
Finland	Helsinki, Tampere, Oulu, Rovaniemi
France	Paris, Nantes, Toulouse, Marseille, Lyon, Lille, Nancy, Bourges, Calais
Germany	Dusseldorf, Frankfurt, Stuttgart, Munich, Nuremberg, Dresden, Berlin, Magdeburg, Hamburg, Hanover
Greece	Athens, Tripoli, Ioannina, Larissa, Thessaloniki
Hungary	Budapest, Pecs, Miskolc, Szeged
Ireland	Dublin, Cork, Galway
Italy	Cagliari, Palermo, Catania, Bari, Naples, Rome, Ancona, Florence, Bologna, Turin, Milan, Venice
Latvia	Riga, Rezekne
Lithuania	Vilnius, Palanga
Netherlands	Amsterdam, Rotterdam, Groningen, Eindhoven
Poland	Warsaw, Wroclaw, Krakow, Lublin, Szczecin, Gdynia, Bialystok
Portugal	Lisbon, Porto
Romania	Bucharest, Timisoara, Constanta, Iasi
Slovakia	Bratislava, Kosice
Slovenia	Ljubljana, Maribor
Spain	Seville, Madrid, Valencia, Barcelona, Bilbao, Vigo, Salamanca
Sweden	Stockholm, Gothenburg, Ostersund, Umea, Lulea
Switzerland	Geneva, Lausanne, Sion, Zurich, Bern, Davos
United Kingdom	London, Norwich, Birmingham, Exeter, Manchester, Hull, Newcastle, Edinburgh, Belfast, Inverness

Table A.6: Locations (cities) considered to calculate the hourly external temperature profile.

B Environmental impact factors by country

Country	RE share [-]		Climate change [gCO ₂ eq/kWh]		Ecological scarcity [UBP/kWh]	Ecological footprint [m ² a/kWh]
	Method 1 ¹	Method 2 ²	GWP100a	GWP20a	Total	Total
Albania	-	-	-	-	-	-
Austria	1.00	0.99	4.03	4.44	11.66	0.016
Belarus	-	-	-	-	-	-
Belgium	1.00	0.99	4.03	4.44	11.66	0.016
Bosnia and Herz.	1.00	0.99	4.03	4.44	11.66	0.016
Bulgaria	1.00	0.99	4.03	4.44	11.66	0.016
Croatia	1.00	0.99	4.03	4.44	11.66	0.016
Cyprus	-	-	-	-	-	-
Czechia	1.00	0.99	4.03	4.44	11.66	0.016
Denmark	1.00	0.99	4.03	4.44	11.66	0.016
Estonia	1.00	0.99	4.03	4.44	11.66	0.016
Finland	1.00	0.99	4.03	4.44	11.66	0.016
France	1.00	0.99	4.03	4.44	11.66	0.016
Germany	1.00	0.99	4.03	4.44	11.66	0.016
Greece	1.00	0.99	4.03	4.44	11.66	0.016
Hungary	1.00	0.99	4.03	4.44	11.66	0.016
Ireland	1.00	0.99	4.03	4.44	11.66	0.016
Italy	1.00	0.99	4.03	4.44	11.66	0.016
Latvia	1.00	0.99	4.03	4.44	11.66	0.016
Lithuania	1.00	0.99	4.03	4.44	11.66	0.016
Luxembourg	1.00	0.99	4.03	4.44	11.66	0.016
Macedonia	1.00	0.99	4.03	4.44	11.66	0.016
Malta	-	-	-	-	-	-
Montenegro	-	-	-	-	-	-
Netherlands	1.00	0.99	4.03	4.44	11.66	0.016
Norway	-	-	-	-	-	-
Poland	1.00	0.99	4.03	4.44	11.66	0.016
Portugal	1.00	0.99	4.03	4.44	11.66	0.016
Romania	1.00	0.99	4.03	4.44	11.66	0.016
Russia	1.00	0.99	4.26	4.74	12.11	0.016
Serbia	1.00	0.99	4.03	4.44	11.66	0.016
Slovakia	1.00	0.99	4.03	4.44	11.66	0.016
Slovenia	1.00	0.99	4.03	4.44	11.66	0.016
Spain	1.00	0.99	4.03	4.44	11.66	0.016
Sweden	1.00	0.99	4.03	4.44	11.66	0.016
Switzerland	1.00	0.99	3.47	3.84	10.95	0.014
Turkey	1.00	0.99	4.26	4.74	12.11	0.016
Ukraine	1.00	0.99	4.03	4.44	11.66	0.016
United Kingdom	1.00	0.99	4.03	4.44	11.66	0.016
Europe	1.00	0.99	4.03	4.44	11.67	0.016

¹ Assume 100% renewable energy use.

² Calculated from the real cumulative energy demand.¹⁰⁹

Table B.1: Environmental impact factors¹⁰⁹ of electricity generation from hydro run-of-river by country and all Europe. Values calculated per kWh of consumed electricity. The impact factors of Europe are obtained weighing the indicators of each country by their electricity demand.

Country	RE share [-]		Climate change [gCO ₂ eq/kWh]		Ecological scarcity [UBP/kWh]	Ecological footprint [m ² a/kWh]
	Method 1 ¹	Method 2 ²	GWP100a	GWP20a	Total	Total
Albania	-	-	-	-	-	-
Austria	1.00	0.99	6.17	7.38	30.78	0.020
Belarus	-	-	-	-	-	-
Belgium	-	-	-	-	-	-
Bosnia and Herz.	1.00	0.99	6.17	7.38	30.78	0.020
Bulgaria	-	-	-	-	-	-
Croatia	1.00	0.99	6.17	7.38	30.78	0.020
Cyprus	-	-	-	-	-	-
Czechia	1.00	0.99	50.56	62.30	50.99	0.155
Denmark	-	-	-	-	-	-
Estonia	-	-	-	-	-	-
Finland	1.00	0.99	50.56	62.30	50.99	0.155
France	1.00	0.99	6.17	7.38	30.78	0.020
Germany	1.00	0.99	50.56	62.30	50.99	0.155
Greece	-	-	-	-	-	-
Hungary	-	-	-	-	-	-
Ireland	-	-	-	-	-	-
Italy	1.00	0.99	6.17	7.38	30.78	0.020
Latvia	-	-	-	-	-	-
Lithuania	-	-	-	-	-	-
Luxembourg	-	-	-	-	-	-
Macedonia	1.00	0.99	6.17	7.38	30.78	0.020
Malta	-	-	-	-	-	-
Montenegro	-	-	-	-	-	-
Netherlands	-	-	-	-	-	-
Norway	1.00	0.99	6.17	7.38	30.78	0.020
Poland	-	-	-	-	-	-
Portugal	1.00	0.99	50.56	62.30	50.99	0.155
Romania	-	-	-	-	-	-
Russia	1.00	0.99	50.97	62.82	51.66	0.156
Serbia	1.00	0.99	6.17	7.38	30.78	0.020
Slovakia	1.00	0.99	50.56	62.30	50.99	0.155
Slovenia	-	-	-	-	-	-
Spain	1.00	0.99	50.56	62.30	50.99	0.155
Sweden	1.00	0.99	50.56	62.30	50.99	0.155
Switzerland	1.00	0.99	6.17	7.38	30.79	0.020
Turkey	1.00	0.99	50.97	62.82	51.66	0.156
Ukraine	-	-	-	-	-	-
United Kingdom	-	-	-	-	-	-
Europe	1.00	0.99	28.41	34.90	40.96	0.088

¹ Assume 100% renewable energy use.

² Calculated from the real cumulative energy demand.¹⁰⁹

Table B.2: Environmental impact factors¹⁰⁹ of electricity generation from hydro reservoir by country and all Europe. Values calculated per kWh of consumed electricity. The impact factors of Europe are obtained weighing the indicators of each country by their electricity demand.

Country	RE share [-]		Climate change [gCO ₂ eq/kWh]		Ecological scarcity [UBP/kWh]	Ecological footprint [m ² a/kWh]
	Method 1 ¹	Method 2 ²	GWP100a	GWP20a	Total	Total
Albania	-	-	-	-	-	-
Austria	1.00	0.94	16.78	19.88	45.87	0.047
Belarus	-	-	-	-	-	-
Belgium	1.00	0.95	15.71	18.58	46.19	0.044
Bosnia and Herz.	-	-	-	-	-	-
Bulgaria	1.00	0.94	18.71	22.12	59.98	0.052
Croatia	1.00	0.95	15.97	18.95	42.78	0.045
Cyprus	1.00	0.92	23.25	27.58	60.01	0.065
Czechia	1.00	0.94	18.27	21.68	48.20	0.051
Denmark	1.00	0.96	12.67	15.05	40.53	0.035
Estonia	1.00	0.94	18.68	22.12	50.91	0.052
Finland	1.00	0.93	22.62	26.62	82.95	0.062
France	1.00	0.95	14.72	17.45	39.55	0.041
Germany	1.00	0.94	19.09	22.62	55.01	0.053
Greece	1.00	0.95	14.45	17.12	45.38	0.040
Hungary	1.00	0.96	12.86	15.23	36.13	0.036
Ireland	1.00	0.96	12.92	15.32	36.75	0.036
Italy	1.00	0.94	18.68	22.16	54.69	0.052
Latvia	1.00	0.95	17.13	20.41	47.56	0.048
Lithuania	1.00	0.96	12.62	14.94	36.20	0.035
Luxembourg	1.00	0.94	17.47	20.75	46.74	0.049
Macedonia	1.00	0.95	15.77	18.69	41.63	0.044
Malta	-	-	-	-	-	-
Montenegro	-	-	-	-	-	-
Netherlands	1.00	0.95	15.68	18.56	50.36	0.044
Norway	1.00	0.95	13.56	16.06	37.74	0.038
Poland	1.00	0.95	15.56	18.44	41.89	0.044
Portugal	1.00	0.96	12.94	15.33	34.98	0.036
Romania	1.00	0.92	24.28	28.66	75.98	0.067
Russia	1.00	0.77	94.47	113.14	258.64	0.268
Serbia	-	-	-	-	-	-
Slovakia	1.00	0.96	14.07	16.85	41.79	0.040
Slovenia	-	-	-	-	-	-
Spain	1.00	0.96	13.35	15.88	37.28	0.038
Sweden	1.00	0.95	15.31	18.17	41.40	0.043
Switzerland	-	-	-	-	-	-
Turkey	1.00	0.96	12.63	14.94	39.22	0.035
Ukraine	1.00	0.91	30.63	36.23	89.43	0.085
United Kingdom	1.00	0.96	13.12	15.55	37.94	0.037
Europe	1.00	0.94	19.16	22.74	54.96	0.054

¹ Assume 100% renewable energy use.

² Calculated from the real cumulative energy demand.¹⁰⁹

Table B.3: Environmental impact factors¹⁰⁹ of electricity generation from wind onshore by country and all Europe. Values calculated per kWh of consumed electricity. The impact factors of Europe are obtained weighing the indicators of each country by their electricity demand.

Country	RE share [-]		Climate change [gCO ₂ eq/kWh]		Ecological scarcity [UBP/kWh]	Ecological footprint [m ² a/kWh]
	Method 1 ¹	Method 2 ²	GWP100a	GWP20a	Total	Total
Albania	-	-	-	-	-	-
Austria	-	-	-	-	-	-
Belarus	-	-	-	-	-	-
Belgium	1.00	0.95	15.35	18.12	41.11	0.040
Bosnia and Herz.	-	-	-	-	-	-
Bulgaria	-	-	-	-	-	-
Croatia	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czechia	-	-	-	-	-	-
Denmark	1.00	0.95	15.35	18.12	41.11	0.040
Estonia	-	-	-	-	-	-
Finland	1.00	0.95	15.35	18.12	41.11	0.040
France	1.00	0.95	15.35	18.12	41.11	0.040
Germany	1.00	0.95	15.35	18.12	41.11	0.040
Greece	-	-	-	-	-	-
Hungary	-	-	-	-	-	-
Ireland	1.00	0.95	15.35	18.12	41.11	0.040
Italy	-	-	-	-	-	-
Latvia	-	-	-	-	-	-
Lithuania	-	-	-	-	-	-
Luxembourg	-	-	-	-	-	-
Macedonia	-	-	-	-	-	-
Malta	-	-	-	-	-	-
Montenegro	-	-	-	-	-	-
Netherlands	1.00	0.95	15.35	18.12	41.11	0.040
Norway	1.00	0.95	15.35	18.12	41.11	0.040
Poland	-	-	-	-	-	-
Portugal	1.00	0.95	15.35	18.12	41.11	0.040
Romania	-	-	-	-	-	-
Russia	-	-	-	-	-	-
Serbia	-	-	-	-	-	-
Slovakia	-	-	-	-	-	-
Slovenia	-	-	-	-	-	-
Spain	1.00	0.95	15.35	18.12	41.11	0.040
Sweden	1.00	0.95	15.35	18.12	41.11	0.040
Switzerland	-	-	-	-	-	-
Turkey	-	-	-	-	-	-
Ukraine	-	-	-	-	-	-
United Kingdom	1.00	0.95	15.35	18.12	41.11	0.040
Europe	1.00	0.95	15.35	18.12	41.11	0.040

¹ Assume 100% renewable energy use.

² Calculated from the real cumulative energy demand.¹⁰⁹

Table B.4: Environmental impact factors¹⁰⁹ of electricity generation from wind offshore by country and all Europe. Values calculated per kWh of consumed electricity. The impact factors of Europe are obtained weighing the indicators of each country by their electricity demand.

Country	RE share [-]		Climate change [gCO ₂ eq/kWh]		Ecological scarcity [UBP/kWh]	Ecological footprint [m ² a/kWh]
	Method 1 ¹	Method 2 ²	GWP100a	GWP20a	Total	Total
Albania	-	-	-	-	-	-
Austria	1.00	0.76	97.56	113.66	247.13	0.267
Belarus	-	-	-	-	-	-
Belgium	1.00	0.75	101.91	118.83	255.99	0.298
Bosnia and Herz.	-	-	-	-	-	-
Bulgaria	1.00	0.81	71.16	82.90	181.30	0.194
Croatia	1.00	0.82	64.73	75.40	165.11	0.177
Cyprus	1.00	0.84	55.10	64.19	141.06	0.151
Czechia	1.00	0.74	108.00	125.81	273.18	0.295
Denmark	1.00	0.77	91.84	106.98	231.45	0.251
Estonia	-	-	-	-	-	-
Finland	1.00	0.76	95.44	111.16	238.87	0.261
France	1.00	0.79	82.72	96.47	205.40	0.247
Germany	1.00	0.75	100.23	116.88	248.07	0.299
Greece	1.00	0.81	69.69	81.19	177.64	0.190
Hungary	1.00	0.78	85.32	99.38	215.91	0.233
Ireland	1.00	0.80	75.68	88.25	202.10	0.206
Italy	1.00	0.80	73.48	85.81	176.56	0.246
Latvia	-	-	-	-	-	-
Lithuania	1.00	0.75	99.44	115.84	251.73	0.272
Luxembourg	1.00	0.77	91.39	106.45	230.40	0.250
Macedonia	1.00	0.81	68.11	79.35	174.01	0.186
Malta	1.00	0.82	67.52	78.67	174.05	0.184
Montenegro	-	-	-	-	-	-
Netherlands	1.00	0.75	99.33	115.72	251.26	0.273
Norway	-	-	-	-	-	-
Poland	1.00	0.77	90.62	105.57	230.24	0.248
Portugal	1.00	0.83	62.71	73.21	152.93	0.203
Romania	1.00	0.79	80.49	93.76	204.57	0.220
Russia	1.00	0.77	92.46	107.72	235.79	0.253
Serbia	1.00	0.80	75.55	88.01	191.19	0.207
Slovakia	1.00	0.78	82.92	96.60	210.66	0.227
Slovenia	1.00	0.80	76.04	88.59	193.55	0.208
Spain	1.00	0.82	64.77	75.58	159.54	0.202
Sweden	1.00	0.75	100.27	116.83	252.54	0.279
Switzerland	1.00	0.78	85.06	99.14	216.62	0.233
Turkey	1.00	0.82	63.43	73.89	161.62	0.173
Ukraine	1.00	0.78	83.52	97.30	212.11	0.228
United Kingdom	1.00	0.78	84.30	98.44	201.55	0.281
Europe	1.00	0.79	82.53	96.17	208.25	0.233

¹ Assume 100% renewable energy use.

² Calculated from the real cumulative energy demand.¹⁰⁹

Table B.5: Environmental impact factors¹⁰⁹ of electricity generation from solar PV by country and all Europe. Values calculated per kWh of consumed electricity. The impact factors of Europe are obtained weighing the indicators of each country by their electricity demand.

C Data errors

Country	ENTSO-E residuals [-]				
	L. Whisker	Q1	Q2	Q3	H. Whisker
Austria	0.004	0.018	0.037	0.076	0.200
Belgium	0.001	0.003	0.006	0.012	0.050
Bulgaria	0.000	0.002	0.025	0.078	0.166
Czechia	0.001	0.006	0.010	0.032	0.082
Denmark	0.003	0.013	0.029	0.086	0.214
Estonia	0.000	0.002	0.005	0.010	0.028
Finland	0.021	0.033	0.042	0.053	0.064
France	0.001	0.006	0.012	0.020	0.034
Germany	0.003	0.014	0.028	0.043	0.065
Greece	0.002	0.010	0.019	0.028	0.040
Hungary	0.004	0.010	0.013	0.024	0.067
Ireland	0.058	0.127	0.187	0.251	0.326
Italy	0.003	0.006	0.009	0.019	0.046
Latvia	0.000	0.002	0.004	0.007	0.012
Lithuania	0.001	0.008	0.028	0.163	0.651
Netherlands	0.144	0.184	0.211	0.245	0.303
Poland	0.045	0.071	0.082	0.089	0.097
Portugal	0.000	0.001	0.010	0.082	0.229
Romania	0.000	0.000	0.001	0.001	0.003
Slovakia	0.002	0.010	0.024	0.051	0.106
Slovenia	0.052	0.076	0.107	0.167	0.248
Spain	0.000	0.002	0.005	0.012	0.021
Sweden	0.004	0.018	0.030	0.042	0.065
Switzerland	0.009	0.046	0.103	0.187	0.336
United Kingdom	0.010	0.043	0.074	0.111	0.167
Europe *	0.012	0.026	0.039	0.058	0.095

* Independent countries with isolated grids.

Table C.1: Relative error of the ENTSO-E data. Residuals of the hourly electricity balance calculated as relative error with respect to the hourly electricity demand. The lower and higher whiskers correspond to the 5- and 95-percentile of the observed residuals, respectively. Q1, Q2 and Q3 are the first, second and third quartiles of the error distributions.

Country	Simulation residuals [-]				
	L. Whisker	Q1	Q2	Q3	H. Whisker
Austria	0.000	0.003	0.012	0.025	0.043
Belgium	0.000	0.015	0.048	0.090	0.155
Bulgaria	0.000	0.003	0.012	0.023	0.042
Czechia	0.000	0.004	0.017	0.036	0.071
Denmark	0.000	0.004	0.019	0.037	0.066
Estonia	0.000	0.003	0.014	0.030	0.055
Finland	0.000	0.003	0.010	0.020	0.036
France	0.000	0.002	0.008	0.018	0.035
Germany	0.000	0.003	0.013	0.028	0.053
Greece	0.000	0.001	0.008	0.018	0.035
Hungary	0.000	0.005	0.025	0.056	0.116
Ireland	0.000	0.005	0.017	0.032	0.055
Italy	0.000	0.002	0.008	0.017	0.031
Latvia	0.000	0.003	0.016	0.034	0.075
Lithuania	0.000	0.004	0.018	0.036	0.067
Netherlands	0.000	0.006	0.021	0.040	0.074
Poland	0.000	0.003	0.016	0.033	0.063
Portugal	0.000	0.002	0.008	0.017	0.033
Romania	0.000	0.002	0.008	0.017	0.031
Slovakia	0.000	0.002	0.006	0.012	0.021
Slovenia	0.000	0.010	0.032	0.063	0.105
Spain	0.000	0.001	0.006	0.014	0.027
Sweden	0.000	0.001	0.004	0.007	0.014
Switzerland	0.000	0.008	0.025	0.051	0.089
United Kingdom	0.000	0.004	0.014	0.027	0.052
Europe *	0.000	0.003	0.013	0.026	0.049
Europe **	0.000	0.002	0.008	0.015	0.027

* Independent countries with isolated grids.

** Interconnected grids.

Table C.2: Error of the simulation algorithm. Residual of the hourly electricity balance calculated as relative error with respect to the hourly electricity demand. The lower and higher whiskers correspond to the 5- and 95-percentile of the observed residuals, respectively. Q1, Q2 and Q3 are the first, second and third quartiles of the error distributions.

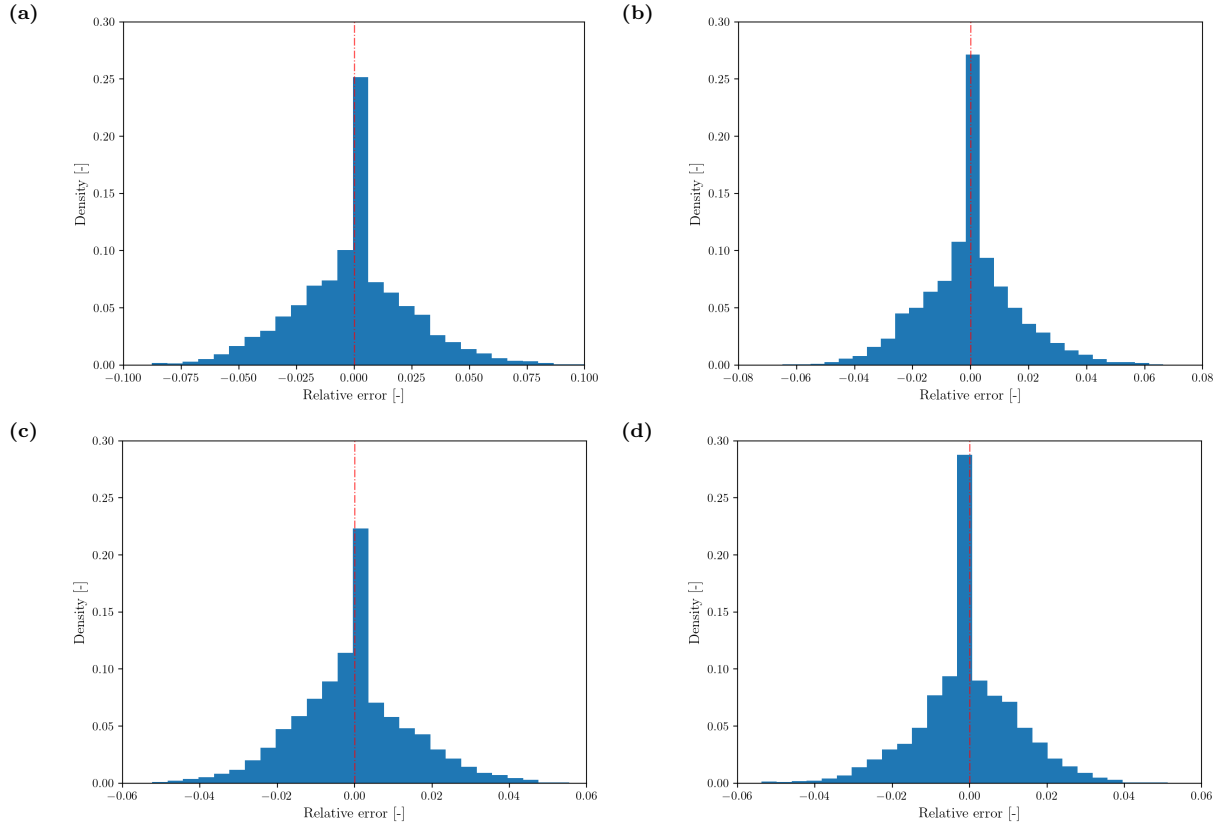


Figure C.1: Error distributions of the simulation algorithm for (a), Germany (b), France (c), Italy (d) Spain. Residuals of the hourly electricity balance calculated as relative error [-] with respect to the hourly electricity demand.

D Cost data

Type	Sub-type	Hydro		Solar	Wind	
		Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Capital	fixed ¹	2250.00	1852.00	934.00	1743.50	3947.00
Maintenance	fixed ²	18.00	19.93	46.70	33.36	118.41
	variable ³	0.95	2.46	-	8.46	-

¹ USD per kW of installed capacity.

² USD/year per kW of installed capacity.

³ USD/year per MWh of annual produced electricity.

Table D.1: Capital (fixed) and maintenance (fixed and variable) costs of the electricity generation technologies. The values correspond to the medians of the empirical distributions obtained from the reviewed literature.

Type	Sub-type	Battery				Power-to-gas	
		Lead-acid	Lithium-ion	Vanadium flow	Zinc flow	SNG	Hydrogen
Capital	fixed	250.00 ¹	377.50 ¹	403.00 ¹	492.50 ¹	-	-
	variable	-	-	-	-	0.0695 ²	0.1790 ²
Maintenance	fixed	9.93 ³	15.00 ³	16.01 ³	19.57 ³	-	-
	variable	0.13 ⁴	0.20 ⁴	0.21 ⁴	0.26 ⁴	0.0034 ⁵	0.0089 ⁵

¹ USD per kWh of installed capacity.

² USD per kWh of produced gas.

³ USD/year per kW of installed peak power.

⁴ USD/year per MWh of annual discharged electricity.

⁵ USD/year per kWh of annual produced gas.

Table D.2: Capital (fixed and variable) and maintenance (fixed and variable) costs of storage. The values correspond to the medians of the empirical distributions obtained from the reviewed literature.

E Environmental impact factors

Storage	Technology	Distribution	min	median	max	Parameters				
						p1	p2	p3	p4	p-value
Battery	Lead-acid	Beta	78.00	115.00	178.00	0.633	0.750	78.00	106.69	0.962
	Lithium-ion	Uniform	18.00	54.70	61.00	-	-	-	-	-
	Vanadium flow	GEV	11.70	15.49	42.00	-0.567	14.389	3.187	-	0.695
	Zinc flow	Uniform	9.19	11.54	31.03	-	-	-	-	-
PtoG	SNG	-	-	150.60	-	-	-	-	-	-
	Hydrogen	-	-	115.80	-	-	-	-	-	-

Table E.1: Probability distributions used to draw the Global Warming Potential (GWP100a) [gCO₂eq/kWh] associated with storage. The distributions are identified using the Kolmogorov-Smirnov test. Not enough data are available from the reviewed literature for the power-to-gas, hence the impact factors associated with the long-term storage are assumed deterministic.

Country	RE share [-]		IPCC 2013 climate change [gCO ₂ eq/kWh]		Ecological scarcity [UBP/kWh]	Ecological footprint [m ² a/kWh]
	Method 1 ¹	Method 2 ²	GWP100a	GWP20a	Total	Total
Austria	0.69	0.61	271.06	307.84	231.03	0.960
Belgium	0.19	0.17	214.74	236.92	313.36	2.003
Bulgaria	0.16	0.14	553.14	571.78	616.11	2.430
Czechia	0.16	0.12	763.49	803.29	657.05	2.968
Denmark	0.71	0.66	207.00	233.94	223.83	1.068
Estonia	0.32	0.31	582.98	608.25	616.39	2.214
Finland	0.42	0.41	191.70	214.69	286.69	1.801
France	0.21	0.19	73.08	80.77	316.34	2.173
Germany	0.44	0.34	443.35	495.82	374.33	1.551
Greece	0.30	0.27	666.00	741.38	579.19	1.758
Hungary	0.19	0.17	380.39	426.22	425.99	2.219
Ireland	0.42	0.39	377.42	396.39	329.66	1.023
Italy	0.37	0.32	382.87	445.01	301.06	1.167
Latvia	0.42	0.38	413.12	454.70	360.39	1.436
Lithuania	0.61	0.55	227.87	254.28	268.96	1.290
Netherlands	0.16	0.15	540.51	596.37	377.79	1.627
Poland	0.16	0.15	947.36	1038.82	782.91	2.531
Portugal	0.53	0.48	299.23	334.80	257.53	1.026
Romania	0.40	0.38	402.25	421.47	819.53	1.689
Slovakia	0.21	0.19	399.63	434.85	487.04	2.358
Slovenia	0.43	0.39	347.35	365.04	448.15	1.691
Spain	0.40	0.37	232.51	255.31	263.58	1.314
Sweden	0.55	0.54	37.44	43.94	181.29	1.300
Switzerland	0.45	0.34	175.59	194.57	313.62	1.805
United Kingdom	0.30	0.28	270.80	286.42	297.84	1.557
Europe	0.34	0.29	337.24	372.31	368.44	1.714

¹ Assume 100% renewable energy use.

² Calculated from the real cumulative energy demand.¹⁰⁹

Table E.2: Environmental impact indicators of the current electricity grid by country and all Europe. The impacts reported in this table are calculated weighting the hourly values by the corresponding hourly electricity demands.

Country	Electricity	Fossil fuels	Heating		Total
	Grid	Mobility	Households	Services	
Austria	271.06	243.84	113.50	113.50	207.57
Belgium	214.74	250.80	218.83	218.83	228.31
Bulgaria	553.14	249.23	65.59	65.59	321.88
Czechia	763.49	247.43	136.35	136.35	345.21
Denmark	207.00	259.31	46.67	46.67	155.56
Estonia	582.98	249.30	34.55	34.55	242.31
Finland	191.70	234.34	31.03	31.03	147.33
France	73.08	250.63	145.86	145.86	158.58
Germany	443.35	251.73	162.69	162.69	264.36
Greece	666.00	253.23	146.60	146.60	360.65
Hungary	380.39	249.64	141.08	141.08	234.65
Ireland	377.42	254.28	256.41	256.41	286.78
Italy	382.87	250.21	161.38	161.38	246.13
Latvia	413.12	259.55	49.35	49.35	186.66
Lithuania	227.87	254.28	66.84	66.84	180.28
Netherlands	540.51	248.24	188.71	188.71	310.38
Poland	947.36	251.52	195.82	195.82	397.45
Portugal	299.23	254.07	100.75	100.75	231.32
Romania	402.25	251.33	101.71	101.71	227.37
Slovakia	399.63	248.82	158.80	158.80	266.64
Slovenia	347.35	254.86	84.05	84.05	235.62
Spain	232.51	247.69	157.66	157.66	222.20
Sweden	37.44	189.88	13.86	13.86	74.93
Switzerland	175.59	224.29	157.40	157.40	184.31
United Kingdom	270.80	246.07	200.48	200.48	233.96
Europe	337.24	247.97	157.24	157.24	239.90

Table E.3: Sector-specific and total Global Warming Potentials (IPCC 2013 climate change GWP100a) of the current energy system by country and all Europe. The indicator is measured in grams of CO₂ equivalent emitted per kWh of consumed energy [gCO₂eq/kWh].

F Electricity generation and demand results

Country	Hydro [-]		Solar [-]	Wind [-]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	0.193	0.494	0.012	0.302	-
Belgium	0.001	-	0.762	0.132	0.105
Bulgaria	0.098	0.033	0.178	0.216	0.476
Czechia	0.010	0.010	0.047	0.934	-
Denmark	0.000	-	0.067	0.556	0.376
Estonia	0.001	-	0.002	0.648	0.348
Finland	0.095	-	0.001	0.406	0.498
France	0.040	0.118	0.072	0.217	0.553
Germany	0.014	0.019	0.120	0.488	0.358
Greece	0.000	0.186	0.120	0.520	0.174
Hungary	0.003	0.035	0.102	0.860	-
Ireland	0.015	-	0.009	0.804	0.171
Italy	0.103	0.117	0.128	0.289	0.363
Latvia	0.122	-	0.054	0.612	0.212
Lithuania	0.027	-	0.042	0.719	0.212
Netherlands	0.000	-	0.033	0.050	0.917
Poland	0.014	0.006	0.006	0.814	0.159
Portugal	0.073	0.076	0.061	0.445	0.345
Romania	0.100	0.213	0.089	0.297	0.301
Slovakia	0.083	0.036	0.028	0.853	-
Slovenia	0.181	-	0.652	0.167	-
Spain	0.021	0.090	0.095	0.585	0.209
Sweden	-	0.637	0.004	0.223	0.136
Switzerland	0.155	0.197	0.447	0.201	-
United Kingdom	0.010	-	0.100	0.699	0.191
Europe *	0.053	0.087	0.133	0.486	0.242
Europe **	0.038	0.142	0.068	0.526	0.227

* Independent countries with isolated grids.

** Interconnected grids.

Table F.1: Electricity production shares [-] of the best observed solutions.

Country	Hydro [-]		Solar [-]	Wind [-]		Generation [GWh]
	Run-of-river	Reservoir		Onshore	Offshore	
Austria	0.235	0.602	0.015	0.368	0.000	114476
Belgium	0.002	0.000	1.137	0.196	0.156	186986
Bulgaria	0.114	0.038	0.208	0.251	0.555	55674
Czechia	0.014	0.013	0.063	1.262	0.000	136123
Denmark	0.000	0.000	0.090	0.742	0.502	73163
Estonia	0.001	0.000	0.003	0.814	0.437	16258
Finland	0.114	0.000	0.001	0.484	0.594	128655
France	0.048	0.143	0.087	0.262	0.666	783599
Germany	0.018	0.025	0.153	0.620	0.455	1035600
Greece	0.000	0.218	0.141	0.609	0.204	80209
Hungary	0.004	0.050	0.147	1.241	0.000	100859
Ireland	0.020	0.000	0.012	1.068	0.228	57967
Italy	0.118	0.134	0.147	0.331	0.415	517089
Latvia	0.159	0.000	0.070	0.796	0.276	17192
Lithuania	0.035	0.000	0.054	0.919	0.271	26166
Netherlands	0.000	0.000	0.046	0.070	1.269	229118
Poland	0.019	0.008	0.008	1.070	0.209	359328
Portugal	0.086	0.089	0.072	0.526	0.408	76071
Romania	0.116	0.247	0.103	0.343	0.348	101583
Slovakia	0.093	0.040	0.032	0.960	0.000	47447
Slovenia	0.231	0.000	0.835	0.214	0.000	24026
Spain	0.024	0.105	0.110	0.682	0.243	389094
Sweden	0.000	0.683	0.004	0.238	0.146	183404
Switzerland	0.209	0.266	0.603	0.271	0.000	116516
United Kingdom	0.012	0.000	0.126	0.881	0.240	612025
Europe	0.043	0.161	0.077	0.596	0.258	4996038

Table F.2: Electricity production, as fraction [-] of the demand, and annual generation [GWh] for the best observed solutions by country.

Country	Hydro [MW]		Solar [MW]	Wind [MW]		Total [MW]
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore	
Austria	6608	39703	1646	14732	-	62689
Belgium	181	-	146194	13573	5000	164949
Bulgaria	2900	1978	7373	6390	6751	25391
Czechia	525	878	5745	58127	-	65275
Denmark	0	-	5180	17227	8224	30631
Estonia	7	-	42	5225	1442	6715
Finland	3148	-	146	18149	16307	37750
France	10956	34983	51577	75257	110301	283074
Germany	3950	19101	130462	260772	104153	518438
Greece	0	9925	6138	15770	3554	35388
Hungary	84	877	11725	40112	-	52797
Ireland	216	-	617	18424	2531	21788
Italy	26811	10968	54853	76959	47765	217356
Latvia	1539	-	1099	4870	928	8436
Lithuania	251	-	1213	6730	1412	9606
Netherlands	0	-	8602	5734	46108	60444
Poland	1246	2208	2712	116946	14565	137676
Portugal	3030	4516	2958	12863	6691	30058
Romania	2760	14636	5938	13364	7778	44476
Slovakia	1207	1940	1212	18042	-	22400
Slovenia	1078	-	16067	3089	-	20233
Spain	6142	26724	22933	107161	20690	183651
Sweden	-	29479	906	16103	6358	52845
Switzerland	4230	10962	59610	12533	-	87335
United Kingdom	3081	-	64916	164280	42080	274357
Europe *	79950	208877	609862	1102432	452639	2453762
Europe **	74492	305940	327363	1304061	388474	2400330

* Independent countries with isolated grids.

** Interconnected grids.

Table F.3: Installed generation capacities [MW] for the best-observed solution.

Country	Hydro [-]		Solar [-]	Wind [-]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	0.662	0.121	0.000	0.217	-
Belgium	0.019	-	0.273	0.296	0.412
Bulgaria	0.186	0.307	0.264	0.244	0.000
Czechia	0.177	0.226	0.457	0.140	-
Denmark	0.000	-	0.056	0.611	0.333
Estonia	0.026	-	0.000	0.974	0.000
Finland	0.672	-	0.000	0.328	0.000
France	0.317	0.223	0.112	0.348	0.000
Germany	0.080	0.007	0.240	0.541	0.131
Greece	0.000	0.243	0.267	0.490	0.000
Hungary	0.044	0.049	0.599	0.308	-
Ireland	0.086	-	0.000	0.914	0.000
Italy	0.237	0.268	0.272	0.224	0.000
Latvia	0.932	-	0.000	0.068	0.000
Lithuania	0.179	-	0.039	0.781	0.000
Netherlands	0.000	-	0.307	0.343	0.350
Poland	0.107	0.010	0.000	0.884	0.000
Portugal	0.237	0.088	0.059	0.616	0.000
Romania	0.426	0.221	0.074	0.280	0.000
Slovakia	0.812	0.066	0.122	0.001	-
Slovenia	0.941	-	0.058	0.001	-
Spain	0.086	0.177	0.153	0.583	0.000
Sweden	-	0.765	0.000	0.235	0.000
Switzerland	0.478	0.465	0.053	0.004	-
United Kingdom	0.068	-	0.154	0.431	0.348
Europe	0.187	0.184	0.156	0.396	0.077

Table F.4: Current resource shares [-] of renewable generation by country and all Europe.

Country	Hydro [EUR/MWh]		Solar [EUR/MWh]	Wind [EUR/MWh]	
	Run-of-river	Reservoir		Onshore	Offshore
Austria	57.07	102.47	130.15	75.82	-
Belgium	139.62	-	112.83	95.91	102.39
Bulgaria	101.03	158.14	81.78	92.86	102.02
Czechia	72.53	98.48	99.70	80.74	-
Denmark	-	-	115.81	75.25	119.59
Estonia	72.67	-	130.15	86.92	102.02
Finland	48.94	-	130.15	63.02	102.02
France	66.96	56.04	100.61	78.28	102.02
Germany	50.22	137.81	115.42	90.22	112.52
Greece	-	97.02	70.08	68.00	102.02
Hungary	54.85	37.78	125.59	81.54	-
Ireland	47.04	-	130.15	70.70	102.02
Italy	95.16	28.16	91.00	90.04	102.02
Latvia	138.78	-	130.15	81.64	102.02
Lithuania	67.12	-	121.42	64.67	102.02
Netherlands	-	-	125.59	87.05	87.93
Poland	46.71	143.49	130.15	71.46	102.02
Portugal	103.46	114.21	70.52	68.20	102.02
Romania	51.70	98.64	72.33	78.43	102.02
Slovakia	58.47	165.07	99.19	78.89	-
Slovenia	47.48	-	112.83	130.92	-
Spain	143.52	110.58	68.46	82.88	102.02
Sweden	-	38.23	130.15	70.61	102.02
Switzerland	44.88	70.21	125.91	93.41	-
United Kingdom	99.73	-	116.30	68.87	144.40
Europe	75.39	63.89	106.46	87.05	137.12

Table F.5: Levelized Cost of Electricity (LCOE) [EUR/MWh] of each generation technology by country and all of Europe.

Country	Solar [-]			Wind [-]			Combined [-]		
	Hourly	Daily	Seasonal	Hourly	Daily	Seasonal	Hourly	Daily	Seasonal
Austria	-	-	-	0.068	0.189	0.300	-	-	-
Belgium	0.107	0.132	0.468	0.057	0.171	0.293	0.077	0.153	0.097
Bulgaria	0.124	0.150	0.330	0.061	0.144	0.215	0.081	0.140	0.097
Czechia	0.107	0.140	0.418	0.068	0.143	0.349	0.067	0.120	0.302
Denmark	0.097	0.126	0.516	0.059	0.185	0.196	0.063	0.183	0.153
Estonia	-	-	-	0.073	0.176	0.225	-	-	-
Finland	-	-	-	0.062	0.163	0.139	-	-	-
France	0.135	0.093	0.388	0.057	0.131	0.323	0.077	0.126	0.164
Germany	0.108	0.095	0.466	0.051	0.132	0.313	0.084	0.122	0.118
Greece	0.147	0.119	0.290	0.056	0.158	0.271	0.096	0.129	0.204
Hungary	0.029	0.046	0.358	0.052	0.176	0.330	0.021	0.070	0.370
Ireland	-	-	-	0.064	0.188	0.246	-	-	-
Italy	0.146	0.097	0.340	0.065	0.157	0.289	0.083	0.114	0.086
Latvia	-	-	-	0.065	0.173	0.215	-	-	-
Lithuania	0.121	0.089	0.547	0.070	0.177	0.262	0.072	0.176	0.224
Netherlands	0.017	0.040	0.397	0.061	0.182	0.288	0.013	0.084	0.362
Poland	-	-	-	0.064	0.143	0.274	-	-	-
Portugal	0.152	0.117	0.261	0.063	0.156	0.245	0.066	0.152	0.210
Romania	0.125	0.119	0.356	0.066	0.166	0.239	0.078	0.162	0.130
Slovakia	0.122	0.117	0.388	0.004	0.010	0.349	0.073	0.117	0.384
Slovenia	0.037	0.136	0.382	0.048	0.074	0.199	0.023	0.136	0.374
Spain	0.153	0.094	0.316	0.055	0.118	0.226	0.067	0.111	0.128
Sweden	-	-	-	0.041	0.114	0.181	-	-	-
Switzerland	0.110	0.134	0.450	0.053	0.150	0.258	0.068	0.130	0.419
United Kingdom	0.101	0.120	0.449	0.091	0.147	0.203	0.107	0.144	0.089
Europe *	0.119	0.099	0.403	0.061	0.142	0.263	0.078	0.129	0.144
Europe **	0.089	0.095	0.348	0.051	0.083	0.241	0.076	0.078	0.107

* Independent countries with isolated grids.

** Interconnected grids.

Table F.6: Hourly, daily and seasonal variability of solar, wind (onshore and offshore) and combined solar + wind generation by country and all Europe. The variability is calculated using the inter -hours, -days, and -seasons load ramps as share [-] of peak loads.

Country	Current electricity[-]			Households heating [-]			Services heating [-]			Electrical mobility [-]		
	Hourly	Daily	Seasonal	Hourly	Daily	Seasonal	Hourly	Daily	Seasonal	Hourly	Daily	Seasonal
Austria	0.165	0.057	0.093	0.022	0.040	0.439	0.020	0.041	0.479	0.181	0.070	0.036
Belgium	0.156	0.042	0.076	0.025	0.042	0.463	0.024	0.044	0.514	0.181	0.070	0.036
Bulgaria	0.124	0.023	0.103	0.026	0.033	0.382	0.021	0.035	0.447	0.180	0.080	0.036
Czechia	0.159	0.045	0.099	0.033	0.041	0.406	0.029	0.044	0.476	0.181	0.070	0.036
Denmark	0.069	0.042	0.088	0.031	0.039	0.346	0.025	0.046	0.478	0.181	0.070	0.036
Estonia	0.148	0.037	0.153	0.016	0.033	0.397	0.013	0.035	0.471	0.180	0.080	0.036
Finland	0.142	0.024	0.153	0.016	0.033	0.388	0.014	0.035	0.470	0.180	0.080	0.036
France	0.177	0.036	0.162	0.026	0.039	0.437	0.024	0.040	0.484	0.181	0.070	0.036
Germany	0.170	0.064	0.058	0.031	0.038	0.425	0.027	0.040	0.488	0.181	0.070	0.036
Greece	0.124	0.033	0.157	0.009	0.022	0.361	0.009	0.022	0.367	0.180	0.080	0.036
Hungary	0.166	0.043	0.046	0.022	0.035	0.426	0.021	0.036	0.459	0.181	0.070	0.036
Ireland	0.127	0.033	0.083	0.039	0.054	0.422	0.034	0.062	0.586	0.182	0.074	0.036
Italy	0.154	0.068	0.084	0.023	0.027	0.363	0.020	0.029	0.401	0.181	0.070	0.036
Latvia	0.124	0.040	0.087	0.027	0.044	0.375	0.023	0.049	0.463	0.180	0.080	0.036
Lithuania	0.171	0.039	0.078	0.032	0.038	0.421	0.029	0.040	0.467	0.180	0.080	0.036
Netherlands	0.135	0.045	0.073	0.023	0.040	0.408	0.020	0.043	0.510	0.181	0.070	0.036
Poland	0.163	0.060	0.060	0.028	0.044	0.405	0.024	0.046	0.471	0.181	0.070	0.036
Portugal	0.127	0.051	0.055	0.100	0.023	0.118	0.019	0.038	0.428	0.182	0.074	0.036
Romania	0.168	0.043	0.059	0.025	0.029	0.390	0.021	0.030	0.440	0.180	0.080	0.036
Slovakia	0.062	0.038	0.074	0.029	0.037	0.429	0.027	0.038	0.472	0.181	0.070	0.036
Slovenia	0.090	0.054	0.056	0.030	0.038	0.409	0.027	0.040	0.459	0.181	0.070	0.036
Spain	0.165	0.049	0.059	0.032	0.030	0.334	0.021	0.034	0.467	0.181	0.070	0.036
Sweden	0.117	0.031	0.190	0.027	0.047	0.411	0.023	0.052	0.491	0.181	0.070	0.036
Switzerland	0.079	0.034	0.107	0.032	0.047	0.434	0.030	0.050	0.479	0.181	0.070	0.036
United Kingdom	0.082	0.038	0.116	0.029	0.044	0.414	0.025	0.048	0.541	0.182	0.074	0.036
Europe *	0.147	0.047	0.099	0.028	0.039	0.408	0.024	0.041	0.483	0.181	0.071	0.036
Europe **	0.132	0.044	0.080	0.026	0.028	0.401	0.021	0.030	0.479	0.172	0.071	0.036

* Independent countries with isolated grids.

** Interconnected grids.

Table F.7: Hourly, daily and seasonal variability of current (electricity consumption), households, services and mobility demands by country and all Europe. The variability is calculated using the inter -hours, -days, and -seasons load ramps as share [-] of peak loads.

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Country	Storage options	
	Battery [-]	Power-to-gas [-]
Austria	0.00073	0.134
Belgium	0.00262	0.245
Bulgaria	0.00076	0.045
Czechia	0.00165	0.062
Denmark	0.00155	0.049
Estonia	0.00130	0.052
Finland	0.00076	0.048
France	0.00076	0.055
Germany	0.00096	0.061
Greece	0.00078	0.034
Hungary	0.00263	0.078
Ireland	0.00136	0.076
Italy	0.00051	0.047
Latvia	0.00187	0.061
Lithuania	0.00137	0.046
Netherlands	0.00165	0.059
Poland	0.00133	0.050
Portugal	0.00064	0.073
Romania	0.00066	0.078
Slovakia	0.00038	0.043
Slovenia	0.00171	0.129
Spain	0.00065	0.052
Sweden	0.00022	0.032
Switzerland	0.00134	0.204
United Kingdom	0.00117	0.061
Europe *	0.00099	0.066
Europe **	0.00048	0.036

* Independent countries with isolated grids.

** Interconnected grids.

Table G.1: Storage capacity as fraction [-] of the annual electricity demand by country. Results for the best-observed solutions.

Country	Storage option	
	Battery [%]	Power-to-gas [%]
Austria	48.26	65.48
Belgium	38.08	68.77
Bulgaria	47.32	69.86
Czechia	44.58	57.81
Denmark	48.45	63.29
Estonia	45.68	61.10
Finland	45.82	67.12
France	48.62	64.11
Germany	48.93	63.84
Greece	50.02	61.64
Hungary	46.26	56.99
Ireland	48.08	61.37
Italy	50.47	70.14
Latvia	47.18	60.82
Lithuania	46.46	61.92
Netherlands	49.53	63.29
Poland	45.79	60.55
Portugal	47.45	61.92
Romania	49.77	69.86
Slovakia	46.22	69.04
Slovenia	37.79	68.49
Spain	47.99	61.37
Sweden	49.94	75.62
Switzerland	40.92	69.32
United Kingdom	49.50	67.12
Europe	46.43	67.12

Table G.2: Storage charging time [%] as a percentage of the annual operating time. Results for the best-observed solutions.

Country	Storage option	
	Battery [-]	Power-to-gas [-]
Austria	0.107	0.283
Belgium	0.590	0.476
Bulgaria	0.113	0.199
Czechia	0.172	0.454
Denmark	0.173	0.428
Estonia	0.140	0.324
Finland	0.092	0.251
France	0.079	0.274
Germany	0.122	0.354
Greece	0.079	0.225
Hungary	0.263	0.551
Ireland	0.147	0.430
Italy	0.074	0.185
Latvia	0.169	0.378
Lithuania	0.170	0.345
Netherlands	0.175	0.503
Poland	0.156	0.405
Portugal	0.083	0.237
Romania	0.079	0.201
Slovakia	0.057	0.165
Slovenia	0.434	0.250
Spain	0.066	0.221
Sweden	0.034	0.093
Switzerland	0.303	0.389
United Kingdom	0.130	0.335
Europe	0.073	0.170

Table G.3: Total electrical energy sent to storage as fraction [-] of the electricity demand. Results for the best-observed solutions.

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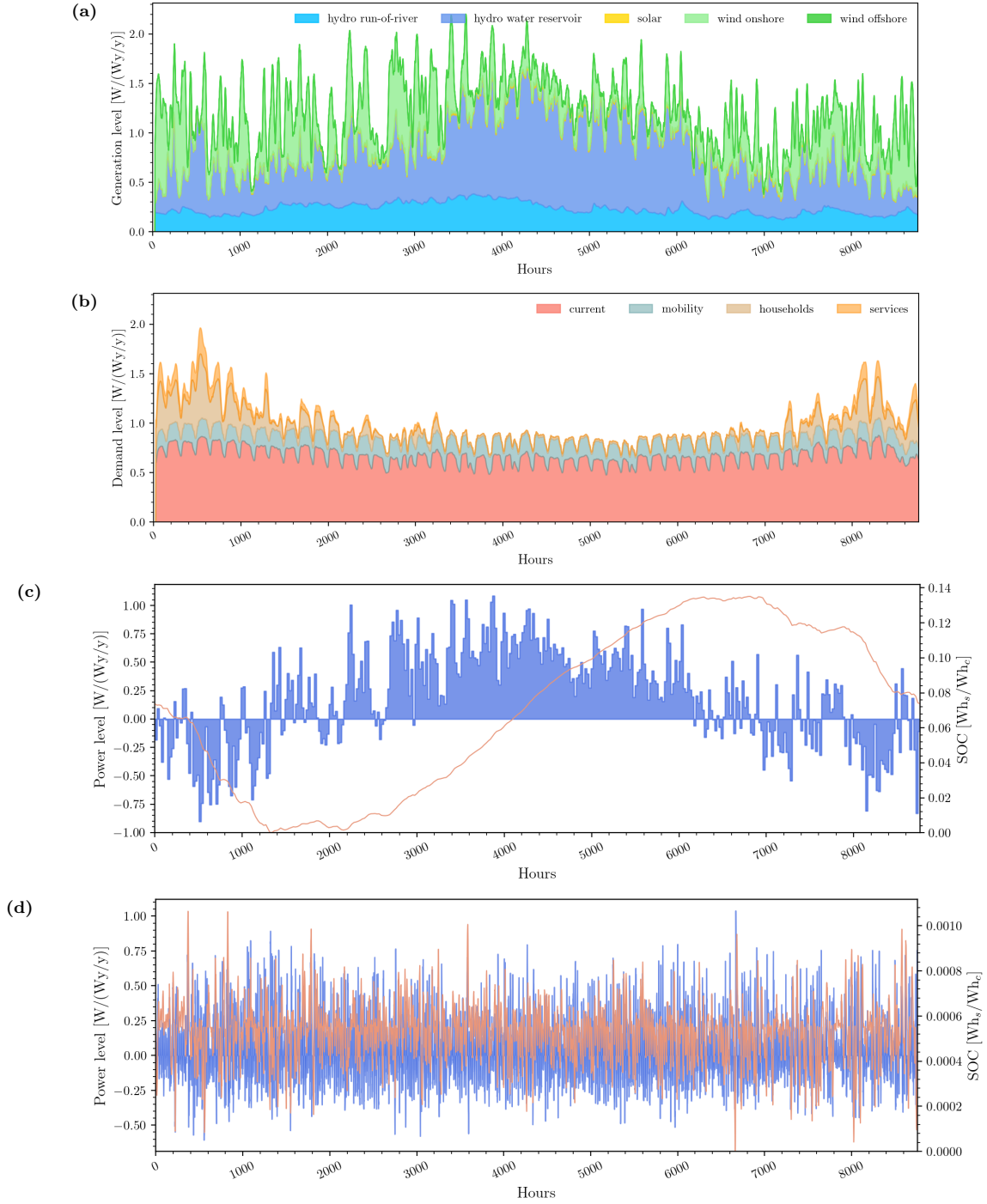


Figure H.1: Hourly electricity production (a) and demand (b) profiles for *Austria*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

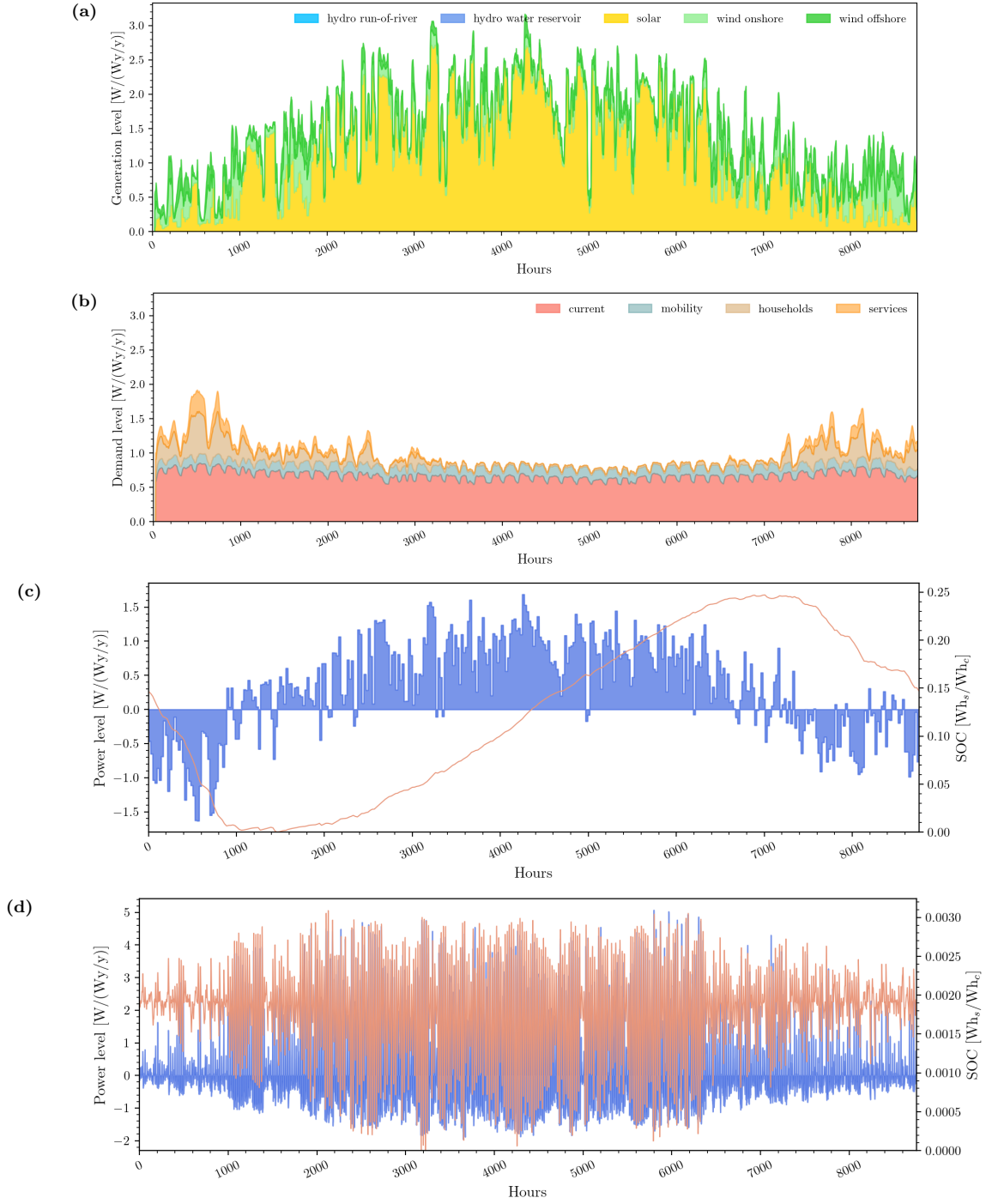


Figure H.2: Hourly electricity production (a) and demand (b) profiles for *Belgium*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

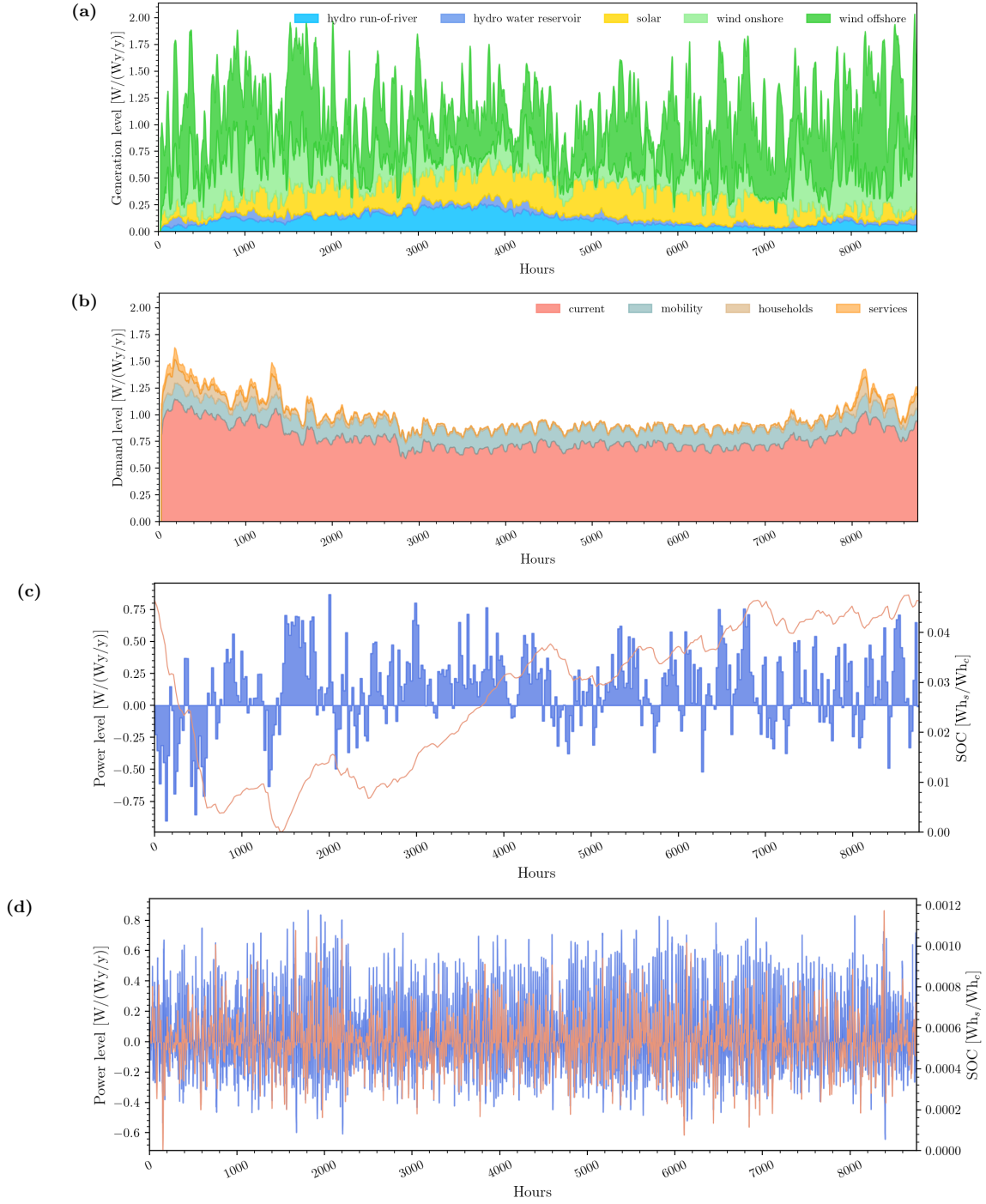


Figure H.3: Hourly electricity production (a) and demand (b) profiles for *Bulgaria*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

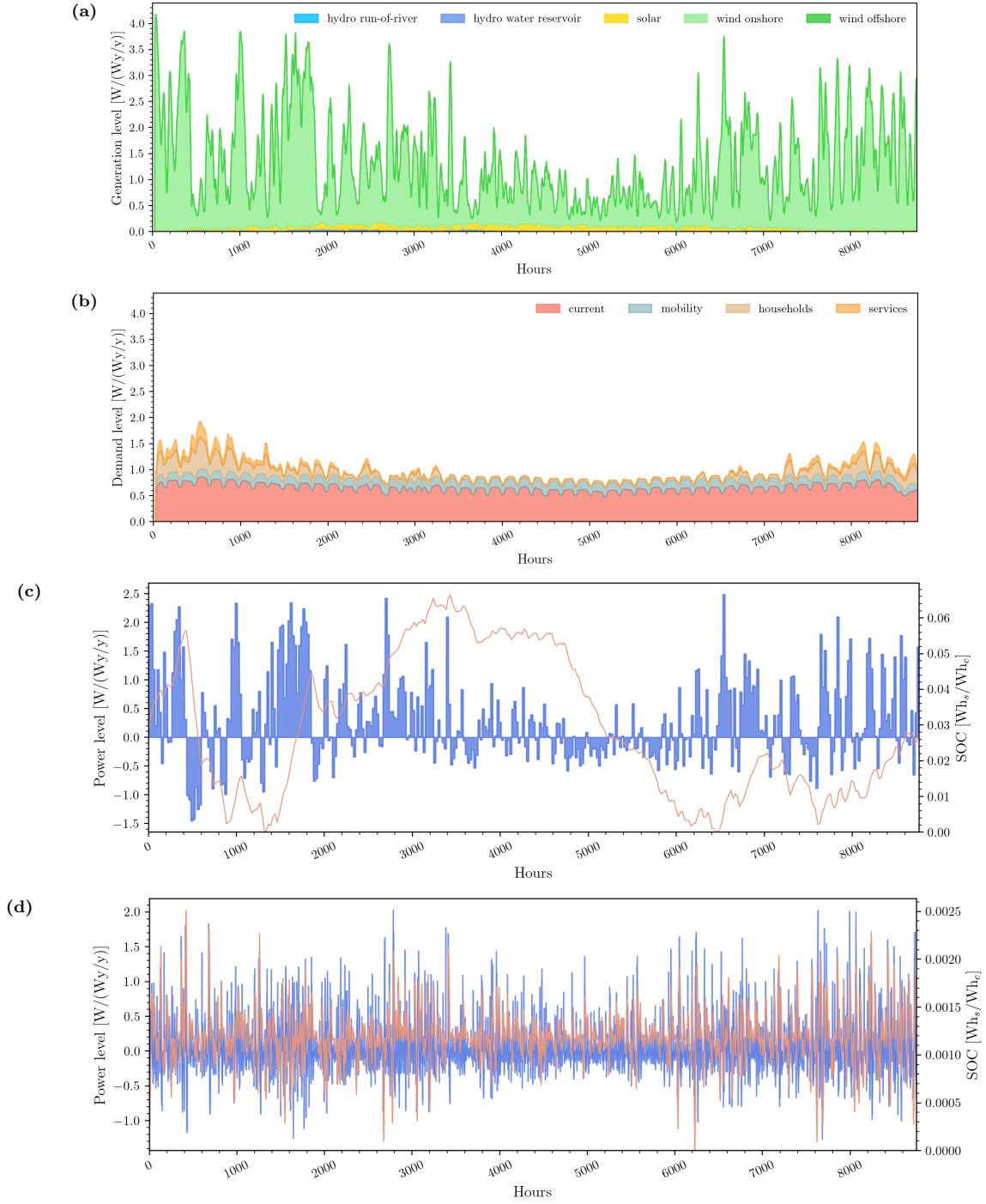


Figure H.4: Hourly electricity production (a) and demand (b) profiles for *Czechia*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

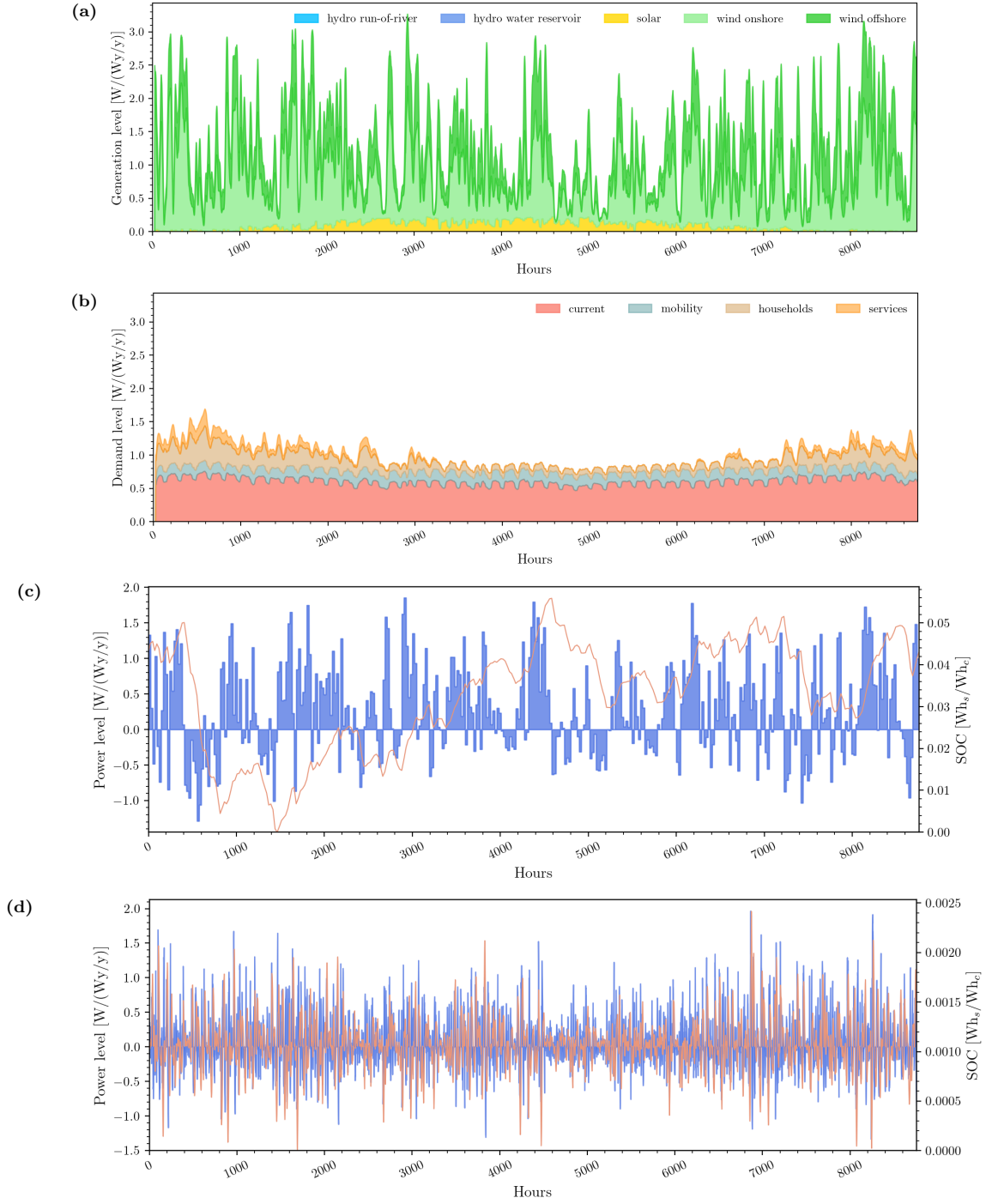


Figure H.5: Hourly electricity production (a) and demand (b) profiles for *Denmark*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

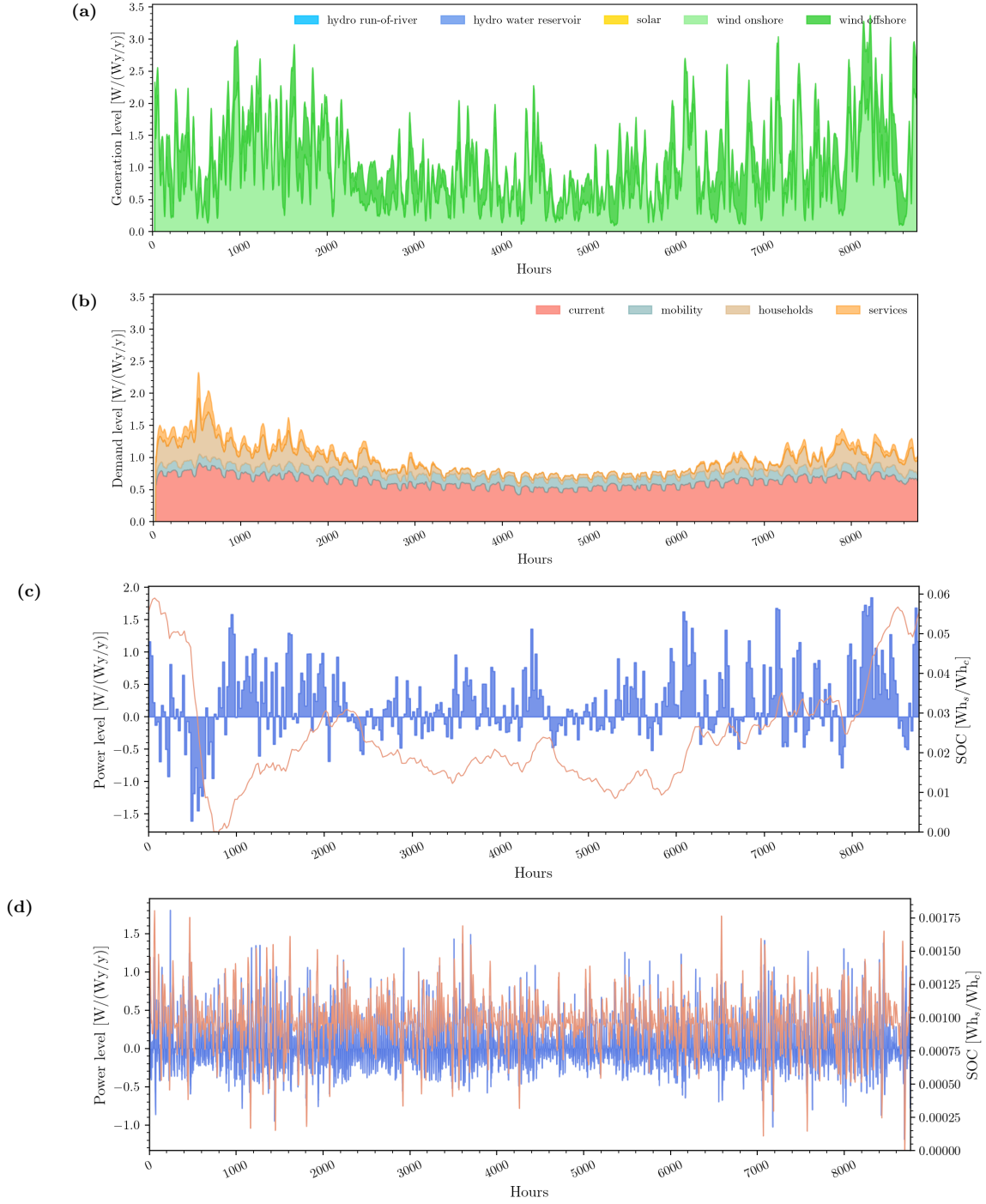


Figure H.6: Hourly electricity production (a) and demand (b) profiles for *Estonia*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

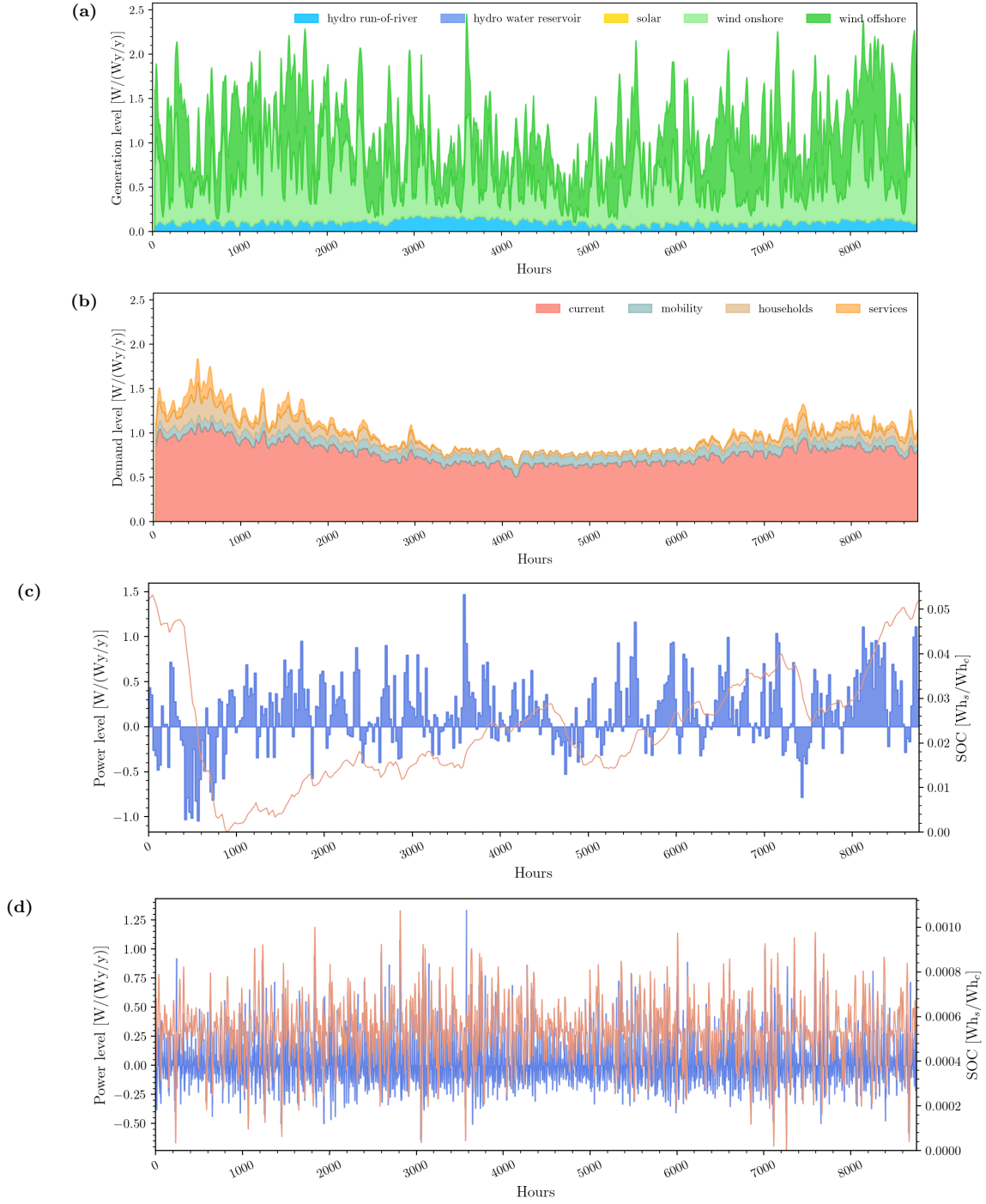


Figure H.7: Hourly electricity production (a) and demand (b) profiles for *Finland*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

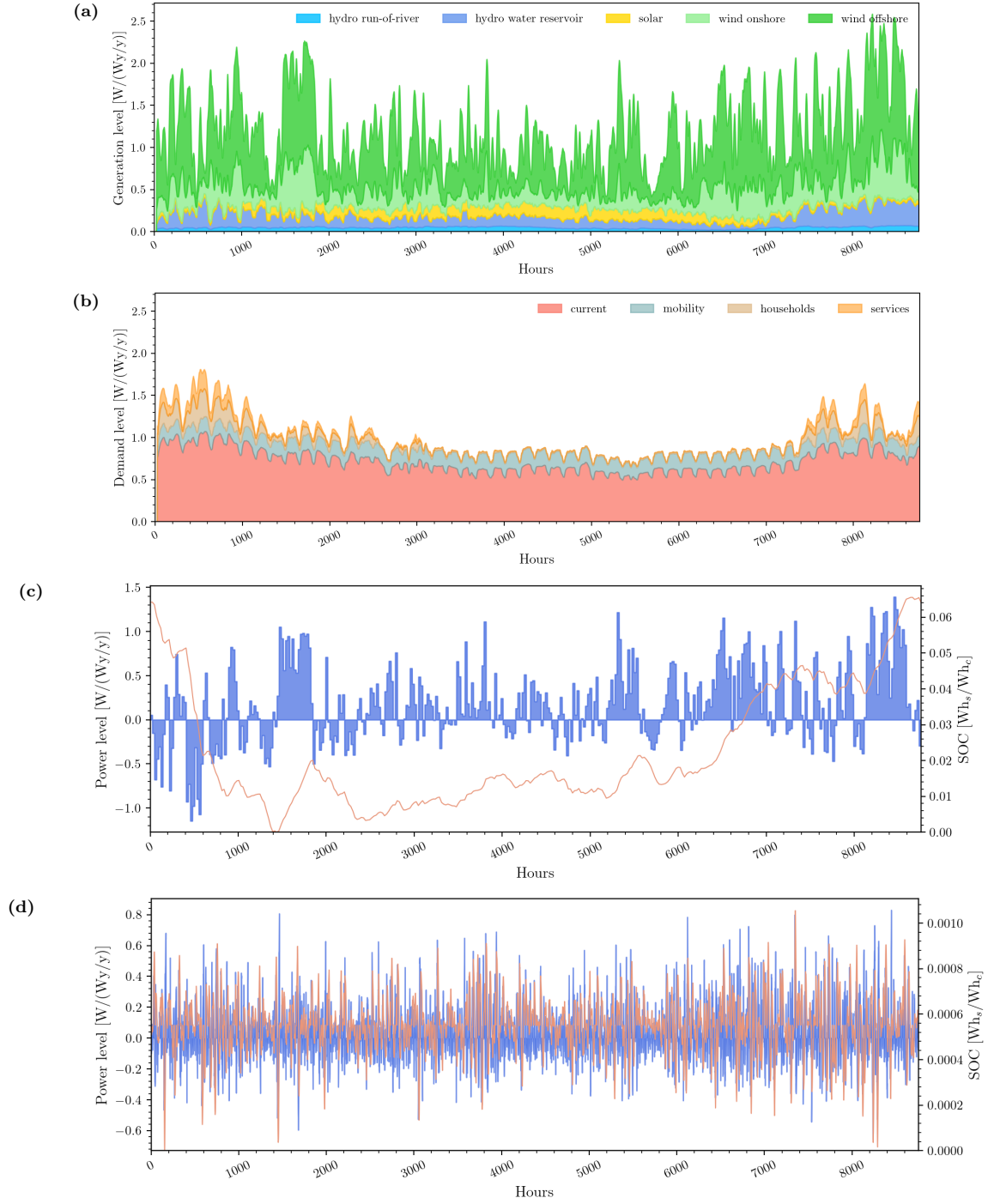


Figure H.8: Hourly electricity production (a) and demand (b) profiles for *France*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

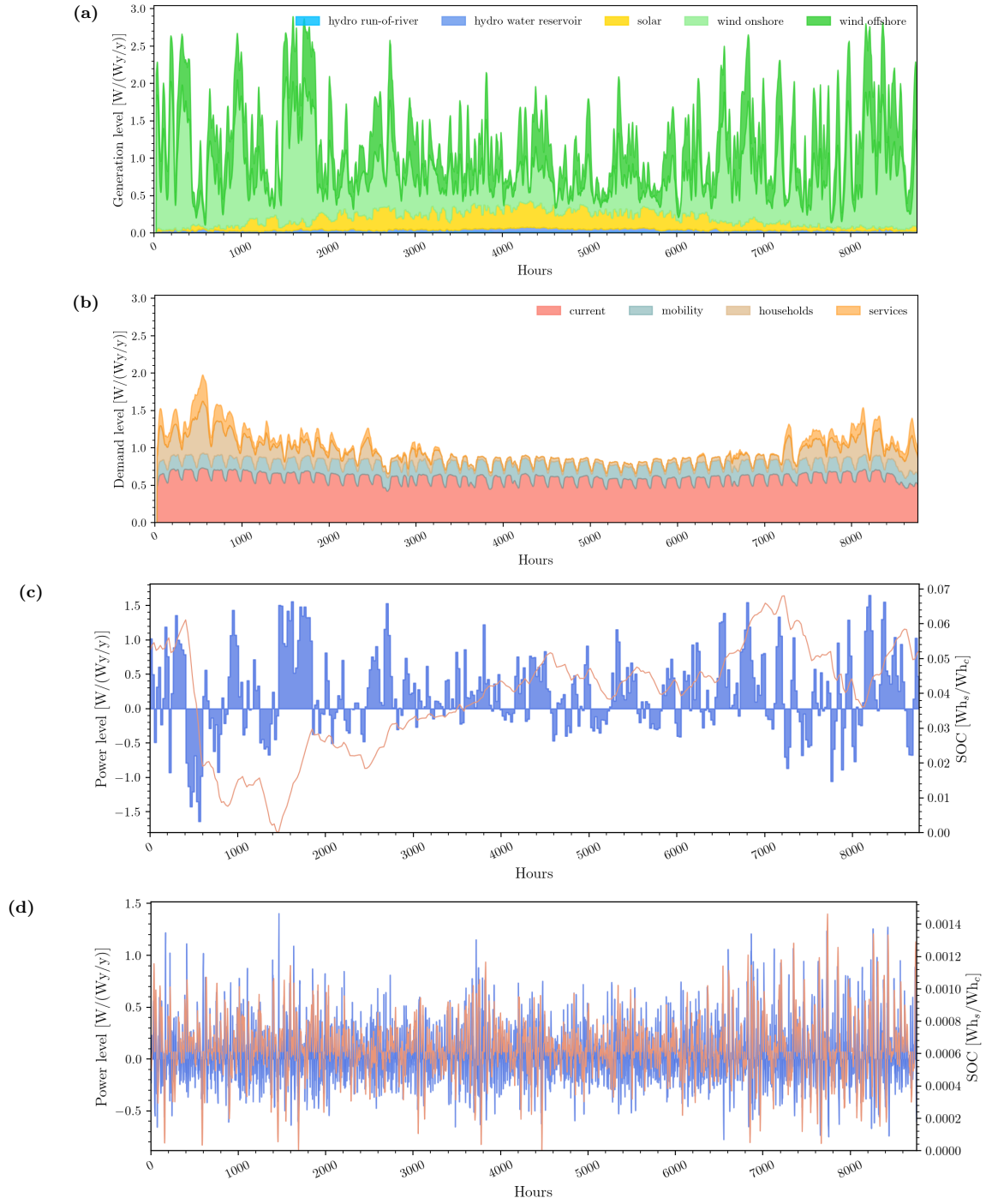


Figure H.9: Hourly electricity production (a) and demand (b) profiles for *Germany*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

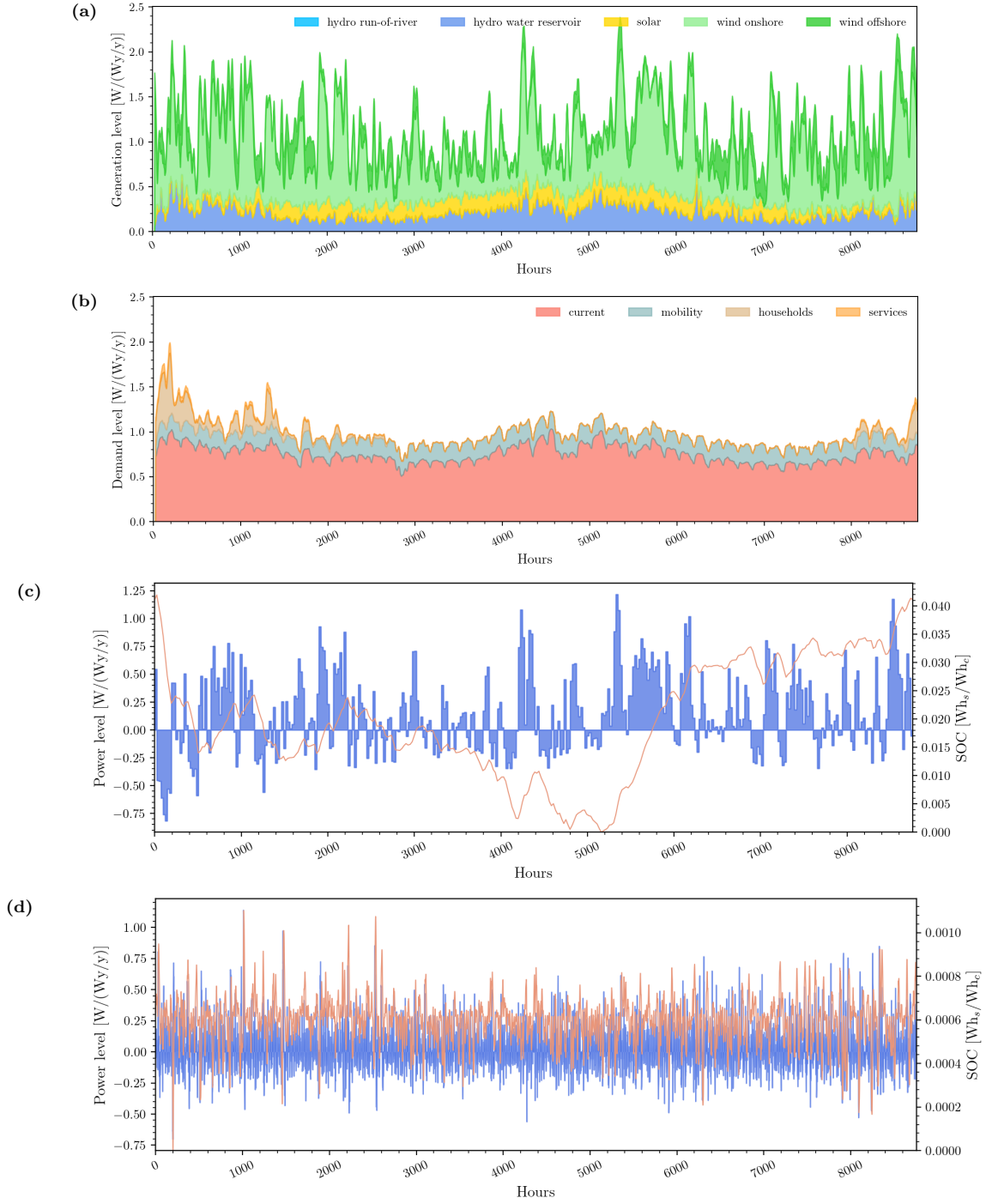


Figure H.10: Hourly electricity production (a) and demand (b) profiles for *Greece*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

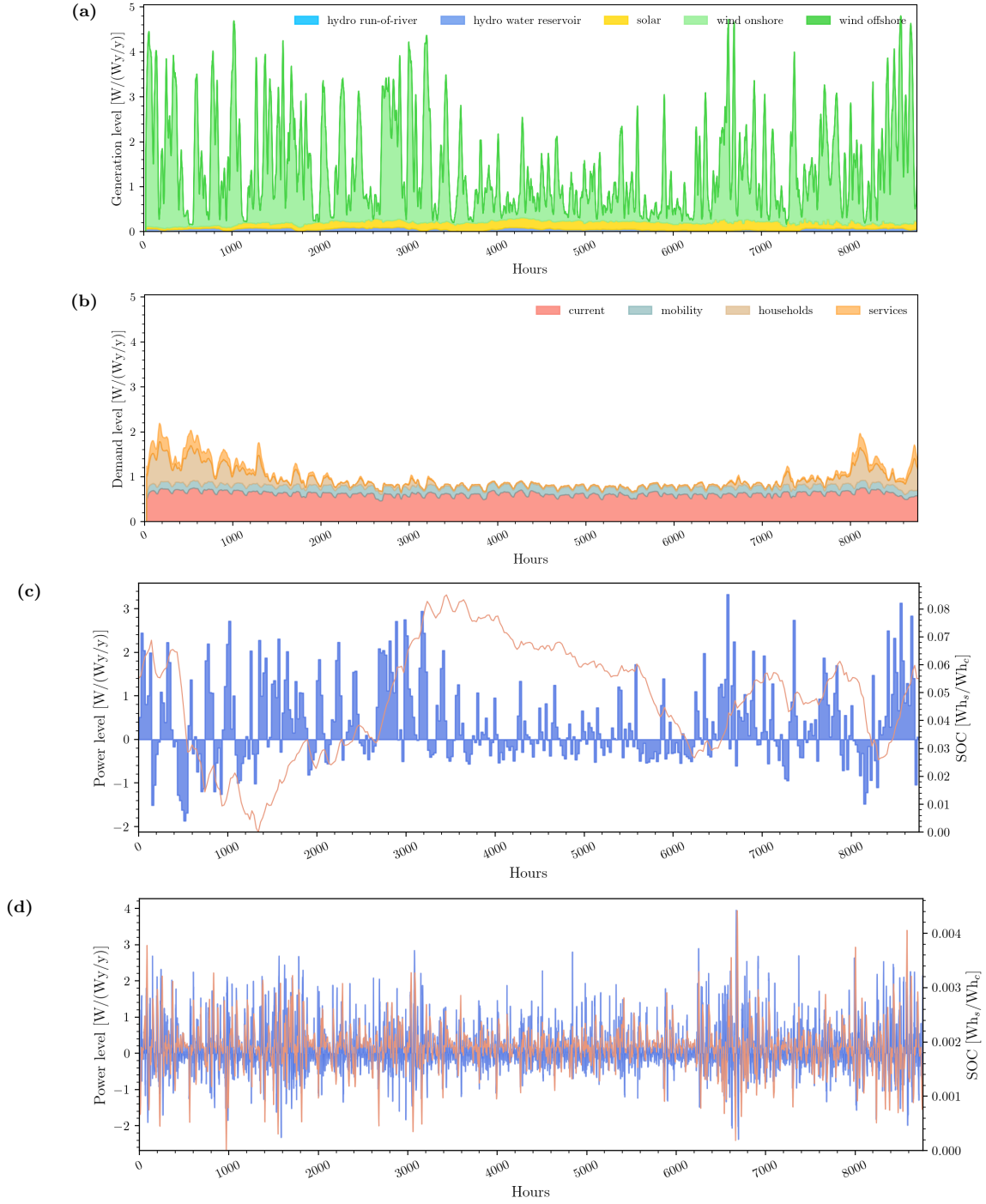


Figure H.11: Hourly electricity production (a) and demand (b) profiles for *Hungary*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

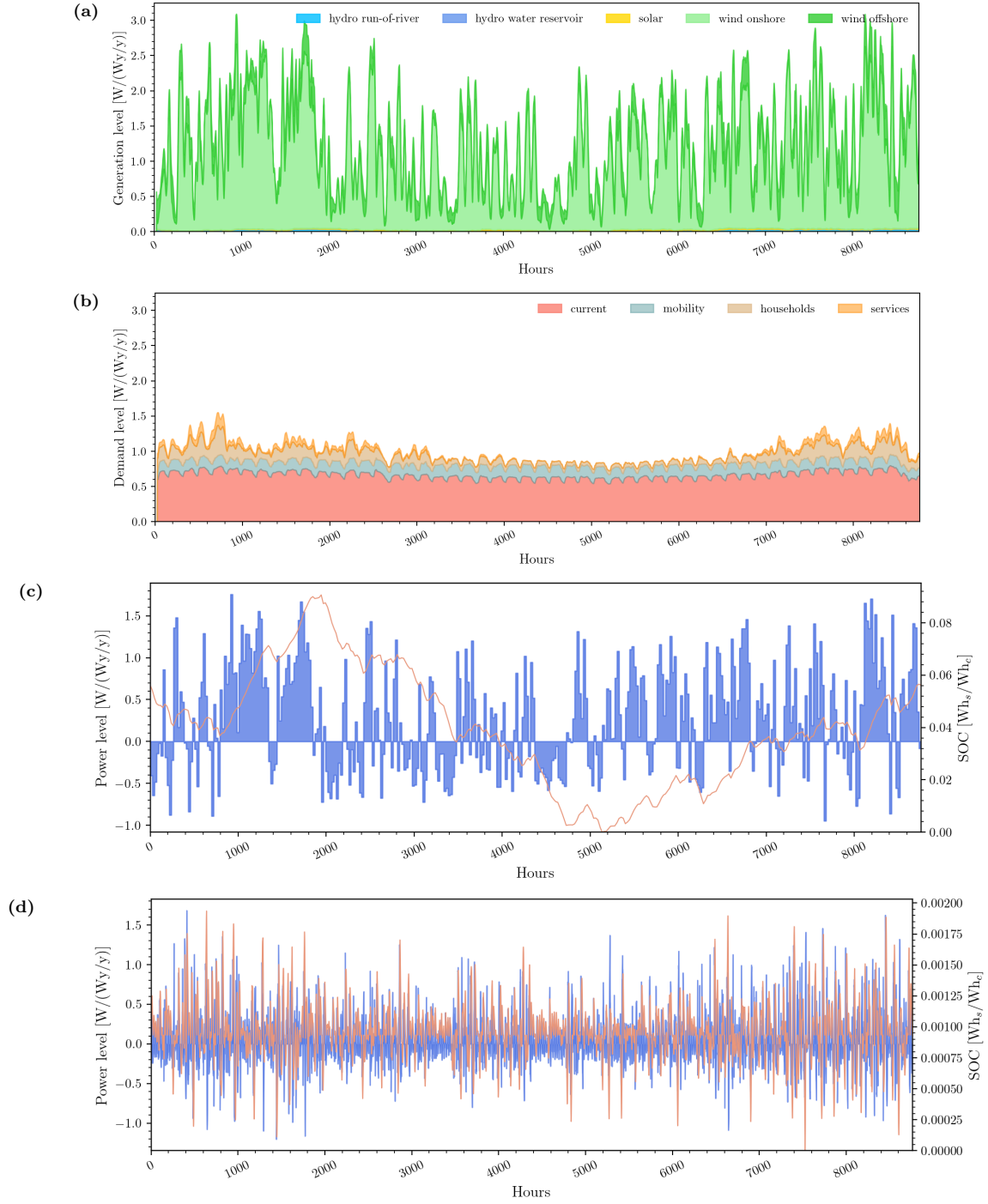


Figure H.12: Hourly electricity production (a) and demand (b) profiles for *Ireland*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

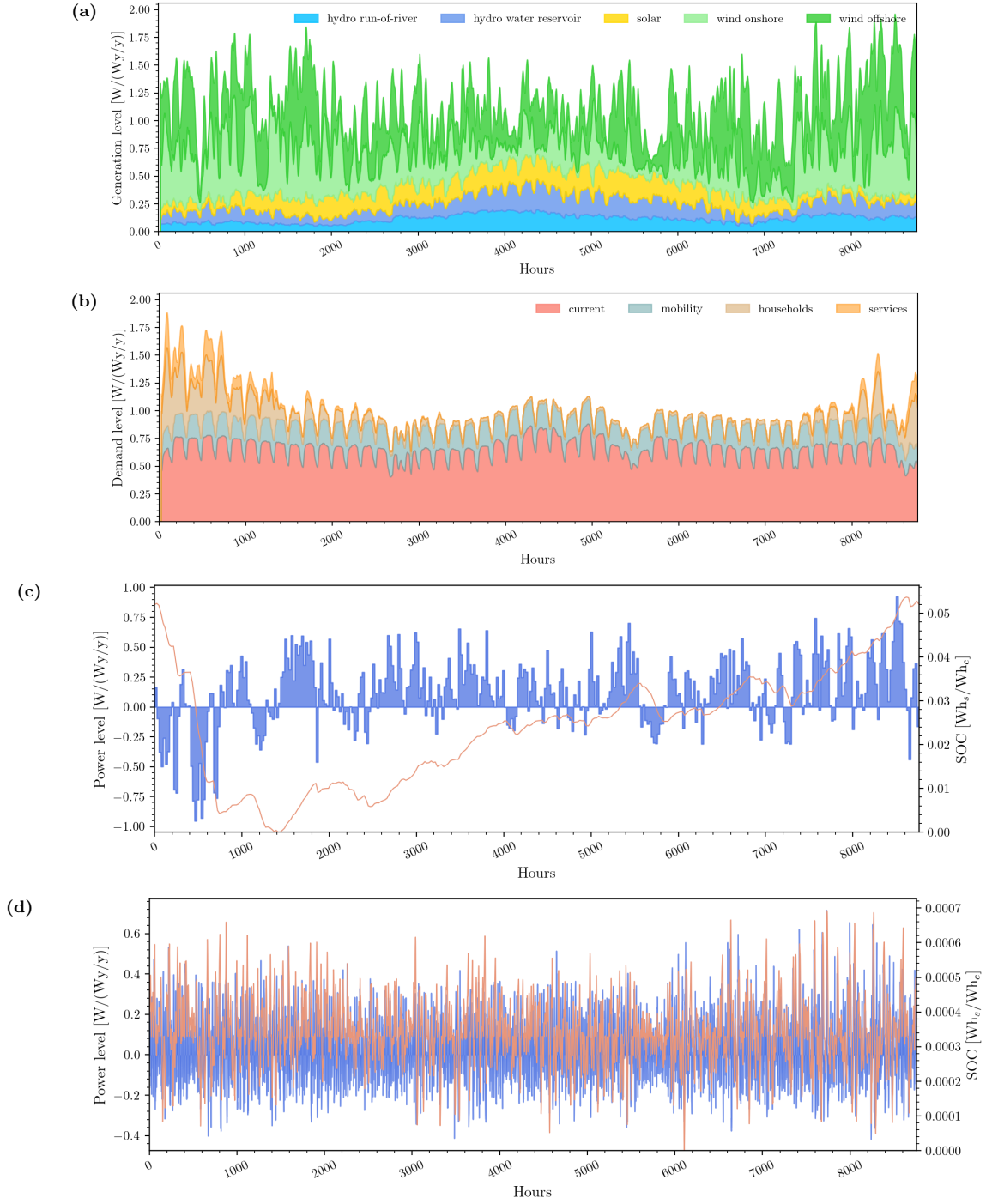


Figure H.13: Hourly electricity production (a) and demand (b) profiles for *Italy*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

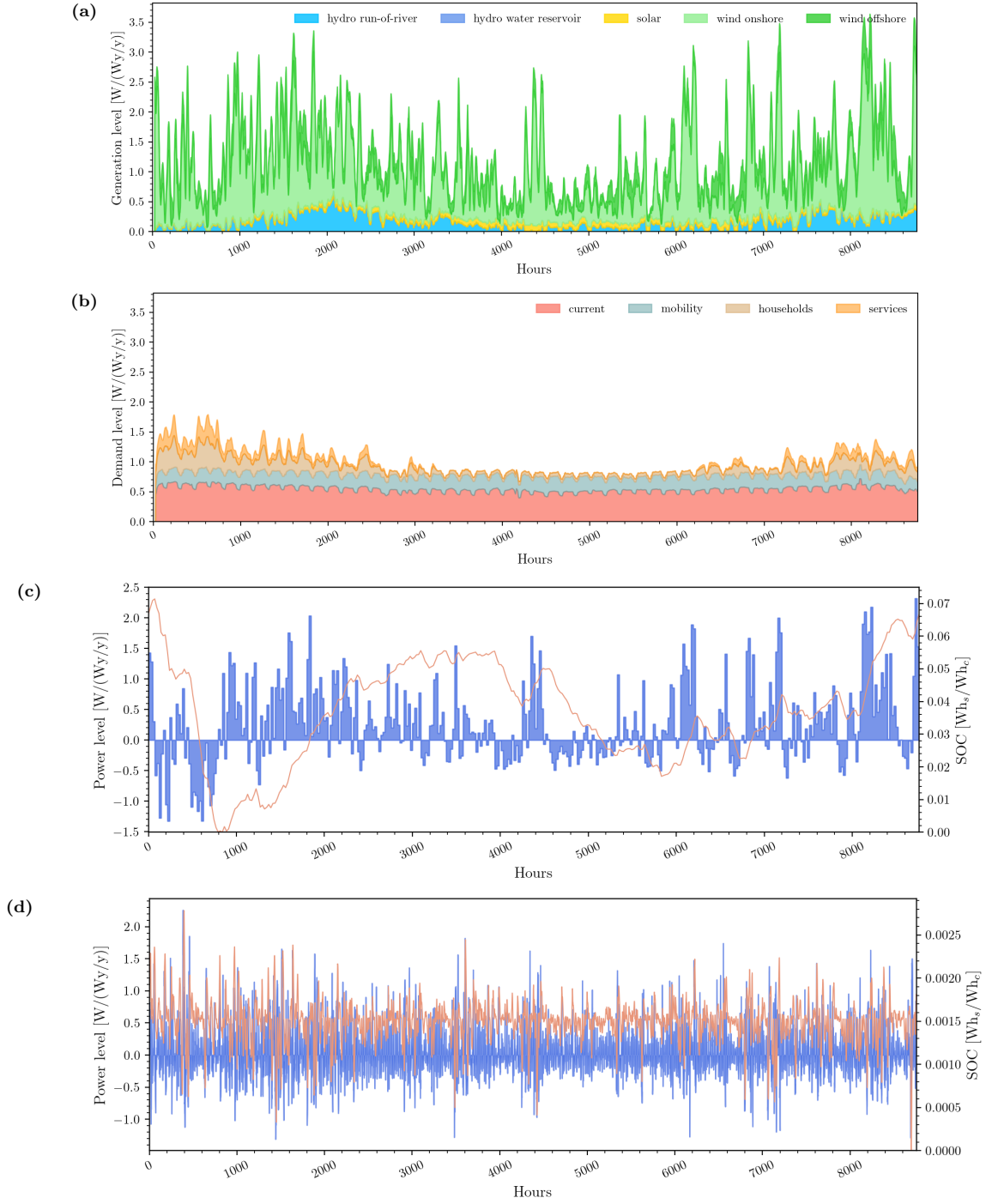


Figure H.14: Hourly electricity production (a) and demand (b) profiles for *Latvia*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

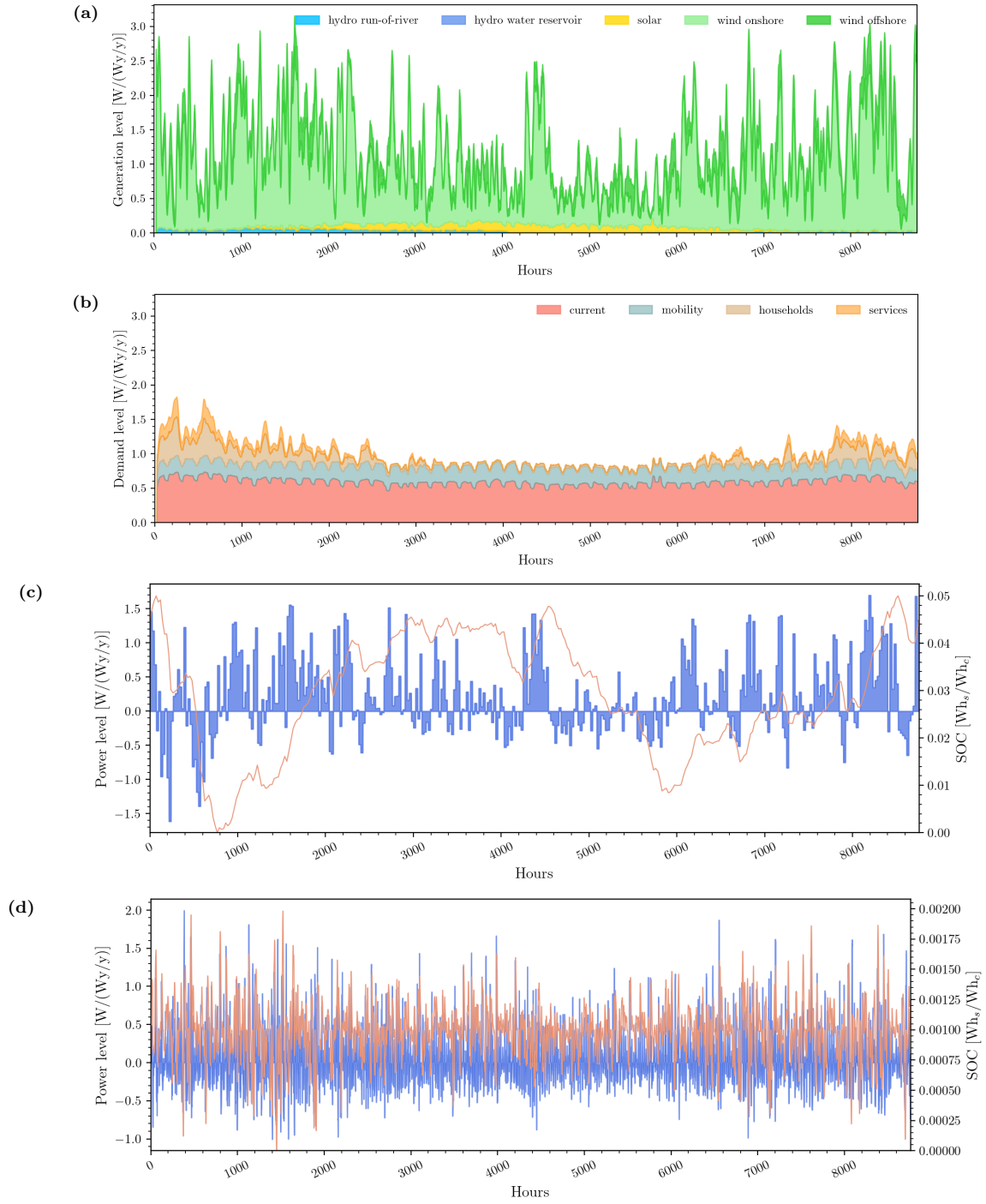


Figure H.15: Hourly electricity production (a) and demand (b) profiles for *Lithuania*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

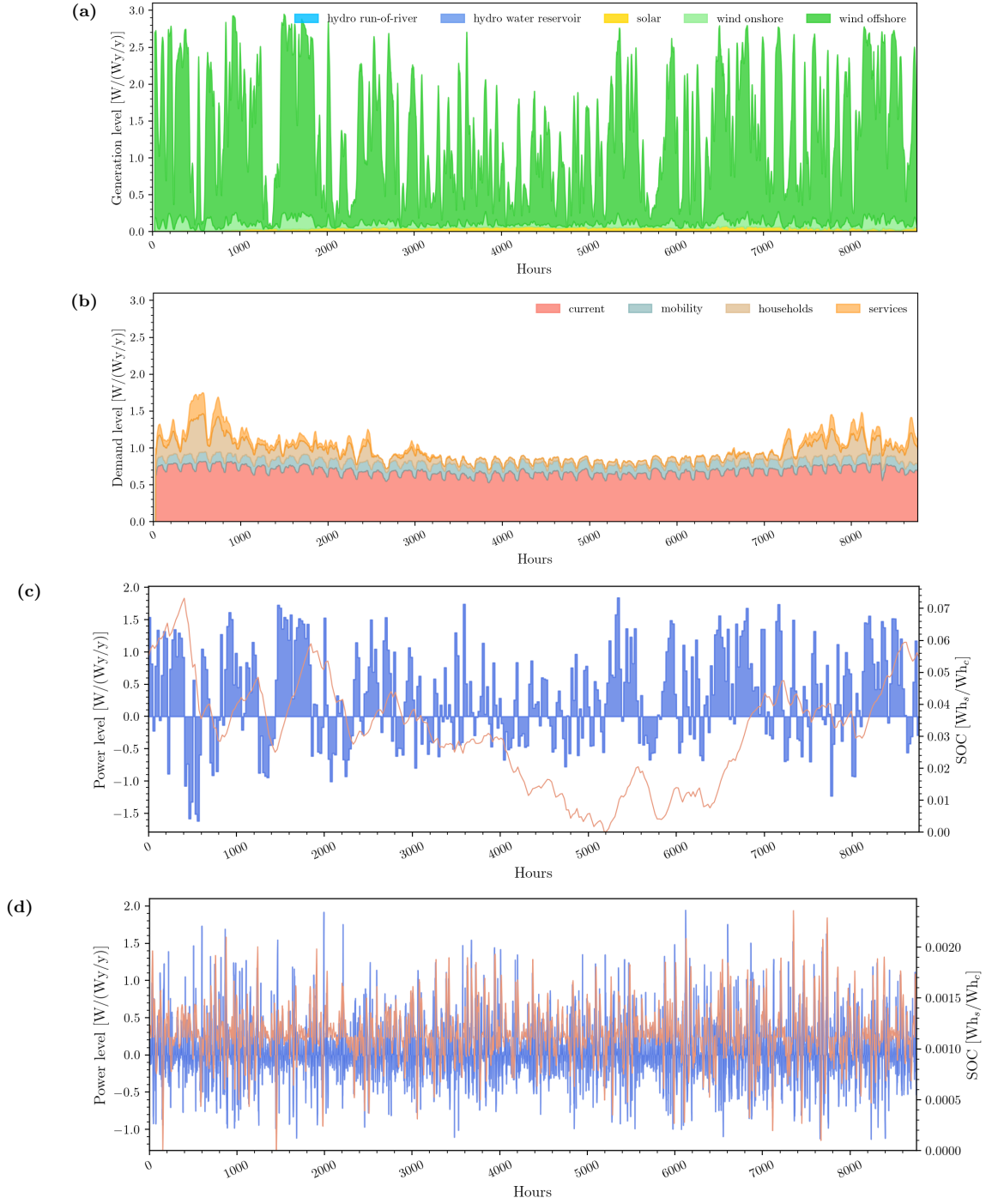


Figure H.16: Hourly electricity production (a) and demand (b) profiles for *Netherlands*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

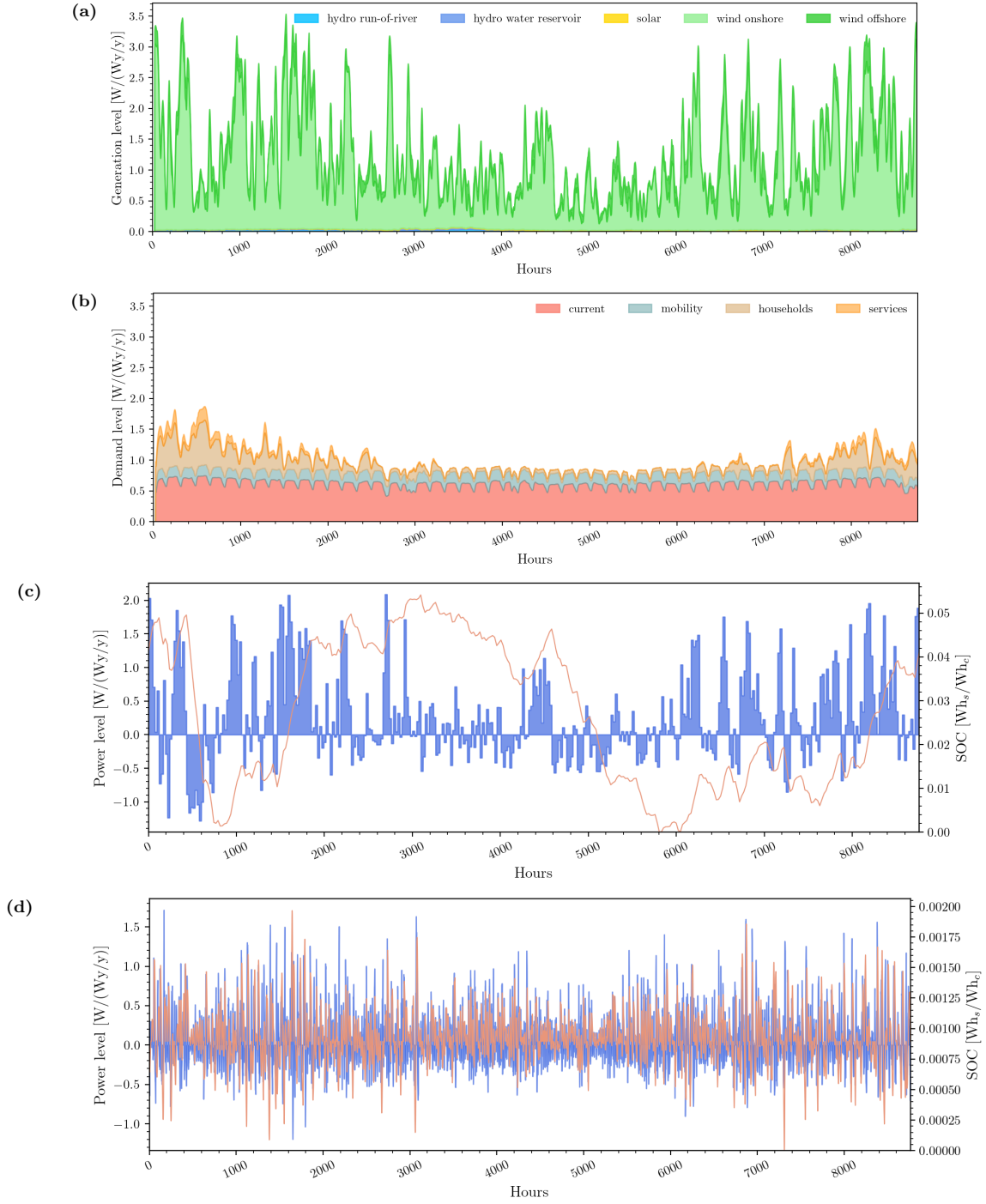


Figure H.17: Hourly electricity production (a) and demand (b) profiles for *Poland*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

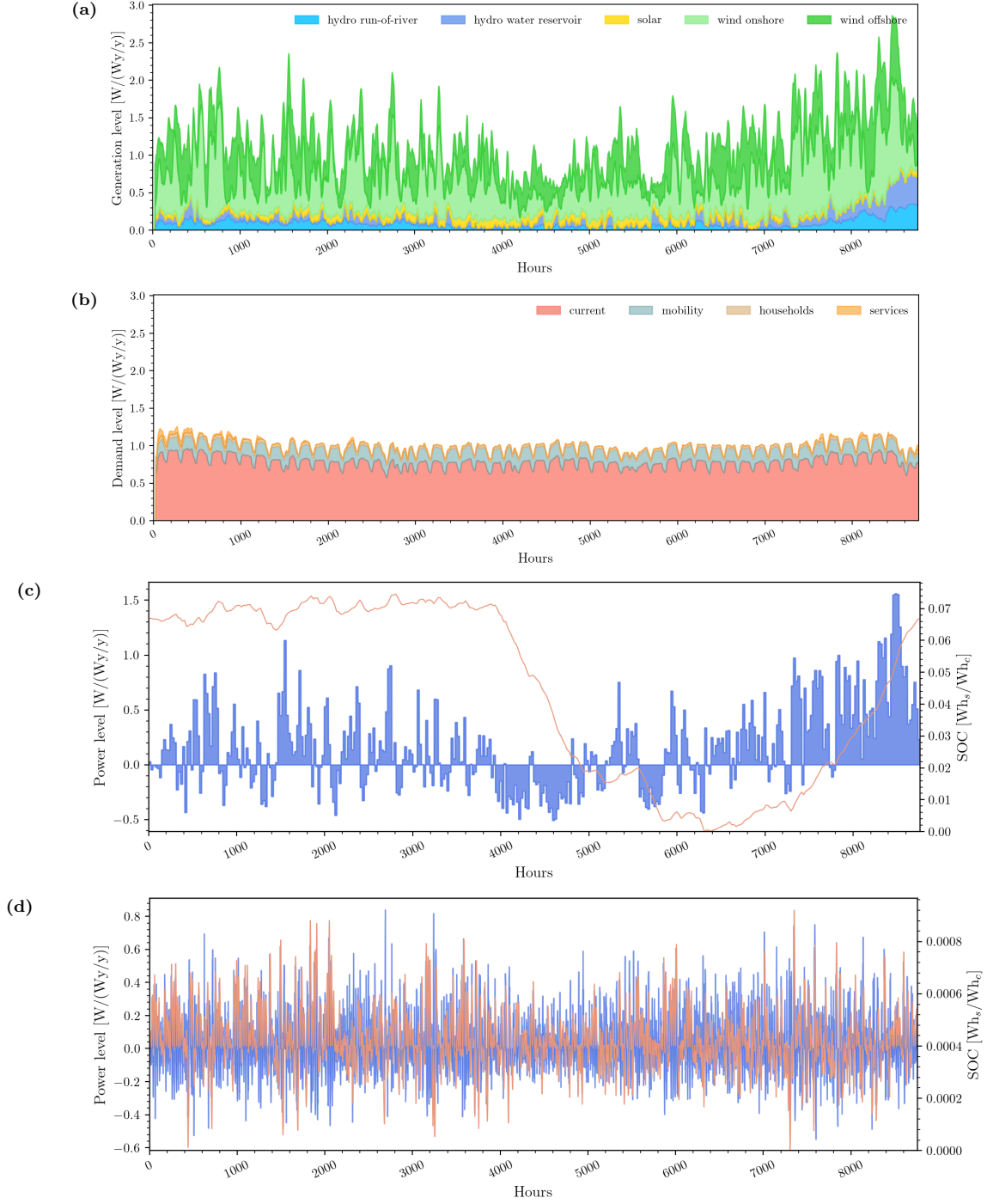


Figure H.18: Hourly electricity production (a) and demand (b) profiles for *Portugal*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

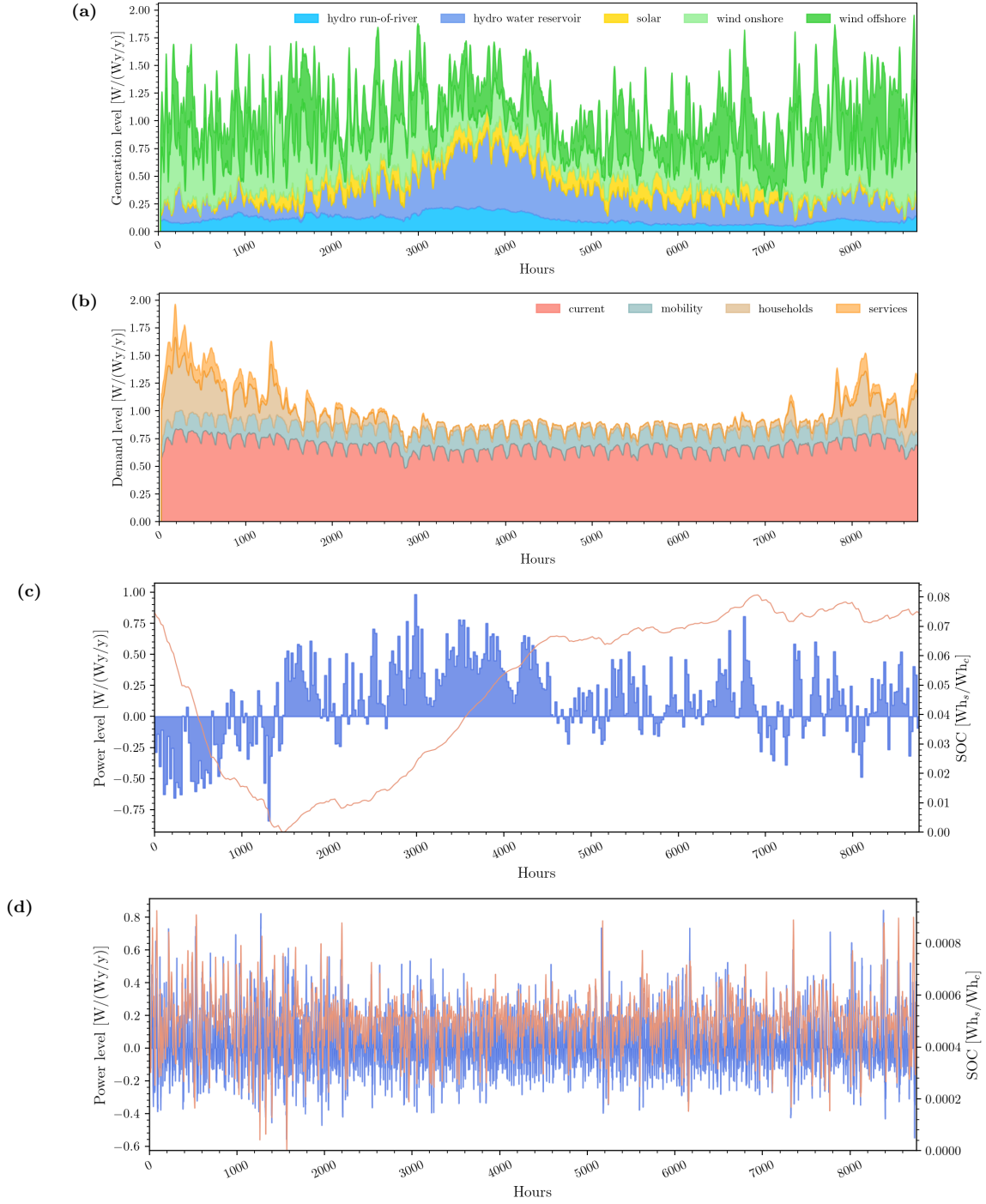


Figure H.19: Hourly electricity production (a) and demand (b) profiles for *Romania*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

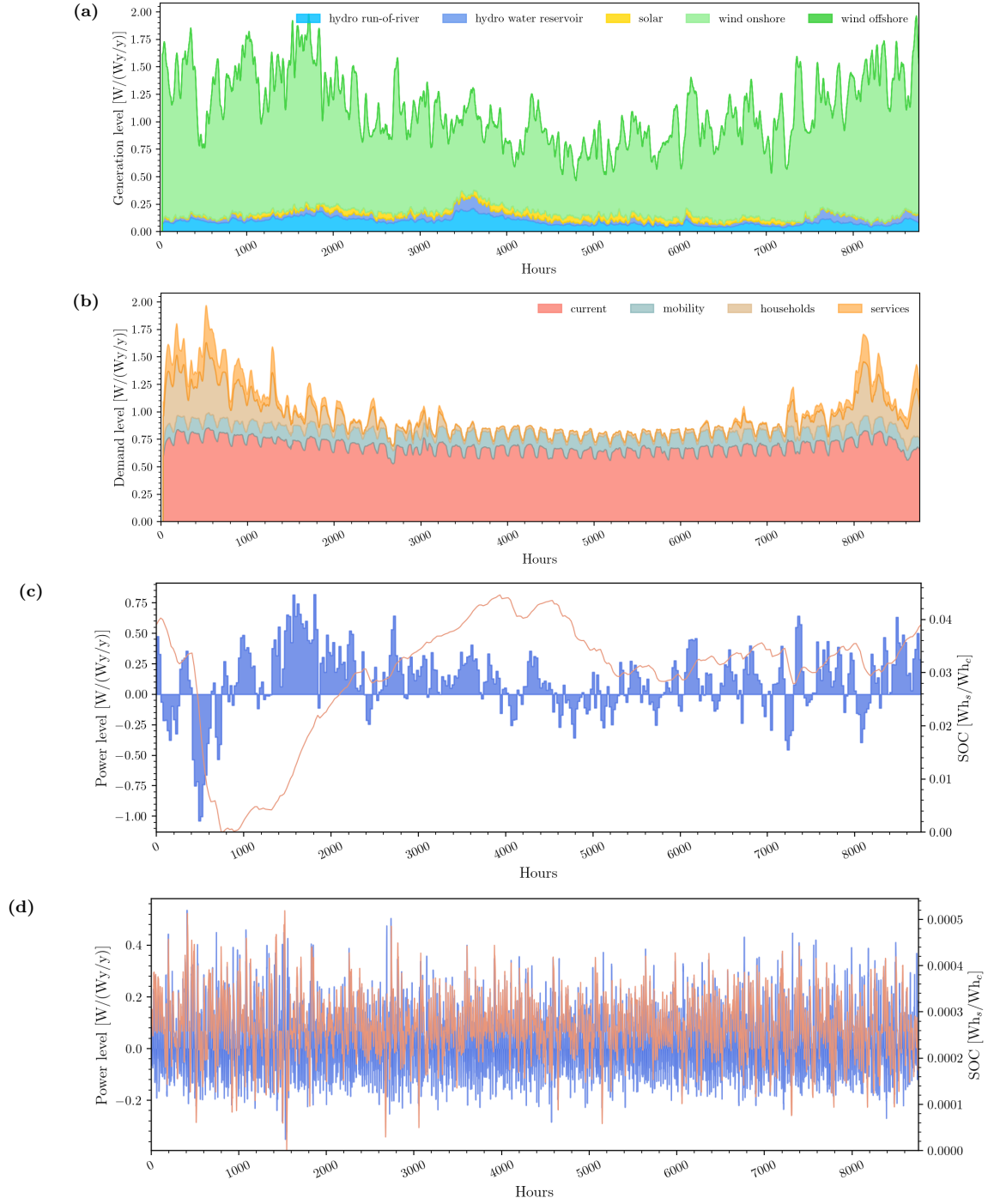


Figure H.20: Hourly electricity production (a) and demand (b) profiles for *Slovakia*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

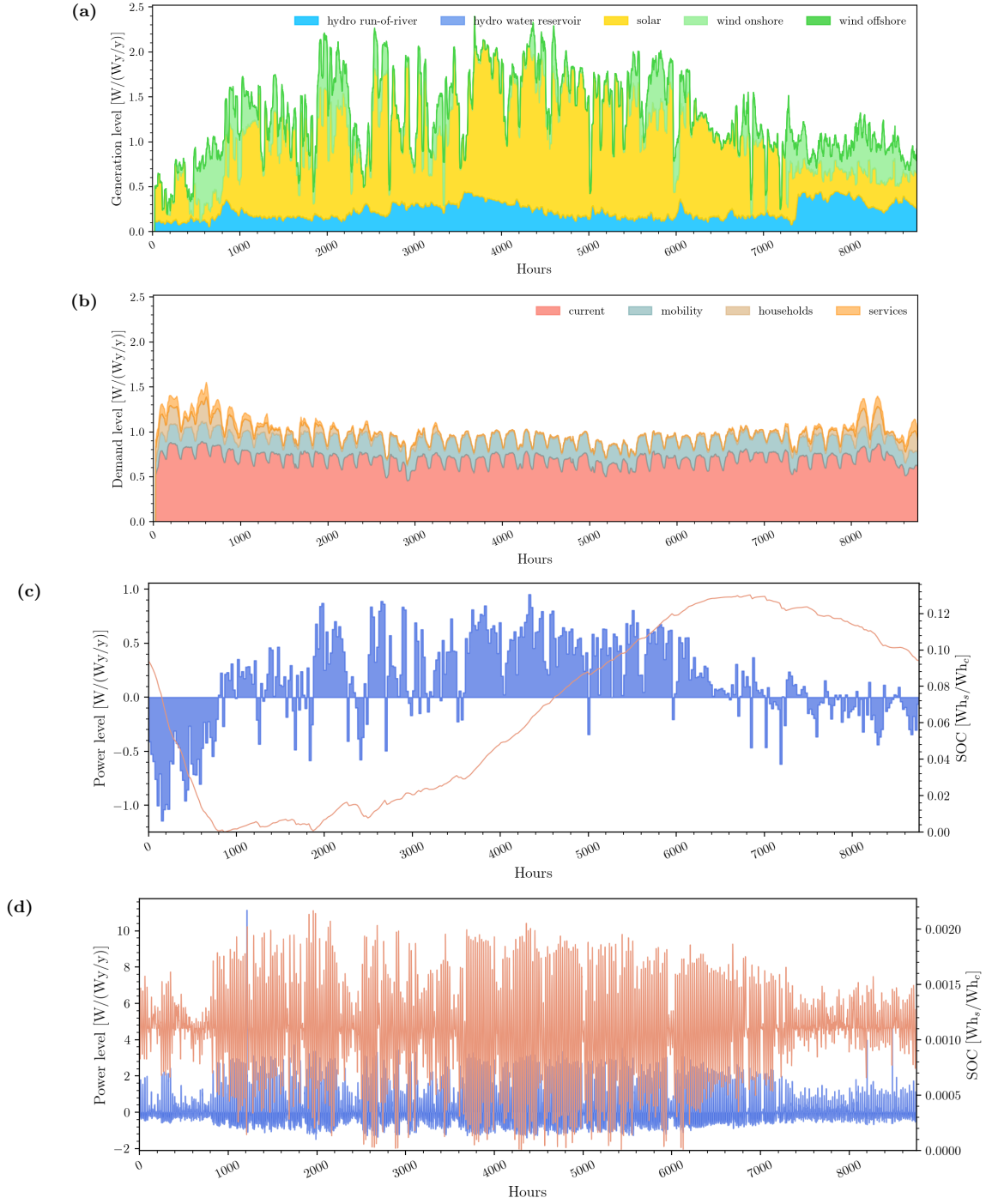


Figure H.21: Hourly electricity production (a) and demand (b) profiles for *Slovenia*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

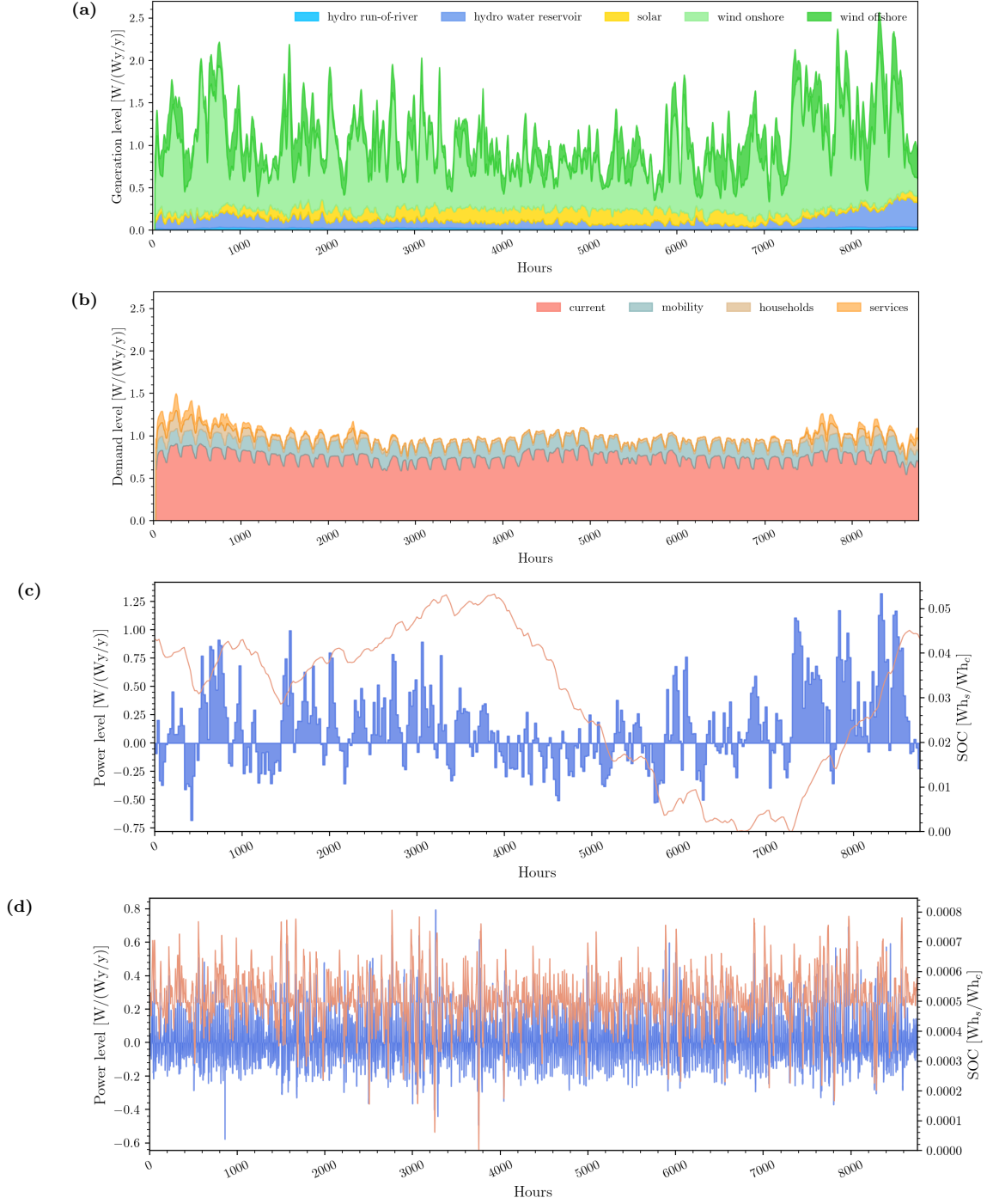


Figure H.22: Hourly electricity production (a) and demand (b) profiles for *Spain*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

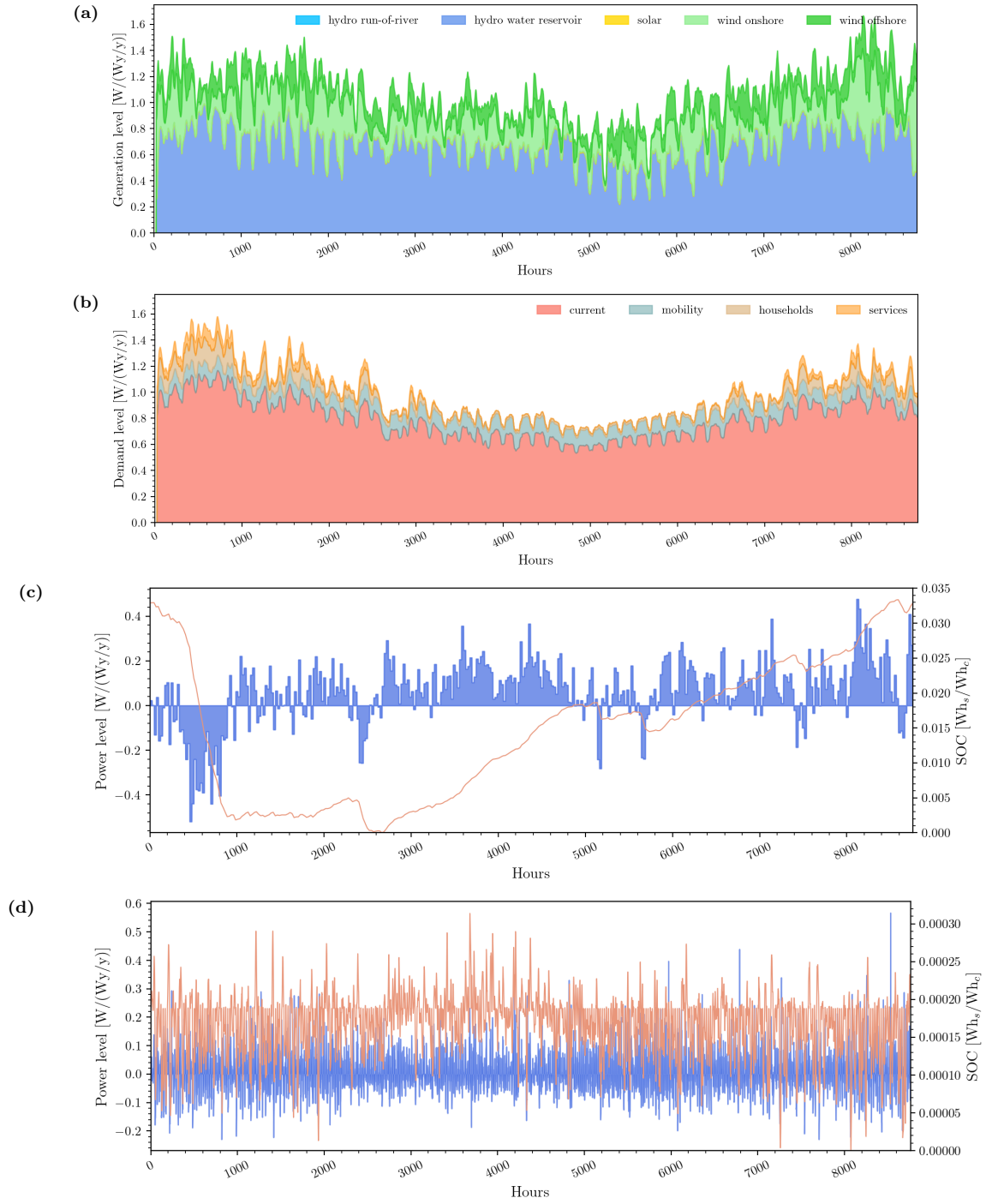


Figure H.23: Hourly electricity production (a) and demand (b) profiles for *Sweden*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

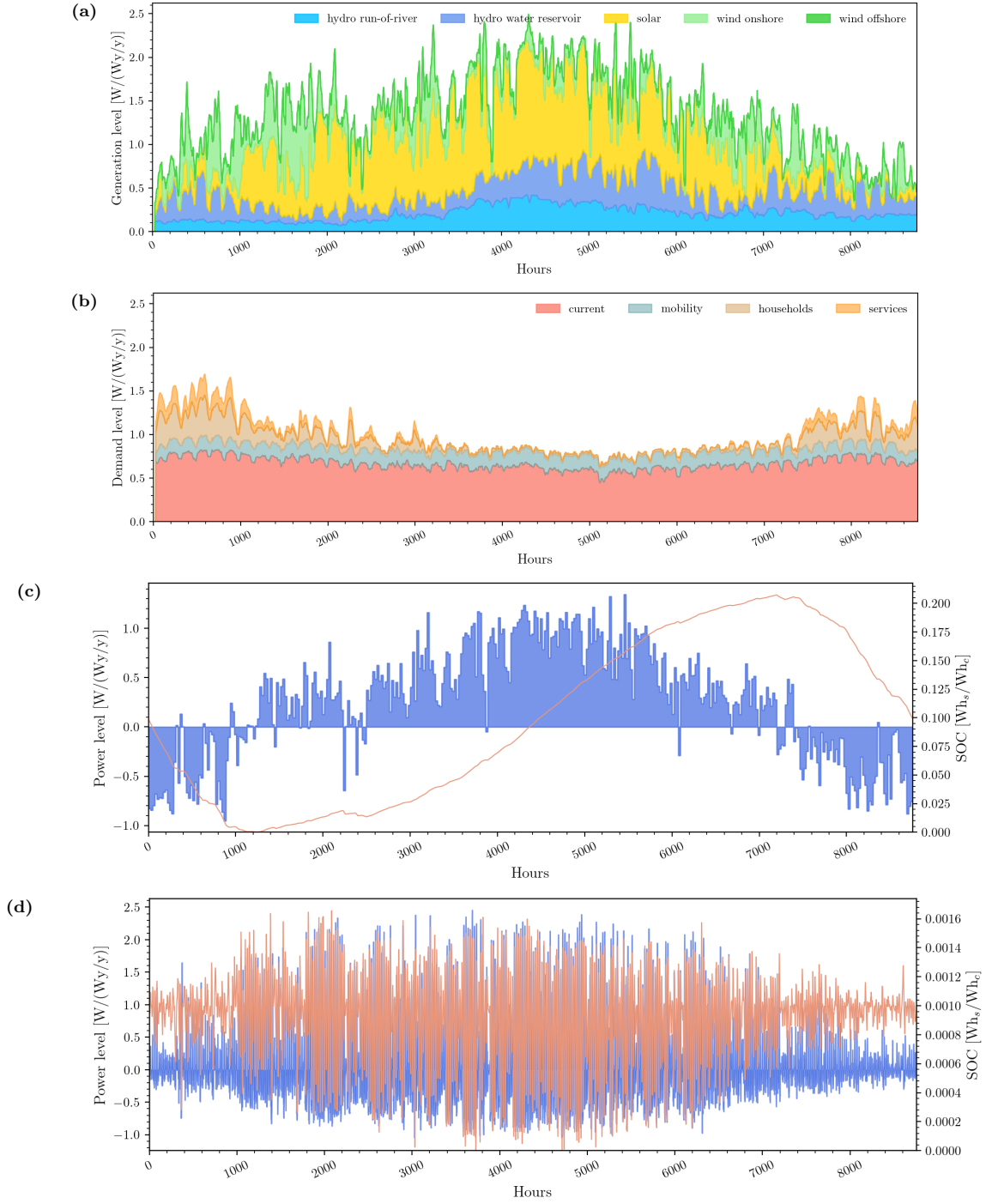


Figure H.24: Hourly electricity production (a) and demand (b) profiles for *Switzerland*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

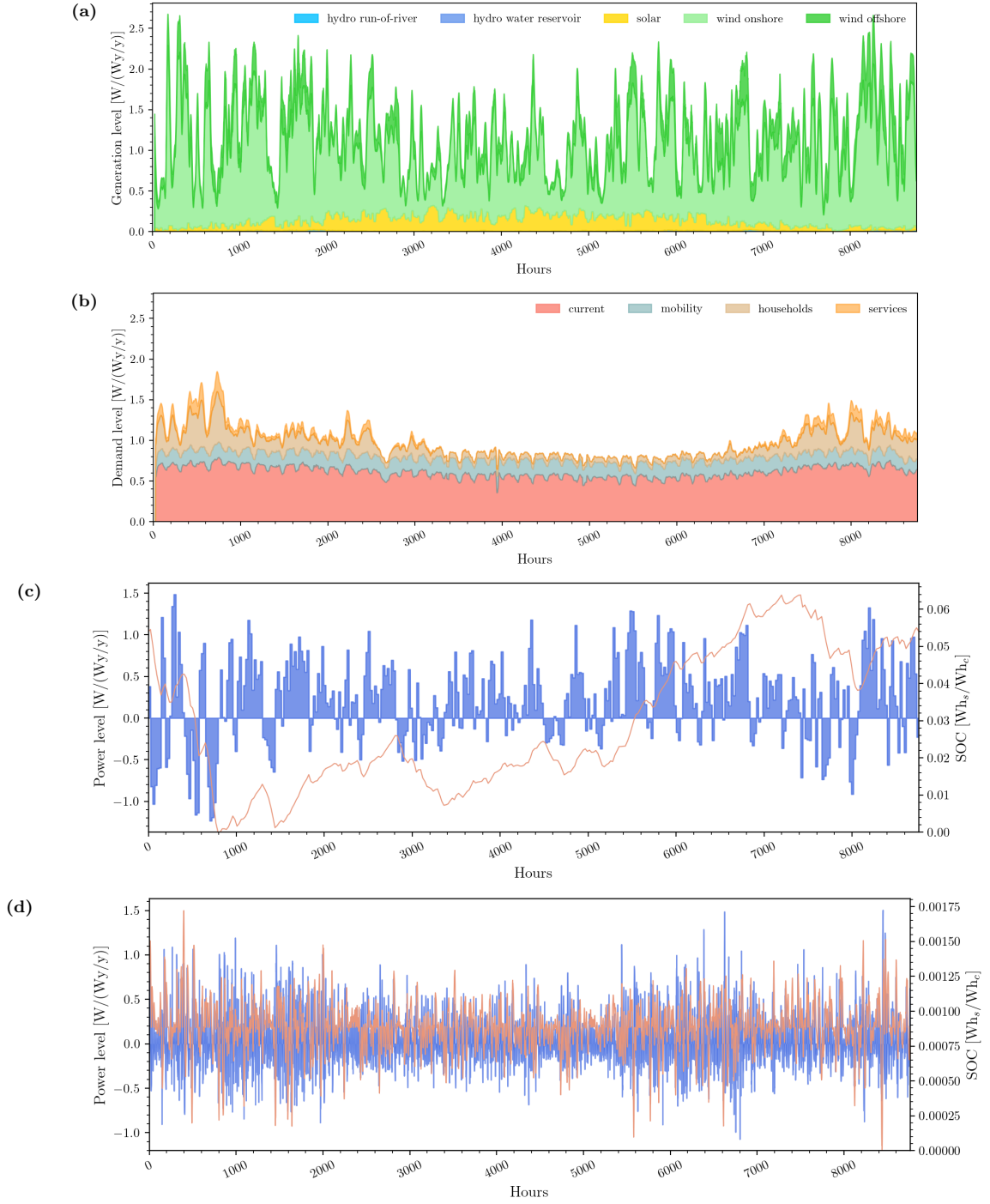


Figure H.25: Hourly electricity production (a) and demand (b) profiles for *United Kingdom*. Hourly power levels (in blue) and State of Charge (in red) of the long-term (c) and short-term (d) storage. Results obtained for the best observed solution.

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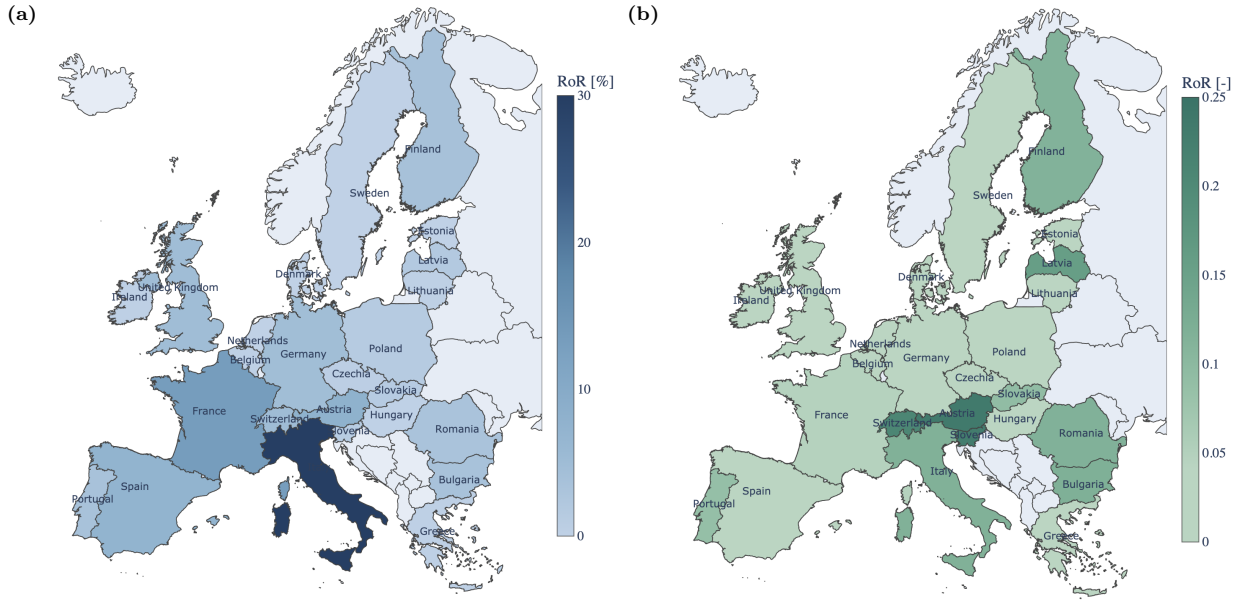


Figure I.1: Potential generation of *hydro run-of-river* in Europe. (a), percentage [%] of the total European potential (Table I.1). (b), potential generation in MWh of produced electricity per MWh of demand [-] (Table I.2).

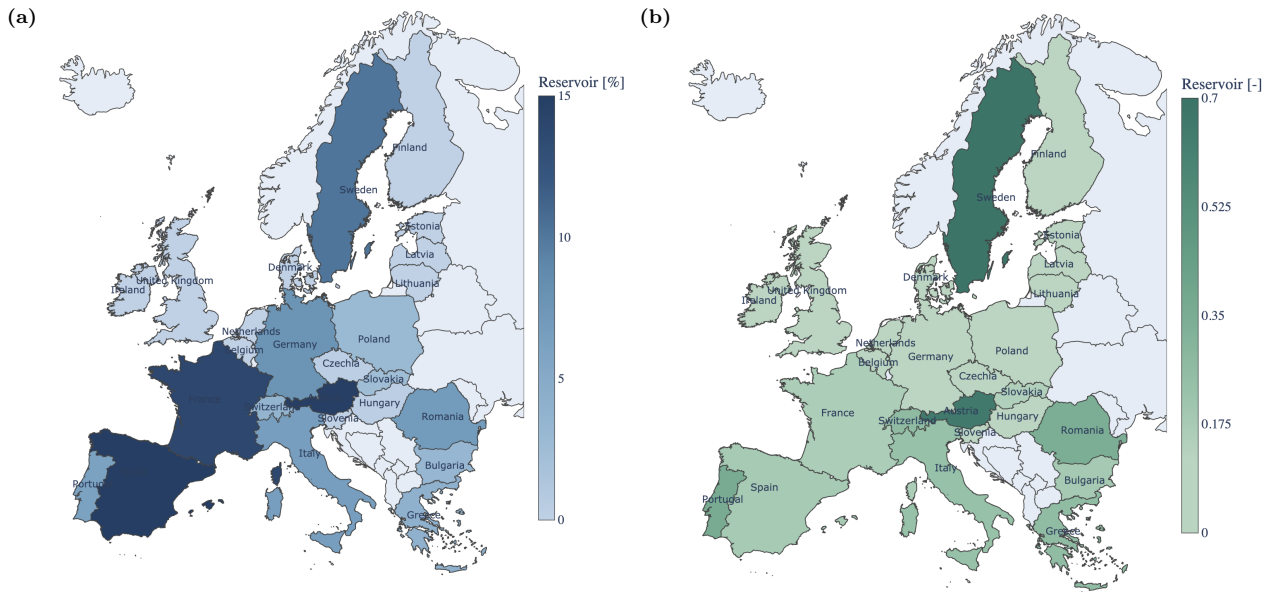


Figure I.2: Potential generation of *hydro reservoir* in Europe. (a), percentage [%] of the total European potential (Table I.1). (b), potential generation in MWh of produced electricity per MWh of demand [-] (Table I.2).

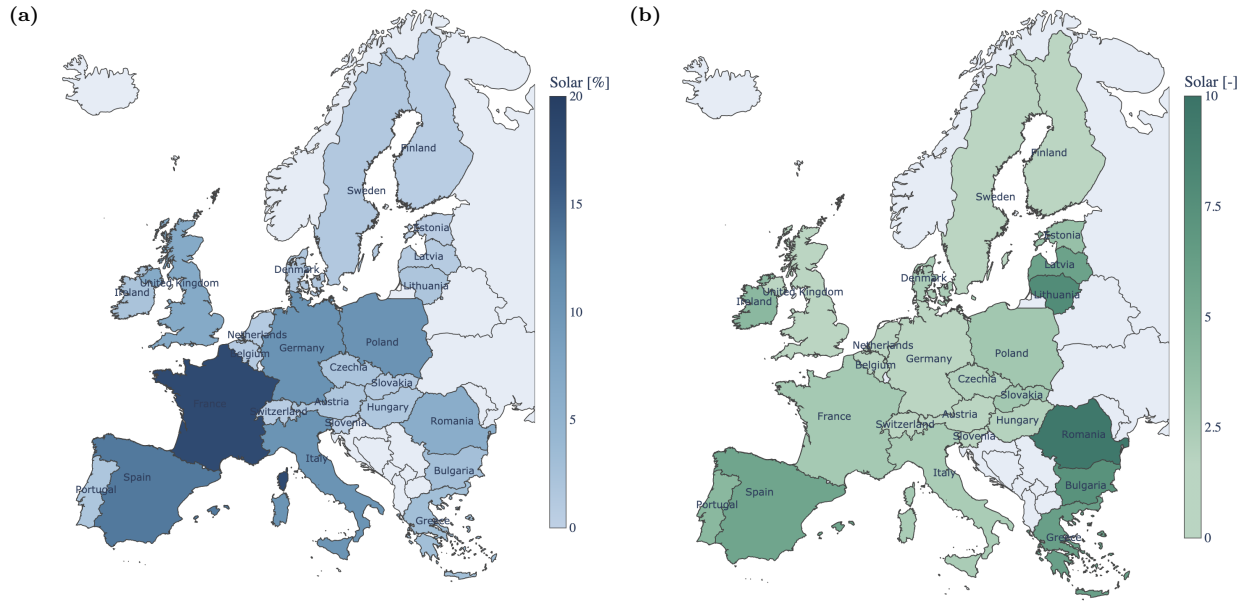


Figure I.3: Potential generation of solar PV in Europe. (a), percentage [%] of the total European potential (Table I.1). (b), potential generation in MWh of produced electricity per MWh of demand [-] (Table I.2).

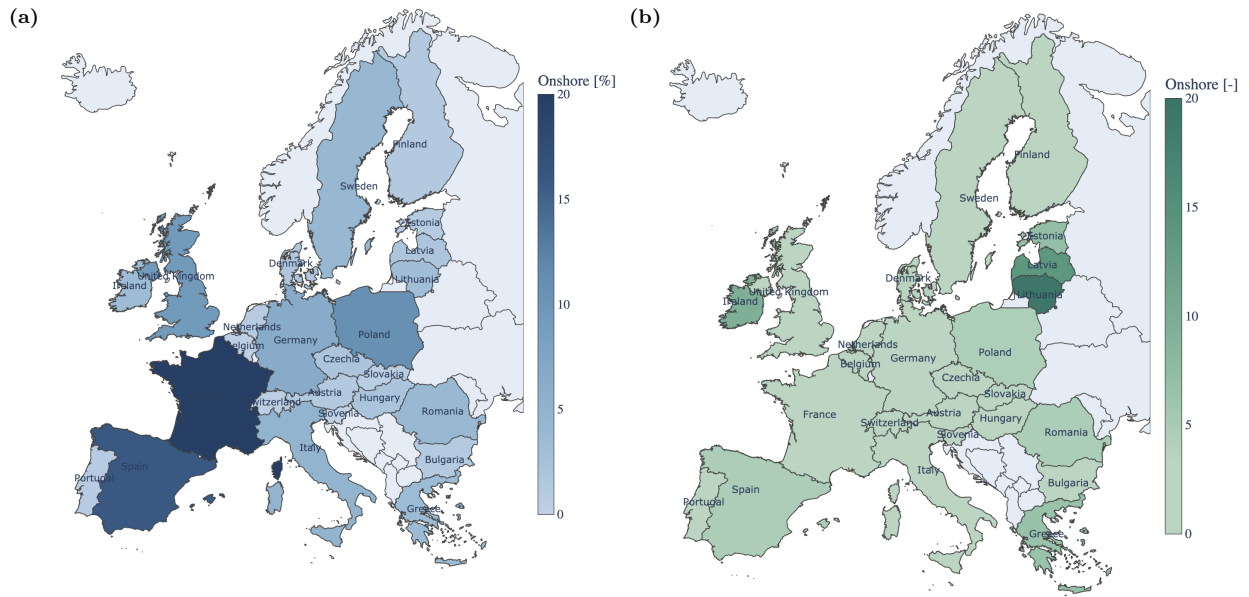


Figure I.4: Potential generation of *wind onshore* in Europe. (a), percentage [%] of the total European potential (Table I.1). (b), potential generation in MWh of produced electricity per MWh of demand [-] (Table I.2).

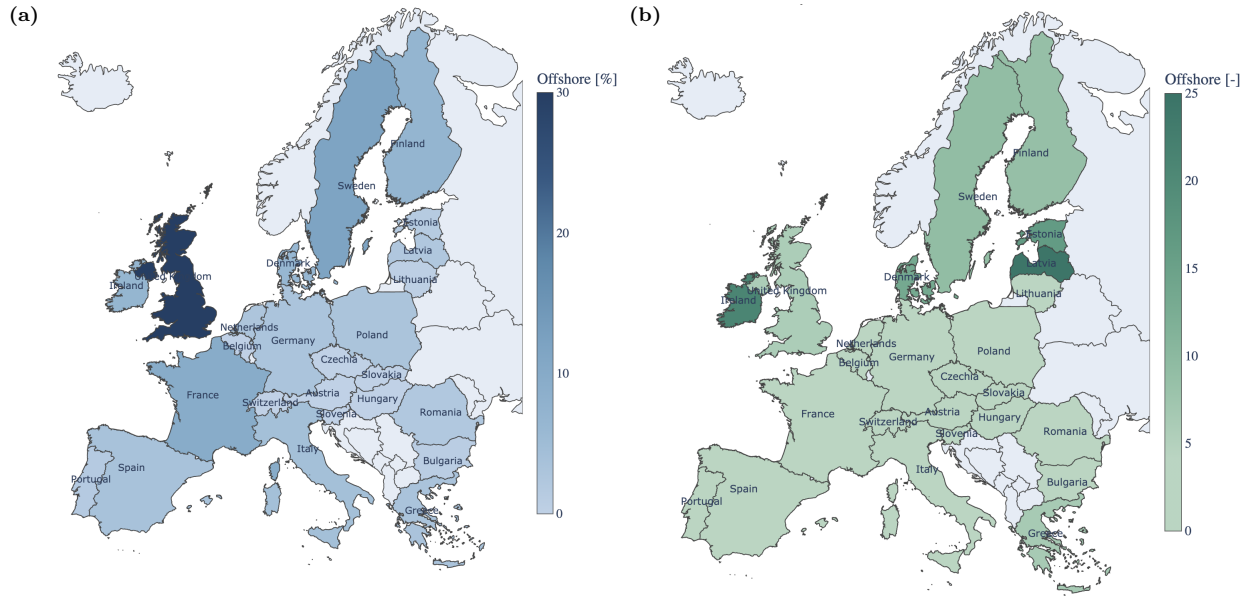


Figure I.5: Potential generation of *wind offshore* in Europe. (a), percentage [%] of the total European potential (Table I.1). (b), potential generation in MWh of produced electricity per MWh of demand [-] (Table I.2).

Country	Hydro [%]		Solar [%]	Wind [%]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	8.14	14.87	1.83	1.35	-
Belgium	0.22	-	1.09	0.28	0.15
Bulgaria	3.72	3.41	2.92	1.24	1.04
Czechia	0.70	0.42	2.11	2.09	-
Denmark	0.01	-	1.58	1.80	6.53
Estonia	0.01	-	0.59	1.00	1.60
Finland	3.88	-	0.73	1.26	7.12
France	13.49	13.91	18.10	20.53	9.82
Germany	4.86	7.80	10.56	6.70	3.14
Greece	0.37	4.08	3.04	3.74	3.38
Hungary	0.10	0.37	1.74	2.13	-
Ireland	0.27	-	2.36	3.57	6.97
Italy	32.64	6.65	10.43	4.91	4.33
Latvia	1.89	-	1.05	1.85	2.46
Lithuania	0.32	-	2.00	3.09	0.62
Netherlands	0.05	-	1.21	1.07	2.88
Poland	1.53	2.92	10.46	10.92	3.35
Portugal	3.81	6.27	1.91	0.94	1.69
Romania	3.40	7.02	6.21	3.98	2.37
Slovakia	1.49	2.47	1.20	0.74	-
Slovenia	1.33	-	0.22	0.07	-
Spain	7.56	15.82	13.30	15.90	3.80
Sweden	-	10.25	1.51	4.18	11.95
Switzerland	5.20	3.74	0.86	0.35	-
United Kingdom	5.01	-	6.88	9.48	30.85
Europe	100.00	100.00	100.00	100.00	100.00

Table I.1: Distribution of generation potentials from renewable sources in Europe. Values given as percentage of the total potential.

Country	Hydro [-]		Solar [-]	Wind [-]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	0.235	0.660	1.469	1.546	-
Belgium	0.002	-	0.758	0.188	0.156
Bulgaria	0.118	0.191	7.326	2.241	2.876
Czechia	0.015	0.018	2.055	2.084	-
Denmark	0.000	-	2.443	3.575	13.435
Estonia	0.001	-	3.428	7.169	16.375
Finland	0.114	-	0.510	1.548	8.740
France	0.048	0.166	2.710	3.283	1.998
Germany	0.018	0.029	1.099	0.732	0.463
Greece	0.011	0.263	6.211	6.643	6.541
Hungary	0.004	0.062	1.946	3.033	-
Ireland	0.020	-	4.068	9.509	21.136
Italy	0.117	0.237	2.485	0.971	1.268
Latvia	0.159	-	5.985	13.889	24.646
Lithuania	0.036	-	7.866	19.394	4.028
Netherlands	0.001	-	0.572	0.597	2.670
Poland	0.019	0.032	2.880	4.592	1.622
Portugal	0.088	0.363	4.116	1.759	3.476
Romania	0.116	0.346	9.573	4.703	3.575
Slovakia	0.093	0.150	2.824	1.810	-
Slovenia	0.231	-	0.997	0.208	-
Spain	0.024	0.183	5.706	4.655	1.506
Sweden	-	0.695	0.665	2.843	9.243
Switzerland	0.209	0.266	0.774	0.352	-
United Kingdom	0.016	-	1.195	2.340	5.943
Europe	0.046	0.154	2.089	2.103	2.235

Table I.2: Potential generation of renewable technologies in MWh of produced electricity per MWh of demand by country [-].

Country	Hydro [MWh/capita]		Solar [MWh/capita]	Wind [MWh/capita]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	2.50	7.03	15.64	16.47	-
Belgium	0.02	-	8.33	2.07	1.72
Bulgaria	0.80	1.30	49.65	15.19	19.49
Czechia	0.14	0.17	19.51	19.79	-
Denmark	0.00	-	23.18	33.92	127.46
Estonia	0.01	-	33.65	70.37	160.74
Finland	2.23	-	9.98	30.27	170.92
France	0.46	1.61	26.35	31.91	19.42
Germany	0.18	0.29	10.82	7.21	4.56
Greece	0.07	1.68	39.57	42.32	41.67
Hungary	0.03	0.44	13.91	21.68	-
Ireland	0.18	-	36.76	85.94	191.03
Italy	0.87	1.77	18.57	7.26	9.48
Latvia	1.08	-	40.92	94.95	168.50
Lithuania	0.26	-	57.32	141.31	29.35
Netherlands	0.01	-	5.51	5.75	25.72
Poland	0.13	0.23	20.73	33.06	11.68
Portugal	0.55	2.27	25.75	11.01	21.75
Romania	0.52	1.56	43.06	21.15	16.08
Slovakia	0.72	1.16	21.86	14.01	-
Slovenia	2.10	-	9.06	1.89	-
Spain	0.17	1.31	40.81	33.29	10.77
Sweden	-	11.76	11.25	48.08	156.35
Switzerland	2.12	2.71	7.88	3.59	-
United Kingdom	0.12	-	8.75	17.14	43.53
Europe	0.40	1.32	17.88	18.00	19.13

Table I.3: Annual potential generation per inhabitant [MWh/capita] by country and technology.

Country	No storage		Storage	
	Current [-]	Potential [-]	Current [-]	Potential [-]
Austria	0.368	3.911	0.302	3.209
Belgium	0.103	1.104	0.069	0.740
Bulgaria	0.113	12.753	0.097	10.944
Czechia	0.049	4.171	0.036	3.087
Denmark	0.312	19.454	0.234	14.583
Estonia	0.057	26.973	0.045	21.482
Finland	0.173	10.912	0.145	9.144
France	0.151	8.204	0.125	6.811
Germany	0.229	2.342	0.181	1.844
Greece	0.217	19.657	0.185	16.771
Hungary	0.025	5.044	0.017	3.496
Ireland	0.238	34.733	0.179	26.156
Italy	0.198	5.079	0.173	4.439
Latvia	0.170	44.678	0.131	34.361
Lithuania	0.093	31.324	0.072	24.502
Netherlands	0.095	3.838	0.069	2.773
Poland	0.063	9.144	0.048	6.959
Portugal	0.342	9.803	0.290	8.297
Romania	0.272	18.314	0.236	15.838
Slovakia	0.116	4.877	0.103	4.332
Slovenia	0.246	1.437	0.192	1.122
Spain	0.281	12.073	0.241	10.355
Sweden	0.500	13.448	0.467	12.550
Switzerland	0.429	1.599	0.318	1.187
United Kingdom	0.170	9.491	0.135	7.530
Europe	0.186	6.627	0.164	5.844

Table I.4: Current and potential generation as fraction [-] of the electricity demand per country and all Europe. The results are shown for the solutions without storage, hence the demand equals the annual electricity consumption, and with storage, which accounts for the charge and discharge losses of the battery and power-to-gas. The countries with a potential capacity that is lower than the sum of the electricity demand and losses are highlighted in red.

Country	Hydro [-]		Solar [-]	Wind [-]	
	Run-of-river	Reservoir	Photovoltaic	Onshore	Offshore
Austria	1.000	0.911	0.010	0.238	-
Belgium	1.000	-	1.501	1.000	1.000
Bulgaria	0.961	0.198	0.028	0.112	0.193
Czechia	0.917	0.719	0.031	0.605	-
Denmark	1.000	-	0.037	0.208	0.037
Estonia	1.000	-	0.001	0.114	0.027
Finland	1.000	-	0.002	0.313	0.068
France	1.000	0.859	0.032	0.080	0.333
Germany	1.000	0.836	0.139	0.847	0.983
Greece	1.000	0.830	0.023	0.092	0.031
Hungary	1.000	0.816	0.075	0.409	-
Ireland	1.000	-	0.003	0.112	0.011
Italy	1.000	0.563	0.059	0.340	0.327
Latvia	1.000	-	0.012	0.057	0.011
Lithuania	0.975	-	0.007	0.047	0.067
Netherlands	1.000	-	0.080	0.117	0.475
Poland	1.000	0.258	0.003	0.233	0.129
Portugal	0.978	0.246	0.017	0.299	0.117
Romania	1.000	0.712	0.011	0.073	0.097
Slovakia	1.000	0.268	0.011	0.531	-
Slovenia	1.000	-	0.837	1.000	-
Spain	1.000	0.577	0.019	0.147	0.162
Sweden	-	0.982	0.007	0.084	0.016
Switzerland	1.000	1.000	0.779	0.769	-
United Kingdom	0.757	-	0.106	0.377	0.041
Europe	0.917	1.000	0.036	0.276	0.111

Table I.5: Shares [-] of the potential generation capacities that are installed for the best-observed solutions. The countries which need a generation capacity that is larger than the available potential are highlighted in red.

J The relevance of storage

Country	Generation share [-]			GWP100a [gCO ₂ eq/kWh]		
	Storage	No Storage	Factor [-]	Storage	No Storage	Increase [%]
Austria	0.312	1.171	-	27.92	-	-
Belgium	1.351	47.834	-	152.16	-	-
Bulgaria	0.091	0.267	2.92	40.94	91.23	+123%
Czechia	0.324	3.132	-	55.66	-	-
Denmark	0.069	0.566	8.26	49.12	209.35	+326%
Estonia	0.047	0.201	4.32	40.24	95.71	+138%
Finland	0.109	0.348	3.19	34.49	69.44	+101%
France	0.147	0.351	2.39	37.19	54.33	+46%
Germany	0.542	5.916	-	54.86	-	-
Greece	0.060	0.142	2.37	40.32	64.69	+60%
Hungary	0.286	5.528	-	61.02	-	-
Ireland	0.038	0.186	4.88	41.88	89.91	+115%
Italy	0.225	0.471	2.09	34.91	51.46	+47%
Latvia	0.029	0.199	6.84	45.50	181.76	+300%
Lithuania	0.041	0.288	7.05	40.72	152.54	+275%
Netherlands	0.361	11.034	-	52.74	-	-
Poland	0.144	0.617	4.29	43.33	89.81	+107%
Portugal	0.121	0.269	2.23	35.48	51.78	+46%
Romania	0.063	0.133	2.11	40.57	65.02	+60%
Slovakia	0.231	0.465	2.02	27.63	37.22	+35%
Slovenia	0.891	21.910	-	84.81	-	-
Spain	0.097	0.226	2.34	37.48	60.09	+60%
Sweden	0.080	0.125	1.57	45.98	50.81	+10%
Switzerland	0.843	13.480	-	82.01	-	-
United Kingdom	0.133	0.524	3.94	44.55	103.02	+131%
Europe	0.171	0.351	2.05	35.94	54.33	+51%

Table J.1: Comparison between solutions with and without storage. The results are shown in terms of electricity generation as share [-] of the potential. Solutions with a ratio that is greater than 1 (highlighted in red) are technically unattainable – there is not enough renewable potential to invest in generation over-capacity without installing any storage. The generation over-sizing factor [-] is included per country. The solutions are also compared in terms of Global Warming Potential (GWP100a).

K Simulation results

Country	No. simulations	Best seed	LCOE [EUR/MWh]	GWP100a [gCO ₂ eq/kWh]
Austria	2995	2791	153.20	27.92
Belgium	2995	2914	281.87	152.16
Bulgaria	999	650	151.60	40.94
Czechia	999	546	192.91	55.66
Denmark	1014	177	203.96	49.12
Estonia	999	650	178.92	40.24
Finland	1997	1890	137.98	34.49
France	2677	1994	150.30	37.19
Germany	2868	329	182.84	54.86
Greece	999	329	140.24	40.32
Hungary	1636	25	243.58	61.02
Ireland	999	759	172.76	41.88
Italy	3154	1033	131.00	34.91
Latvia	999	394	225.03	45.50
Lithuania	999	650	162.83	40.72
Netherlands	3009	2791	208.67	52.74
Poland	2777	329	170.02	43.33
Portugal	999	329	137.42	35.48
Romania	2995	2791	134.47	40.57
Slovakia	1880	546	113.80	27.63
Slovenia	1999	1439	250.13	84.81
Spain	3020	329	139.31	37.48
Sweden	2664	75	73.89	45.98
Switzerland	1958	1157	198.59	82.01
United Kingdom	3262	2351	181.55	44.55
Europe *	-	-	164.99	47.54
Europe **	5048	4731	135.38	35.94

* Independent countries with isolated grids.

** Interconnected grids.

Table K.1: Results of the best observed simulations. The Levelized Cost of Electricity (LCOE) [EUR/MWh] and the Global Warming Potential (GWP100a) [gCO₂eq/kWh] are given for the best observed seed, that is located at the knee of the Pareto front.

Country	Generation [-]					Storage [-]	
	H. RoR	H. Reservoir	PV	W. Onshore	W. Offshore	Battery	PtoG
Austria	0.088	0.402	0.013	0.182	-	0.201	0.115
Belgium	0.001	-	0.455	0.067	0.057	0.315	0.105
Bulgaria	0.076	0.040	0.112	0.154	0.373	0.164	0.082
Czechia	0.005	0.007	0.033	0.528	-	0.281	0.146
Denmark	0.000	-	0.051	0.274	0.294	0.250	0.130
Estonia	0.001	-	0.002	0.396	0.249	0.240	0.113
Finland	0.040	-	0.001	0.221	0.439	0.185	0.113
France	0.021	0.053	0.058	0.136	0.452	0.166	0.113
Germany	0.005	0.019	0.096	0.306	0.280	0.174	0.120
Greece	0.000	0.151	0.070	0.295	0.148	0.235	0.100
Hungary	0.001	0.008	0.076	0.416	-	0.359	0.141
Ireland	0.005	-	0.009	0.437	0.134	0.259	0.155
Italy	0.086	0.029	0.102	0.227	0.323	0.145	0.088
Latvia	0.098	-	0.041	0.289	0.125	0.343	0.105
Lithuania	0.014	-	0.040	0.365	0.170	0.279	0.132
Netherlands	0.000	-	0.027	0.029	0.535	0.259	0.150
Poland	0.005	0.007	0.006	0.450	0.125	0.258	0.148
Portugal	0.065	0.074	0.037	0.261	0.303	0.153	0.107
Romania	0.045	0.181	0.055	0.200	0.264	0.162	0.093
Slovakia	0.048	0.058	0.028	0.666	-	0.110	0.090
Slovenia	0.044	-	0.377	0.112	-	0.279	0.189
Spain	0.025	0.084	0.054	0.406	0.178	0.154	0.099
Sweden	-	0.353	0.008	0.228	0.201	0.131	0.078
Switzerland	0.047	0.094	0.382	0.127	-	0.228	0.122
United Kingdom	0.007	-	0.081	0.334	0.191	0.272	0.115
Europe *	0.023	0.053	0.081	0.270	0.257	0.200	0.114
Europe **	0.024	0.076	0.060	0.383	0.261	0.118	0.078

* Independent countries with isolated grids.

** Interconnected grids.

Table K.2: Contributions [-] of generation and storage technologies to the Levelized Cost of Electricity (LCOE) [EUR/MWh] of the whole energy system. Results of the best-observed solutions.

Country	Generation [-]					Storage [-]		Total [-]
	H. RoR	H. Reservoir	PV	W. Onshore	W. Offshore	Battery	PtoG	
Austria	0.080	0.394	0.008	0.137	-	0.112	0.149	0.879
Belgium	0.001	-	0.298	0.052	0.043	0.102	0.289	0.784
Bulgaria	0.069	0.039	0.073	0.118	0.283	0.080	0.155	0.818
Czechia	0.005	0.006	0.021	0.402	-	0.143	0.266	0.842
Denmark	0.000	-	0.033	0.207	0.223	0.127	0.236	0.827
Estonia	0.001	-	0.001	0.303	0.189	0.110	0.225	0.828
Finland	0.037	-	0.001	0.164	0.333	0.110	0.171	0.815
France	0.019	0.051	0.038	0.103	0.343	0.110	0.158	0.823
Germany	0.005	0.018	0.063	0.235	0.212	0.117	0.163	0.813
Greece	0.000	0.147	0.046	0.221	0.113	0.097	0.172	0.796
Hungary	0.001	0.007	0.050	0.316	-	0.137	0.335	0.846
Ireland	0.005	-	0.006	0.328	0.102	0.151	0.245	0.836
Italy	0.078	0.026	0.067	0.175	0.245	0.086	0.121	0.798
Latvia	0.090	-	0.027	0.220	0.095	0.102	0.258	0.791
Lithuania	0.013	-	0.026	0.271	0.129	0.128	0.261	0.828
Netherlands	0.000	-	0.018	0.022	0.406	0.146	0.245	0.837
Poland	0.005	0.007	0.004	0.338	0.095	0.144	0.244	0.836
Portugal	0.059	0.073	0.024	0.195	0.230	0.105	0.143	0.829
Romania	0.040	0.177	0.036	0.152	0.200	0.091	0.153	0.849
Slovakia	0.044	0.058	0.018	0.505	-	0.088	0.103	0.815
Slovenia	0.040	-	0.246	0.088	-	0.184	0.213	0.771
Spain	0.023	0.082	0.035	0.309	0.135	0.096	0.146	0.827
Sweden	-	0.332	0.005	0.171	0.153	0.076	0.094	0.832
Switzerland	0.043	0.091	0.250	0.098	-	0.119	0.209	0.810
United Kingdom	0.006	-	0.053	0.250	0.145	0.112	0.200	0.767
Europe *	0.021	0.051	0.053	0.205	0.195	0.111	0.177	0.815
Europe **	0.022	0.073	0.039	0.294	0.198	0.076	0.110	0.811

* Independent countries with isolated grids.

** Interconnected grids.

Table K.3: Contribution of capital costs [-] to the system Levelized Cost Of Electricity (LCOE). Results of the best-observed solutions.

Country	Storage option	
	Battery [-]	Power-to-gas [-]
Austria	0.032	0.187
Belgium	0.177	0.314
Bulgaria	0.034	0.131
Czechia	0.052	0.299
Denmark	0.052	0.282
Estonia	0.042	0.214
Finland	0.028	0.166
France	0.024	0.181
Germany	0.037	0.233
Greece	0.024	0.148
Hungary	0.079	0.364
Ireland	0.044	0.284
Italy	0.022	0.122
Latvia	0.051	0.250
Lithuania	0.051	0.227
Netherlands	0.053	0.332
Poland	0.047	0.267
Portugal	0.025	0.157
Romania	0.024	0.133
Slovakia	0.017	0.109
Slovenia	0.130	0.150
Spain	0.020	0.146
Sweden	0.010	0.061
Switzerland	0.091	0.257
United Kingdom	0.039	0.221
Europe *	0.038	0.203
Europe **	0.022	0.112

* Independent countries with isolated grids.

** Interconnected grids.

Table K.4: Shares [-] of electricity demand that is lost due to storage inefficiencies. Results for the best-observed solutions.

Country	Capacity [GWh]	Partial cycles	Average DoD [-]	Capacity factor [-]		
				1-hour	4-hours	24-hours
Austria	69	712	0.172	0.014	0.056	0.335
Belgium	329	430	0.438	0.022	0.086	0.516
Bulgaria	36	617	0.202	0.014	0.057	0.341
Czechia	166	608	0.144	0.010	0.040	0.239
Denmark	85	513	0.182	0.011	0.043	0.255
Estonia	17	563	0.161	0.010	0.041	0.248
Finland	82	503	0.202	0.012	0.046	0.278
France	497	593	0.146	0.010	0.040	0.237
Germany	781	569	0.188	0.012	0.049	0.293
Greece	53	748	0.113	0.010	0.039	0.233
Hungary	184	626	0.133	0.010	0.038	0.229
Ireland	59	495	0.183	0.010	0.041	0.248
Italy	232	645	0.188	0.014	0.055	0.331
Latvia	25	687	0.110	0.009	0.034	0.206
Lithuania	28	567	0.183	0.012	0.047	0.284
Netherlands	273	614	0.145	0.010	0.041	0.244
Poland	365	471	0.208	0.011	0.045	0.269
Portugal	41	626	0.175	0.012	0.050	0.300
Romania	58	597	0.167	0.011	0.045	0.273
Slovakia	16	627	0.200	0.014	0.057	0.344
Slovenia	32	516	0.411	0.024	0.097	0.581
Spain	218	583	0.145	0.010	0.039	0.232
Sweden	38	688	0.183	0.014	0.058	0.346
Switzerland	116	478	0.395	0.022	0.086	0.518
United Kingdom	569	741	0.125	0.011	0.042	0.255
Europe	2106	511	0.249	0.015	0.058	0.349

Table K.5: Battery design and operating characteristics by country and all Europe. The average depth of discharge (DoD) is the mean share [-] of battery capacity that is discharged during each partial cycle. The capacity factor represents the average amount of energy, calculated as share [-] of battery capacity, stored at different time intervals (from 1 hour to 24 hours).