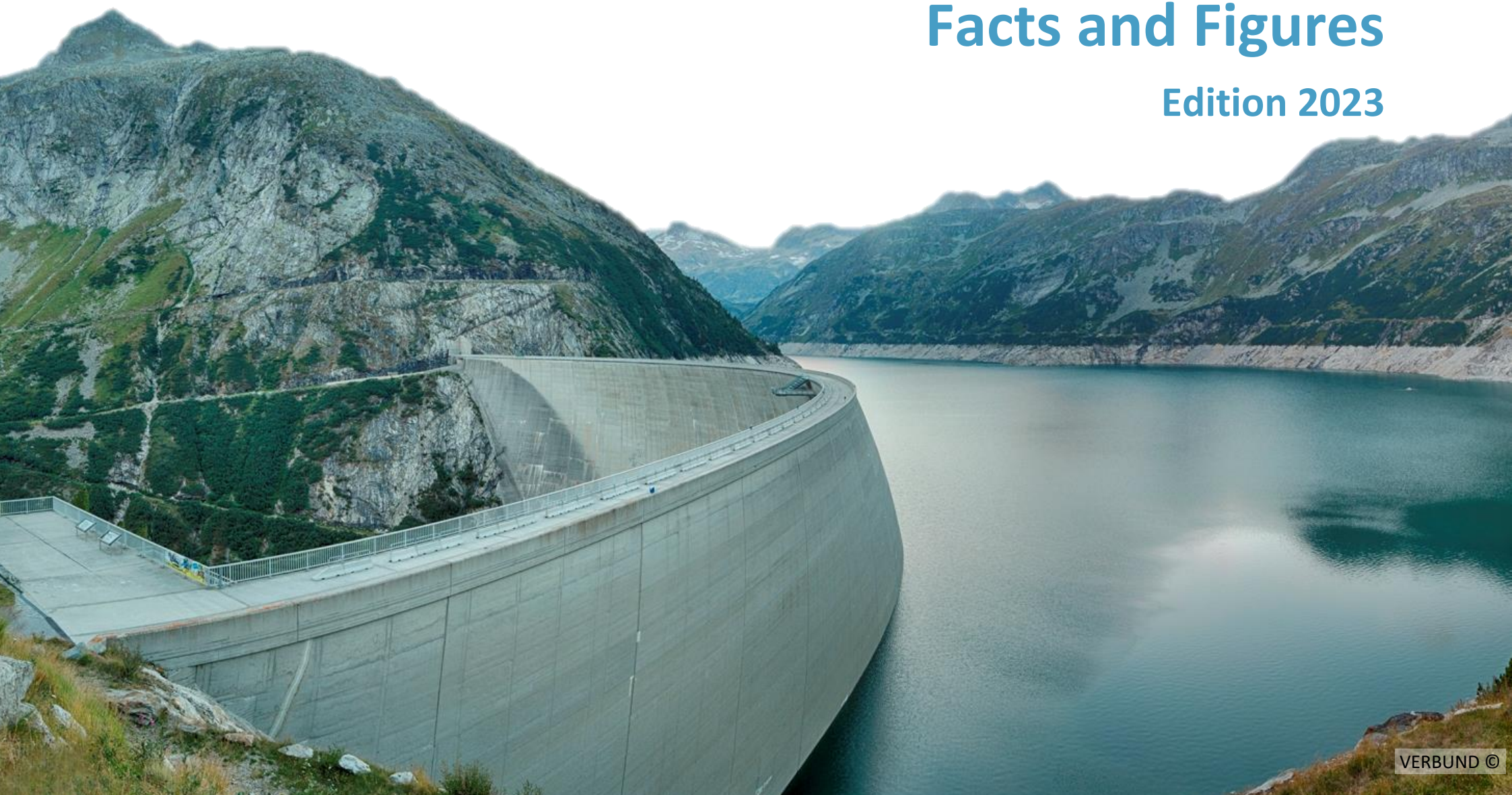
Hydropower in Europe: Facts and Figures

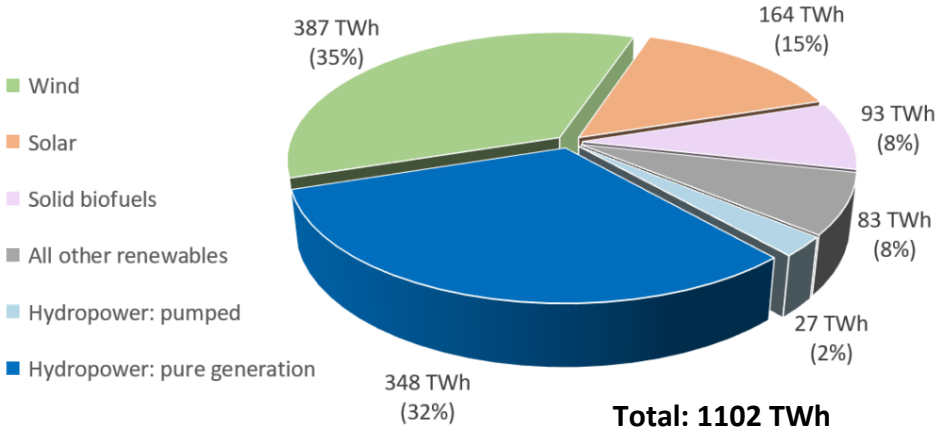
Edition 2023



Renewable and flexible Hydropower is indispensable for Europe

Hydropower contributes significantly to achieving the European Union's (EU) decarbonisation and renewable energy targets with a total generation of nearly 350 TWh per year from pure generation plants (run-of-river and reservoir storage) and almost 30 TWh from pumped storage. These two forms of hydropower generation provide about 34% of the electricity generated from renewable energy sources and about 13% of the gross electricity generation of EU27 in 2021.

Shares of renewable electricity generation in the EU in 2021 (in TWh)[1]



Total: 1102 TWh

Installed capacity & annual generation of hydropower in 2021

Hydropower	EU27	EU27 + CH + IS + NO + TR + UK[2]
Capacity of pure generation plants	106 GW	187 GW
Capacity of pumped storage plants	46 GW	53 GW
Generation of pure generation plants	348 TWh	605 TWh
Generation of pumped storage plants	27 TWh	30 TWh

[1] EUROSTAT 2023 – Complete energy balances [nrg_bal_c]; data basis 2021

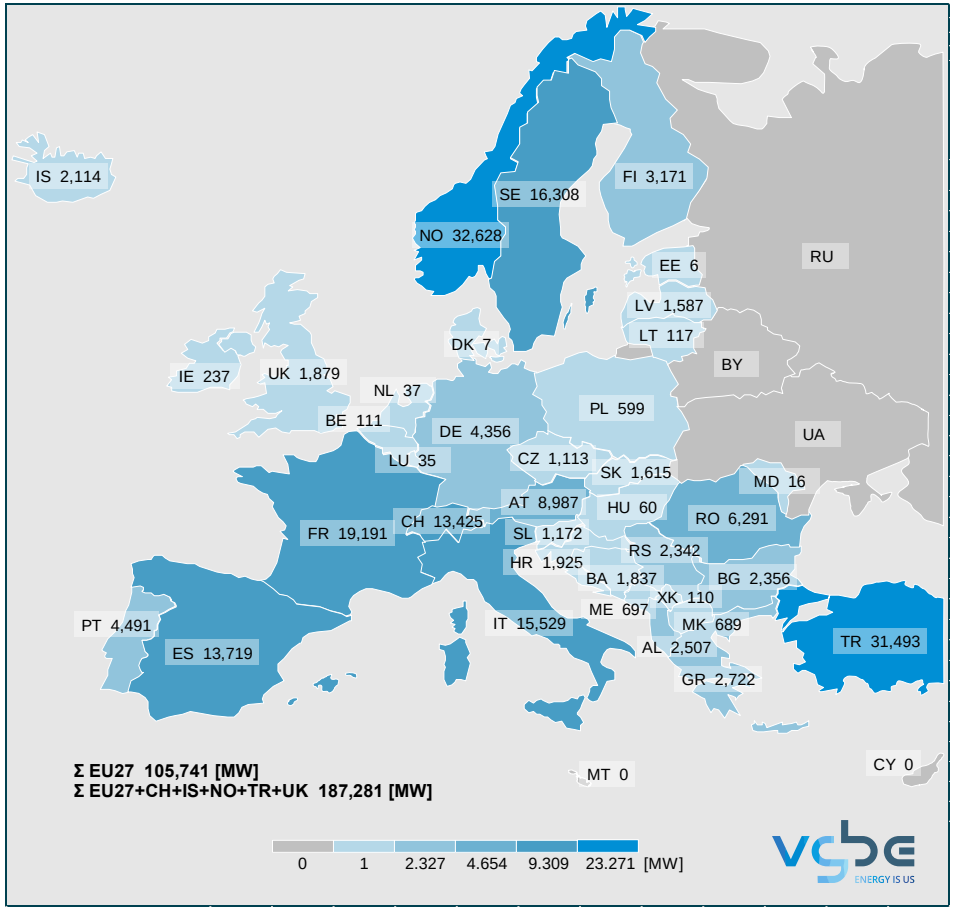
[2] This publication focuses on 32 countries (EU27 + CH + IS + NO + TR + UK). The countries outside of the EU27 are included because of their hydropower activity and regular availability of data.

Installed Capacity of Pure Generation Plants in 2021[3;4;5;6]

Installed hydropower capacity varies significantly throughout Europe, depending on the geographical region, water resources, available heads and national energy policies.

	Country	Code	[MW]
	Austria	AT	8,987
	Belgium	BE	111
	Bulgaria	BG	2,356
	Croatia	HR	1,925
	Cyprus	CY	0
	Czech Rep.	CZ	1,113
	Denmark	DK	7
	Estonia	EE	6
	Finland	FI	3,171
	France	FR	19,191
	Germany	DE	4,356
	Greece	GR	2,722
	Hungary	HU	60
	Iceland	IS	2,114
	Ireland	IE	237
	Italy	IT	15,529
	EU27	EU27	105,741

	Country	Code	[MW]
	Latvia	LV	1,587
	Lithuania	LT	117
	Luxembourg	LU	35
	Malta	MT	0
	Norway	NO	32,628
	The Netherlands	NL	37
	Poland	PL	599
	Portugal	PT	4,491
	Romania	RO	6,291
	Slovakia	SK	1,615
	Slovenia	SI	1,172
	Spain	ES	13,719
	Sweden	SE	16,308
	Switzerland	CH	13,425
	Turkey	TR	31,493
	United Kingdom	UK	1,879
	EU27 + CH + IS + NO + TR + UK	EU32	187,281



[3] EUROSTAT 2023 - Electricity production capacities for renewables and wastes [nrg_inf_epc]; Installed Capacity Hydropower = Net maximum electrical capacity pure hydropower (auto+main)

[4] Bundesamt für Energie, BFE, 2021: Versorgung, Erneuerbare Energien, Wasserkraft: Statistik der Wasserkraftanlagen der Schweiz am 31.12.2021

[5] International Hydropower Association: IHA, 2021: Country Profile United Kingdom

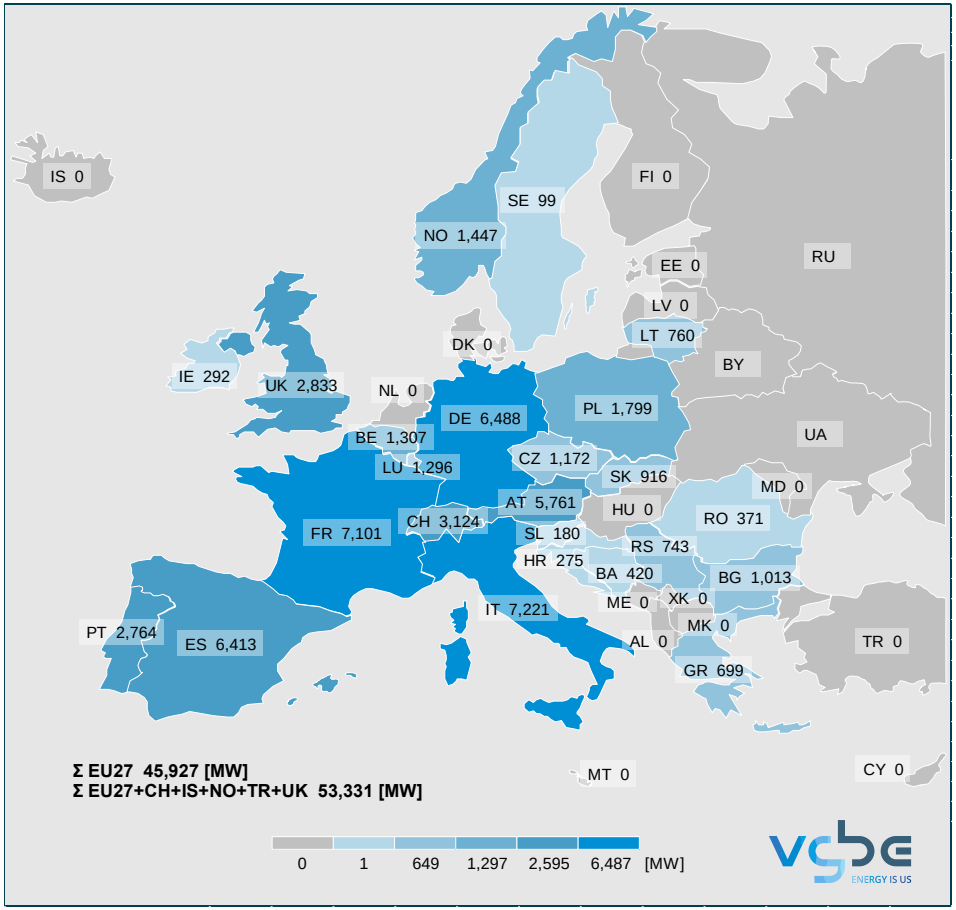
[6] Statista: Hydropower capacity in Turkey from 2008 to 2021

Installed Turbine Capacity of Pumped Storage in 2021[4;5;6;7]

Italy, France and Germany have the largest installed pumped storage capacity in Europe.
Alpine pumped storage is the largest flexibility provider in central Europe.

	Country	Code	[MW]
	Austria	AT	5,761
	Belgium	BE	1,307
	Bulgaria	BG	1,013
	Croatia	HR	275
	Cyprus	CY	0
	Czech Rep.	CZ	1,172
	Denmark	DK	0
	Estonia	EE	0
	Finland	FI	0
	France	FR	7,101
	Germany	DE	6,488
	Greece	GR	699
	Hungary	HU	0
	Iceland	IS	0
	Ireland	IE	292
	Italy	IT	7,221
	EU27	EU27	45,927

	Country	Code	[MW]
	Latvia	LV	0
	Lithuania	LT	760
	Luxembourg	LU	1,296
	Malta	MT	0
	Norway	NO	1,447
	The Netherlands	NL	0
	Poland	PL	1,799
	Portugal	PT	2,764
	Romania	RO	371
	Slovakia	SK	916
	Slovenia	SI	180
	Spain	ES	6,413
	Sweden	SE	99
	Switzerland	CH	3,124
	Turkey	TR	0
	United Kingdom	UK	2,833
	EU27 + CH + IS + NO + TR + UK	EU32	53,331



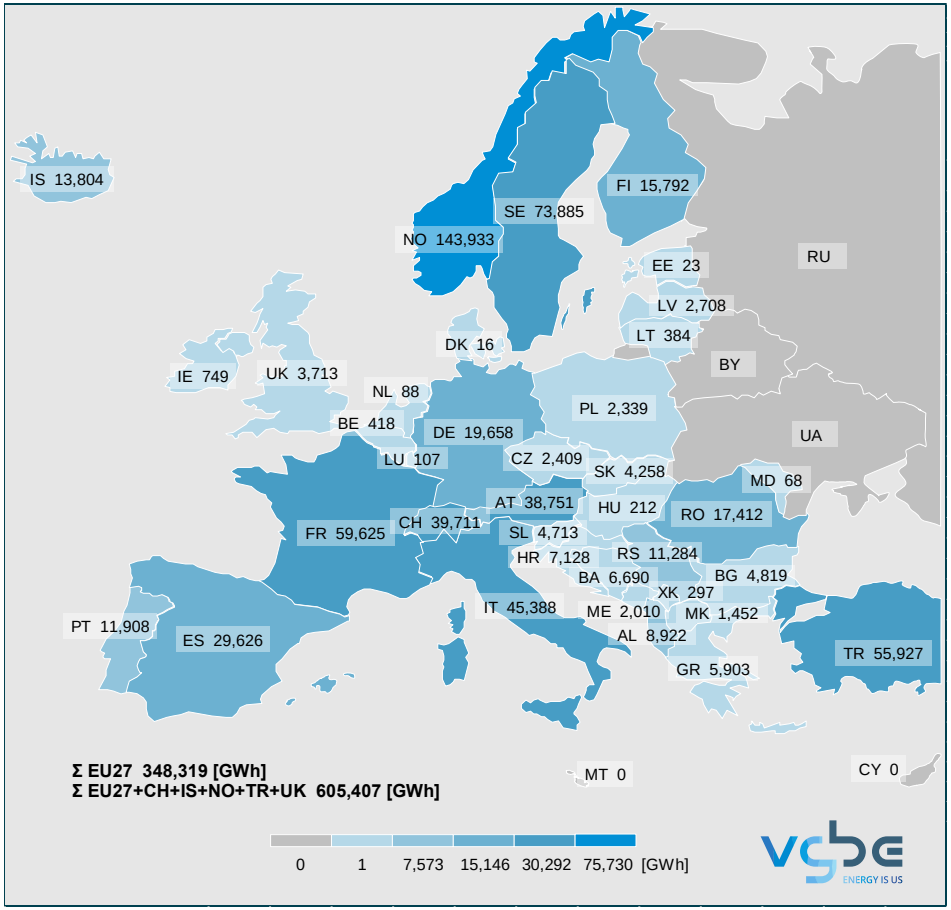
[7] EUROSTAT 2023 - Electricity production capacities for renewables and wastes [nrg_inf_epc]; Installed Turbine Capacity Pumped Storage = Net maximum electrical capacity (auto+main) mixed hydropower + net maximum electrical capacity (auto+main) pumped hydropower

Gross Electricity Generation from Pure Generation Plants in 2021[4;8;9]

Hydropower generation plays a significant role across Europe: from North to South and from East to West.

	Country	Code	[GWh]
	Austria	AT	38,751
	Belgium	BE	418
	Bulgaria	BG	4,819
	Croatia	HR	7,128
	Cyprus	CY	0
	Czech Rep.	CZ	2,409
	Denmark	DK	16
	Estonia	EE	23
	Finland	FI	15,792
	France	FR	59,625
	Germany	DE	19,658
	Greece	GR	5,903
	Hungary	HU	212
	Iceland	IS	13,804
	Ireland	IE	749
	Italy	IT	45,388
	EU27	EU27	348,319

	Country	Code	[GWh]
	Latvia	LV	2,708
	Lithuania	LT	384
	Luxembourg	LU	107
	Malta	MT	0
	Norway	NO	143,933
	The Netherlands	NL	88
	Poland	PL	2,339
	Portugal	PT	11,908
	Romania	RO	17,412
	Slovakia	SK	4,258
	Slovenia	SI	4,713
	Spain	ES	29,626
	Sweden	SE	73,885
	Switzerland	CH	39,711
	Turkey	TR	55,927
	United Kingdom	UK	3,713
	EU27 + CH + IS + NO + TR + UK	EU32	605,407



[8] EUROSTAT 2023 - Gross and net production of electricity and derived heat by type of plant and operator [nrg_ind_peh]; Gross Electricity Generation Hydropower = hydro(main) - pump(main) + hydro(auto) - pump(auto)

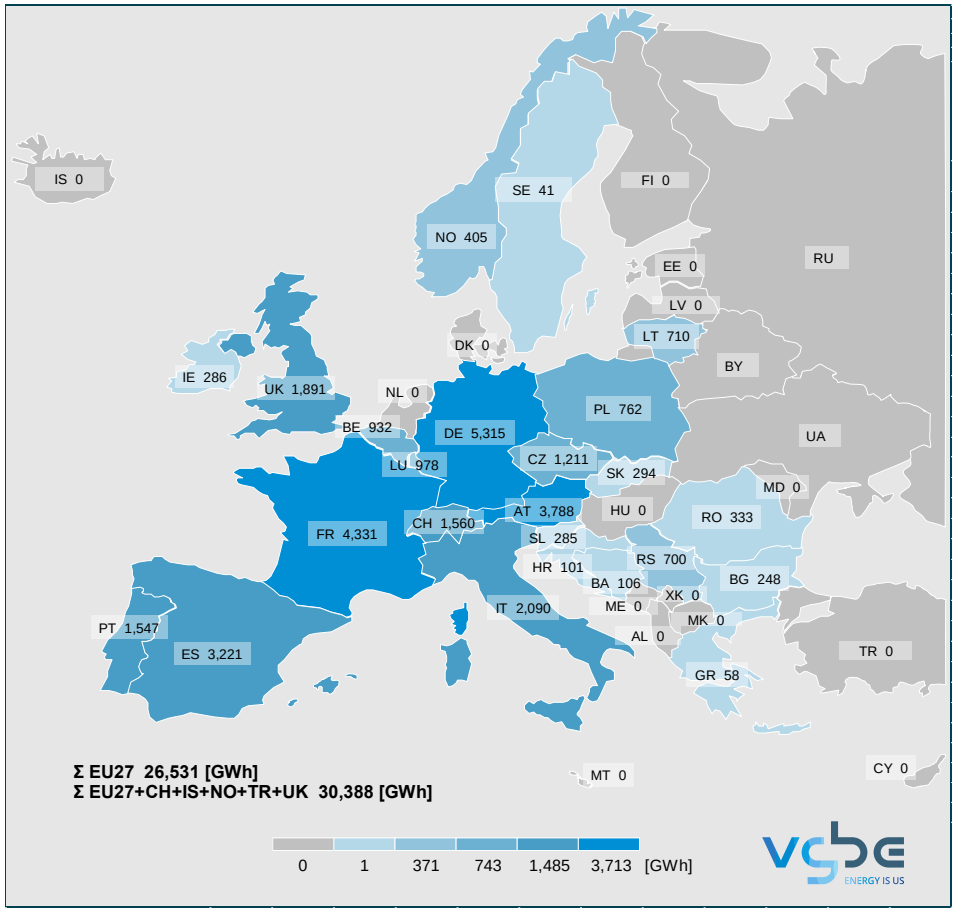
[9] Department for Business, Energy & Industrial Strategy, UK GOV, 2022: Historical electricity data: 1920 to 2021

Gross Electricity Generation from Pumped Storage in 2021[4;9;10]

Germany, France and Austria have the highest generation from pumped storage.

	Country	Code	[GWh]
	Austria	AT	3,788
	Belgium	BE	932
	Bulgaria	BG	248
	Croatia	HR	101
	Cyprus	CY	0
	Czech Rep.	CZ	1,211
	Denmark	DK	0
	Estonia	EE	0
	Finland	FI	0
	France	FR	4,331
	Germany	DE	5,315
	Greece	GR	58
	Hungary	HU	0
	Iceland	IS	0
	Ireland	IE	286
	Italy	IT	2,090
	EU27	EU27	26,531

	Country	Code	[GWh]
	Latvia	LV	0
	Lithuania	LT	710
	Luxembourg	LU	978
	Malta	MT	0
	Norway	NO	405
	The Netherlands	NL	0
	Poland	PL	762
	Portugal	PT	1,547
	Romania	RO	333
	Slovakia	SK	294
	Slovenia	SI	285
	Spain	ES	3,221
	Sweden	SE	41
	Switzerland	CH	1,560
	Turkey	TR	0
	United Kingdom	UK	1,891
	EU27 + CH + IS + NO + TR + UK	EU32	30,388



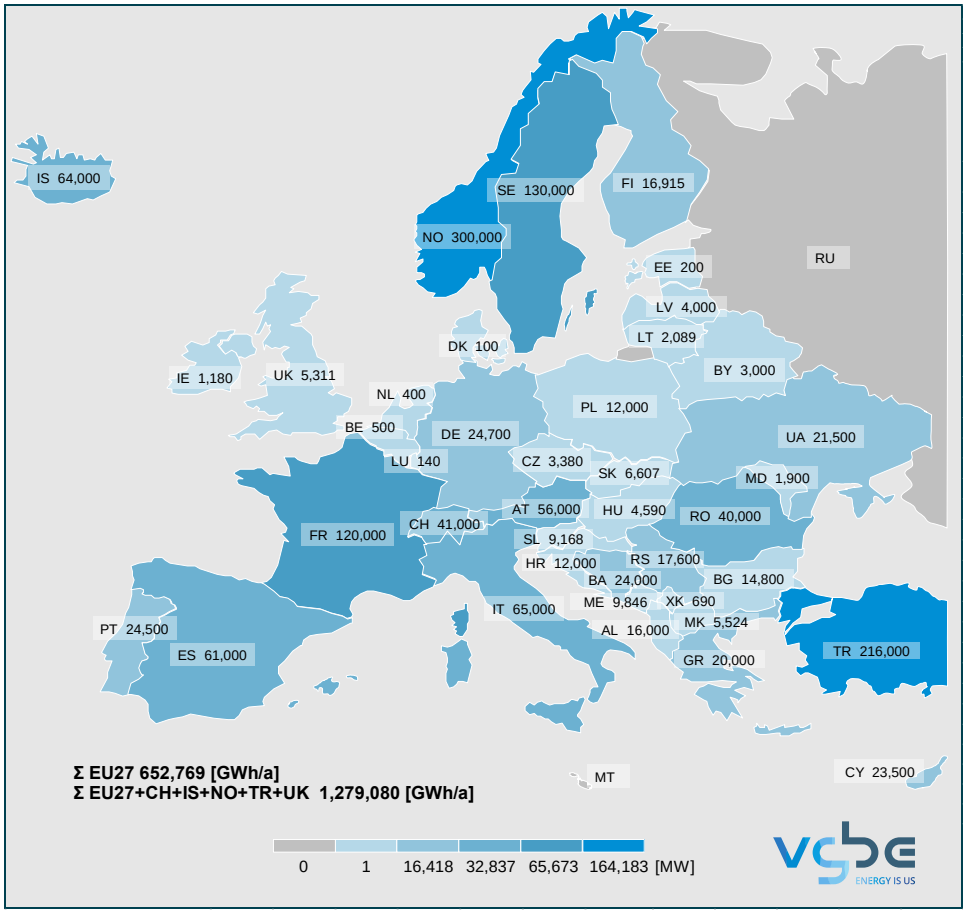
[10] EUROSTAT 2023 - Gross and net production of electricity and derived heat by type of plant and operator [nrg_ind_peh]; Gross Electricity Generation Pumped = pump(main) + pump(auto)

Technically Feasible Hydropower Potential in 2021[11]

Technically feasible potential is a theoretical value that is not realized to 100% in practice as there are important social, economic, environmental and regulatory factors that must be taken into consideration. Additionally, it should be noted that pumped storage (which is not shown in this potential) also has a large potential across Europe, in particular in the Alpine regions.

	Country	Code	[GWh/a]
	Austria	AT	56,000
	Belgium	BE	500
	Bulgaria	BG	14,800
	Croatia	HR	12,000
	Cyprus	CY	23,500
	Czech Rep.	CZ	3,380
	Denmark	DK	100
	Estonia	EE	200
	Finland	FI	16,915
	France	FR	120,000
	Germany	DE	24,700
	Greece	GR	20,000
	Hungary	HU	4,590
	Iceland	IS	64,000
	Ireland	IE	1,180
	Italy	IT	65,000
	EU27	EU27	652,769

	Country	Code	[GWh/a]
	Latvia	LV	4,000
	Lithuania	LT	2,089
	Luxembourg	LU	140
	Malta	MT	
	Norway	NO	300,000
	The Netherlands	NL	400
	Poland	PL	12,000
	Portugal	PT	24,500
	Romania	RO	40,000
	Slovakia	SK	6,607
	Slovenia	SI	9,168
	Spain	ES	61,000
	Sweden	SE	130,000
	Switzerland	CH	41,000
	Turkey	TR	216,000
	United Kingdom	UK	5,311
	EU27 + CH + IS + NO + TR + UK	EU32	1,279,080



[11] Hydropower & Dams World Atlas, 2022: Technically feasible hydropower potential – This data does not include pumped storage

Providing Security of Supply and Grid Stability

Hydropower provides various services to the power system. Hydropower is able to schedule energy production in the long and short term and provides physical rotation mass for grid stabilization. Additionally, pumped storage hydropower offers a huge capacity of stored energy, which can be available at any time. Through these various services and long lifespans of hydropower facilities, hydropower helps ensure a reliable and stable electricity supply and non-supply to the grid system.

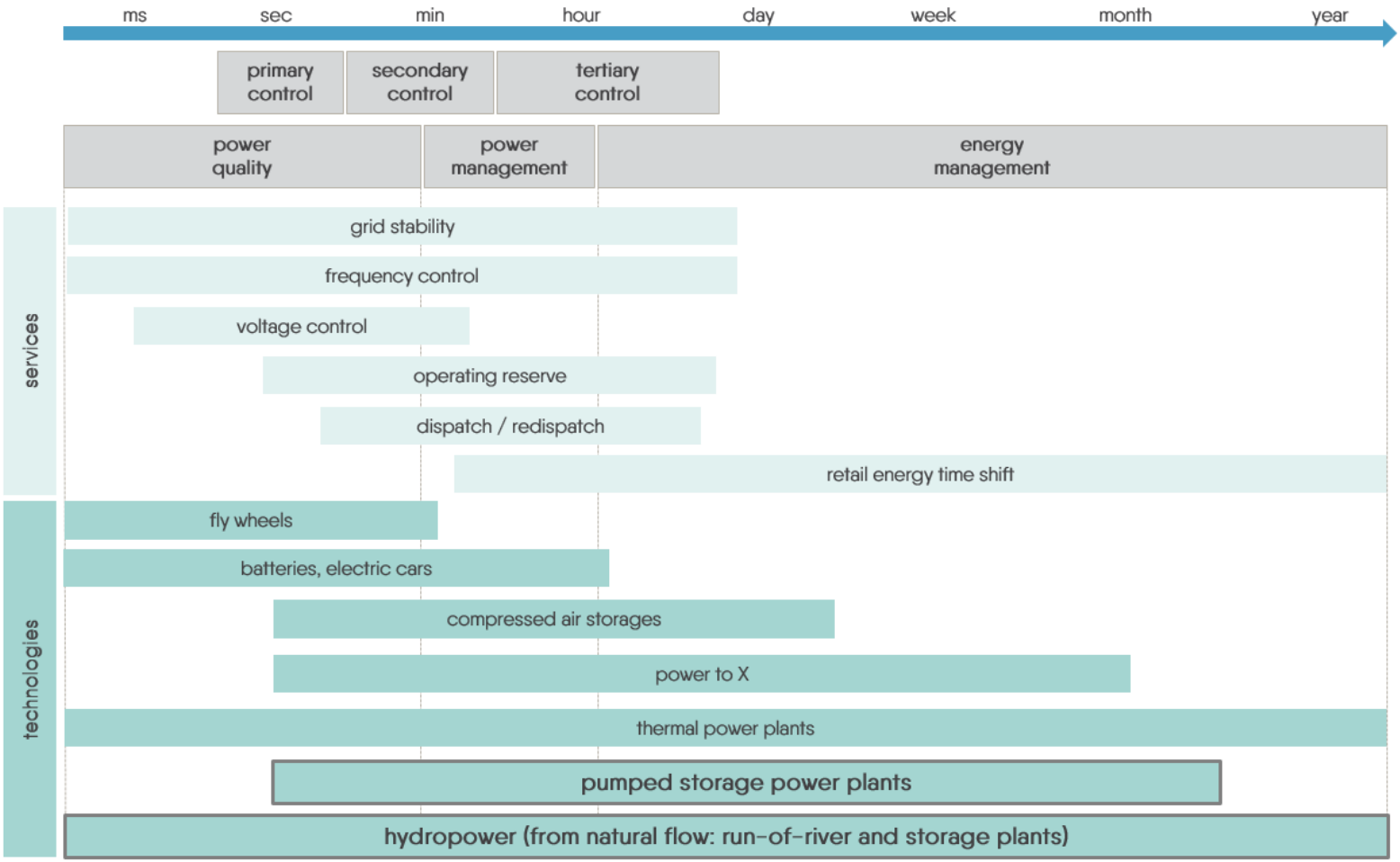
Services	Contribution to the power system
Back-up and reserve capacity	Hydropower offers a backup supply and operating reserve capacity for bottleneck situations and longer imbalances.
Quick start capability	Hydropower is able to start operation within a few seconds enabling quick system stabilizations.
Black start capability	Many hydropower plants are able to start generation from a total shutdown without any external power supply and thus can help restore the grid after a blackout.
Dispatch / Redispatch	Hydropower helps to prevent an overload of the power grid. Pumped storage power plants, in particular, provide redispatch capacity as they are able to adjust - even from a standstill - the power they input into or use from the grid in order to avoid or mitigate grid congestion measures.
Short-circuit power (short-circuit capacity)	In case of grid failures, synchronous machine units of hydropower plants provide short circuit current, which is indispensable for selective grid protection.
Regulation and frequency response (control)	Hydropower contributes to maintaining the grid frequency by the continuous modulation of active power compensating moment-to-moment fluctuations in the system. Frequency control comprises the provision of balancing power for primary control, secondary control, tertiary control and interruptible loads.
Peak load control	Storage and pumped storage hydropower can generate less electricity during off-peak hours and quickly responds to peak demands via flexible operations (fast starts and stops).

Services	Contribution to the power system
High ramp rates	Hydropower plants are a flexible supply-side capacity as they can ramp up and down very rapidly and be restarted and re-stopped relatively smoothly. Pumped storage power plants can extend this range towards a demand-side response resource in pumping mode. Modern concepts like variable speed units and hydraulic short-circuit enable them to adjust and regulate electric power also in pump mode.
Reactive power control / Voltage stability	Reactive power is an indispensable element in voltage stability. Hydropower can control reactive power by ensuring that both inductive and capacitive reactive power flows from generation to load. This means that voltage control or grid voltage stabilization is achieved by absorbing energy and by releasing it back (phase-shifted) into the grid.
Synchronous condenser operation	Special plants provide even an option of synchronous condenser operation mode, a type of operation exclusively for the supply of reactive power (without active power) and inertia reserve by means of the rotating masses (turbine runner is dewatered and rotates in air).
Rotating masses (inertia) and spinning reserve	Due to their high rotating masses (inertia), hydropower units are capable to resist or slow down frequency deviations which may be induced by high renewables production. Also, hydropower can provide a spinning reserve; an additional power capacity that can be instantly activated in case of unexpected load changes in the grid.

Hydropower is Highly Flexible and operates at All Timescales

Hydropower operates at all timescales supporting:

- **power quality –** monitoring and regulation of voltage fluctuations, frequency disruptions and harmonic distortions
- **power management –** short-term power supply for critical demands
- **energy management –** energy storage for extended periods of time



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vgbe energy e.V. is the international technical association for the generation and storage of power and heat. vgbe's more than 400 members located in 29 countries represent a power plant capacity of 342,000 MW. The main focus of vgbe's work is the development of technical competence and of operational services leading to the compilation of technical standards as well as the implementation and coordination of research and innovation projects at industry, national and international levels.

vgbe I Hydro acts as the European platform for 68 operators and 24 other hydropower stakeholders (equipment suppliers, consultants, etc.) and is the first address for solving techno-economic, ecological and strategic challenges for hydropower. Currently, more than 250 experts share experiences and knowledge on a high level of expertise, actively participating in vgbe's hydropower committees and expert groups.

More information about **vgbe energy | Hydro** https://www.vgbe.energy/en/hydropower/

vgbe energy e.V.

Deilbachtal 173, 45257 Essen • Germany
T + 49 201 8128 0
E info@vgbe.energy
I www.vgbe.energy/