Hydropower in Europe: Facts and Figures

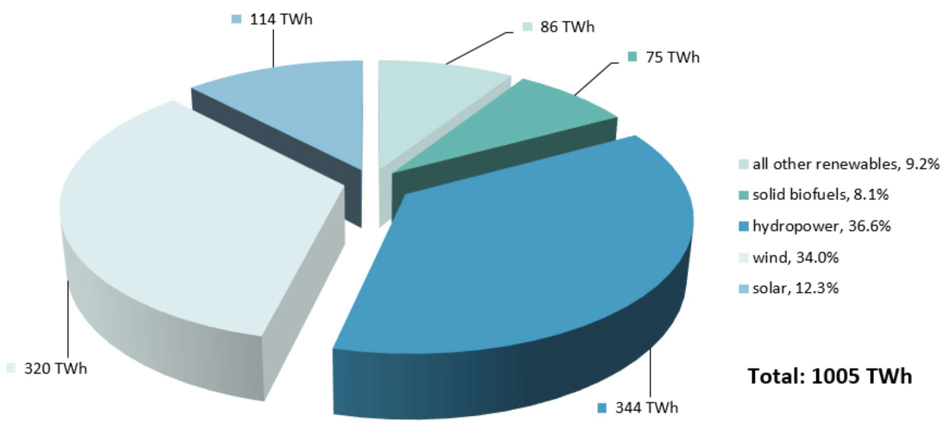
Edition 2020

Renewable and flexible Hydropower is indispensable for Europe

The Paris Agreement, the European Green Deal and the Next Generation EU offer Europe a unique opportunity to establish its global leadership in clean technologies and sustainability, simultaneously fighting climate change as well as contributing to the economic recovery. Even though, the revised Renewable Energy Directive 2018/2001/EU (RED II) only foresees an overall EU target for renewable energy sources consumption by 2030 of at least 32%, the majority of electricity will be provided by renewables in the future. By 2045, renewables will represent more than 80% of energy supply driven by rapid cost decline, increasing capacity factors, and large untapped resource potentials.[1]

Hydropower contributes significantly to achieving EU's decarbonisation and renewable energy targets: With a total generation of more than 340 TWh generation per year of run-of-river and reservoir storage plants (without pumped storage) equalling to about 37% of the electricity generated from renewable energy sources and about 11% of the gross electricity generation of EU27 in 2018. Generation of renewable electricity from hydropower increased in the EU in 2018 by around 11% compared with 2017 (301 TWh).

Shares of renewable electricity generation in the EU in 2018 (in TWh)[2]



Installed capacity & annual generation of hydropower in 2018

Hydropower	EU27	EU27 + CH + IS + NO + TR + UK[3]
Capacity of run-of-river and reservoir storage plants	105 GW	180 GW
Turbine capacity of pumped storage plants	46 GW	53 GW
Generation of run-of-river and reservoir storage plants	344 TWh	596 TWh
Generation of pumped storage plants	26 TWh	31 TWh

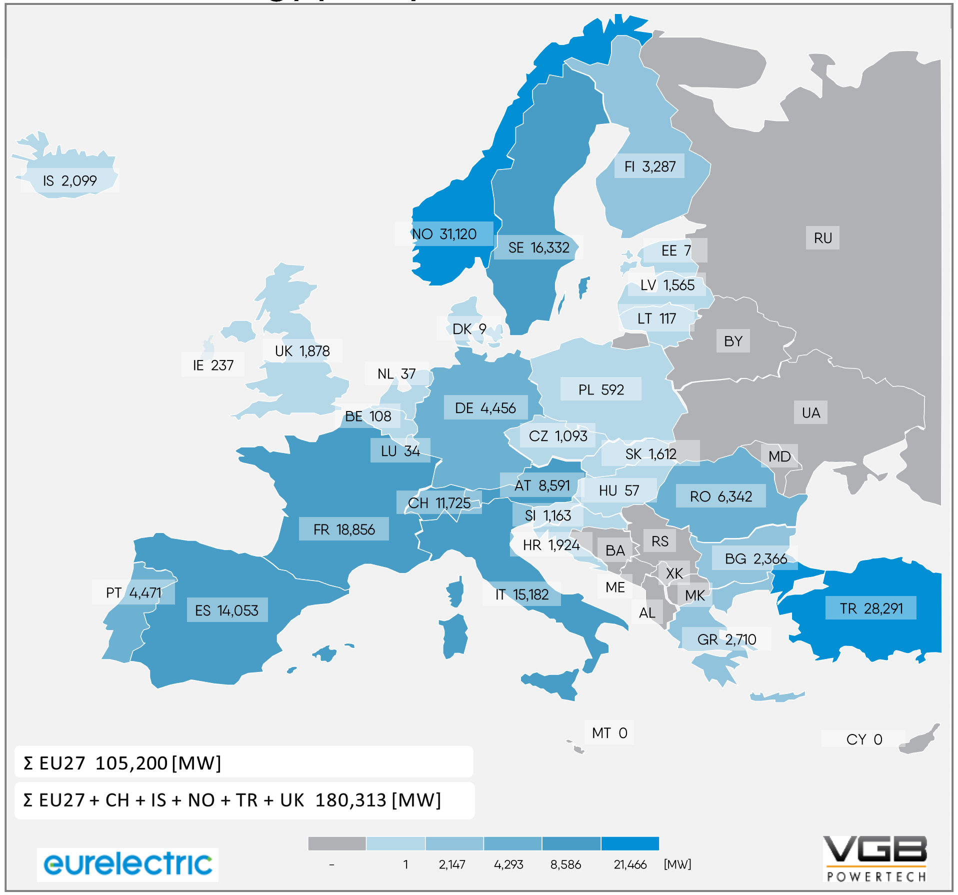
[1] Eurelectric 2017: Decarbonisation Pathways
[2] EUROSTAT 2020: SHARES tool – data basis 2018 (generation data of hydropower and wind have been normalised)
[3] This publication focuses on 32 countries (EU27 + CH + IS + NO + TR + UK), whose national electricity associations or leading companies are full members of Eurelectric.

Installed Capacity of Run-of-River and Reservoir Storage Plants in 2018[4;5]

The overall installed hydropower capacity varies significantly throughout Europe, depending on water resources, available heads and the national energy policy.

	Country	Code	[MW]
	Austria	AT	8,591
	Belgium	BE	108
	Bulgaria	BG	2,366
	Croatia	HR	1,924
	Cyprus	CY	0
	Czech Rep.	CZ	1,093
	Denmark	DK	9
	Estonia	EE	7
	Finland	FI	3,287
	France	FR	18,856
	Germany	DE	4,456
	Greece	GR	2,710
	Hungary	HU	57
	Iceland	IS	2,099
	Ireland	IE	237
	Italy	IT	15,182

	Country	Code	[MW]
	Latvia	LV	1,565
	Lithuania	LT	117
	Luxembourg	LU	34
	Malta	MT	0
	Norway	NO	31,120
	Poland	PL	592
	Portugal	PT	4,471
	Romania	RO	6,342
	Slovakia	SK	1,612
	Slovenia	SI	1,163
	Spain	ES	14,053
	Sweden	SE	16,332
	Switzerland	CH	11,725
	The Netherlands	NL	37
	Turkey	TR	28,291
	United Kingdom	UK	1,878



4 EUROSTAT 2020 - Electricity production capacities for renewables and wastes [nrg_inf_epcrw]; Installed Capacity Hydropower = Net maximum electrical capacity pure hydropower

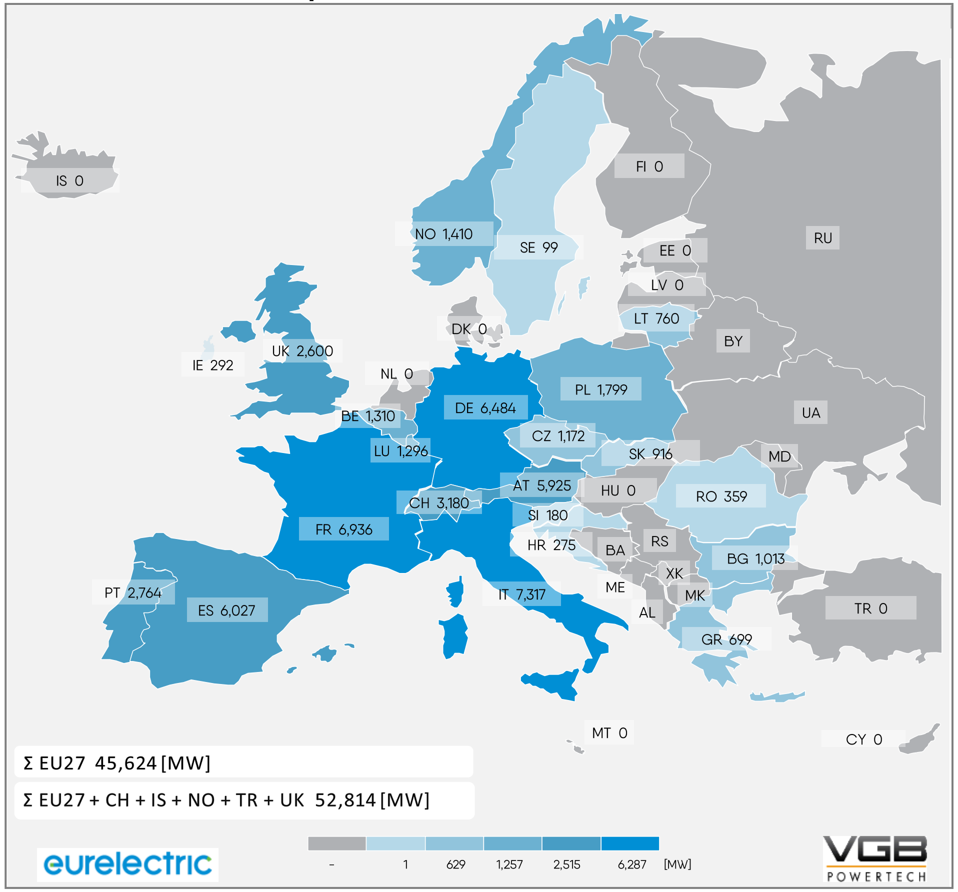
5 Bundesamt für Energie, BFE, 2019: Stand der Wasserkraftnutzung in der Schweiz; and: Statistik der Wasserkraftanlagen der Schweiz am 1.1.2019

Installed Turbine Capacity of Pumped Storage in 2018[6]

Italy, France and Germany are the top three countries for installed pumped storage capacity: Alpine pumped storage is the key flexibility provider at the heart of Europe.

	Country	Code	[MW]
	Austria	AT	5,925
	Belgium	BE	1,310
	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	6,936
	Germany	DE	6,484
	Greece	GR	699
	Hungary	HU	0
	Iceland	IS	0
	Ireland	IE	292
	Italy	IT	7,317

	Country	Code	[MW]
	Latvia	LV	0
	Lithuania	LT	760
	Luxembourg	LU	1,296
	Malta	MT	0
	Norway	NO	1,410
	Poland	PL	1,799
	Portugal	PT	2,764
	Romania	RO	359
	Slovakia	SK	916
	Slovenia	SI	180
	Spain	ES	6,027
	Sweden	SE	99
	Switzerland	CH	3,180
	The Netherlands	NL	0
	Turkey	TR	0
	United Kingdom	UK	2,600



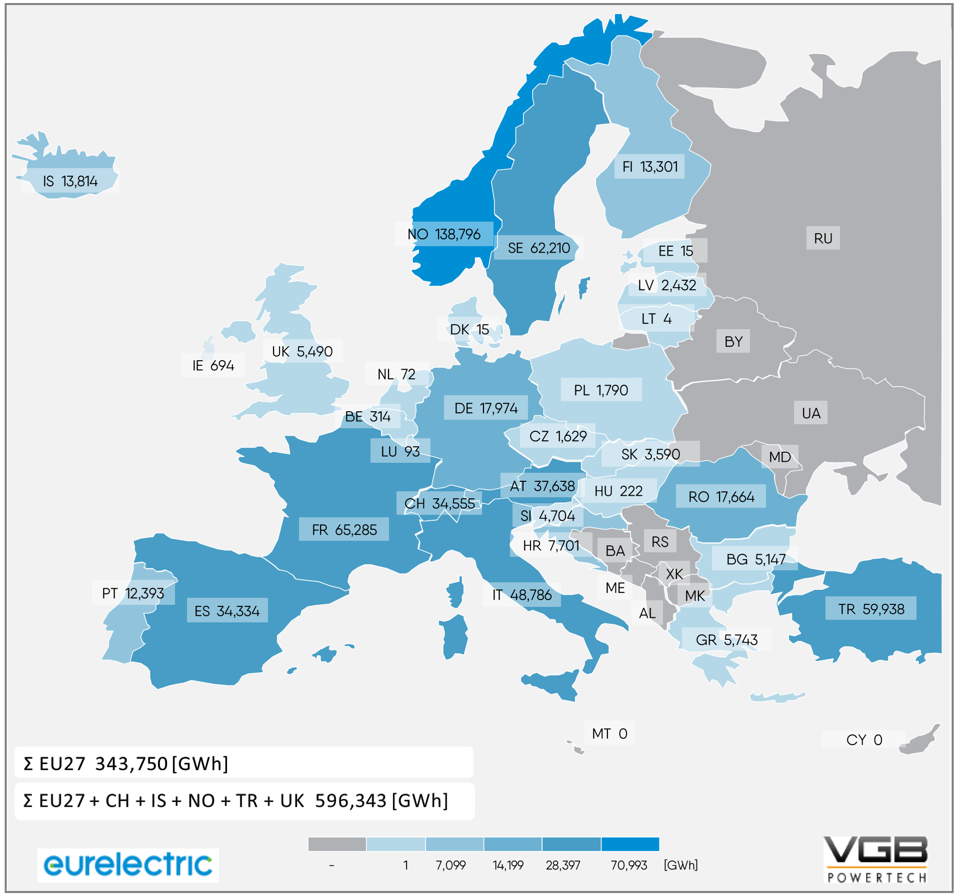
[6] EUROSTAT 2020 – Electricity production capacities for renewables and wastes [nrg_inf_epcrw]; Installed Turbine Capacity Pumped Storage = Net maximum electrical capacity mixed hydropower + net maximum electrical capacity pumped hydropower

Gross Electricity Generation of Run-of-River and Reservoir Storage Plants in 2018[7]

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

	Country	Code	[GWh]
	Austria	AT	37,638
	Belgium	BE	314
	Bulgaria	BG	5,147
	Croatia	HR	7,701
	Cyprus	CY	0
	Czech Rep.	CZ	1,629
	Denmark	DK	15
	Estonia	EE	15
	Finland	FI	13,301
	France	FR	65,285
	Germany	DE	17,974
	Greece	GR	5,743
	Hungary	HU	222
	Iceland	IS	13,814
	Ireland	IE	694
	Italy	IT	48,786

	Country	Code	[GWh]
	Latvia	LV	2,432
	Lithuania	LT	4
	Luxembourg	LU	93
	Malta	MT	0
	Norway	NO	138,796
	Poland	PL	1,790
	Portugal	PT	12,393
	Romania	RO	17,664
	Slovakia	SK	3,590
	Slovenia	SI	4,704
	Spain	ES	34,334
	Sweden	SE	62,210
	Switzerland	CH	34,555
	The Netherlands	NL	72
	Turkey	TR	59,938
	United Kingdom	UK	5,490



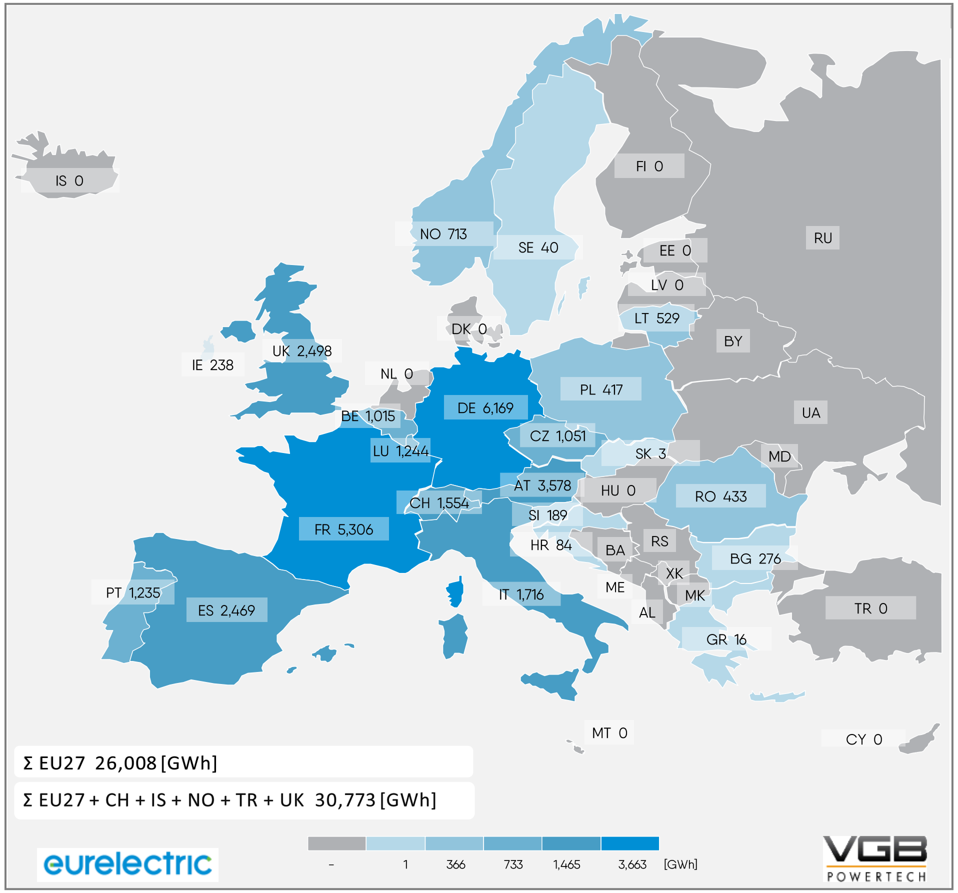
[7] EUROSTAT 2020 – Gross and net production of electricity and derived heat by type of plant and operator [nrg_ind_peh]; Gross Electricity Generation Hydropower = hydro(main) – pump(main) + hydro(auto) – pump(auto)

Gross Electricity Generation of Pumped Storage in 2018[8]

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

	Country	Code	[GWh]
	Austria	AT	3,578
	Belgium	BE	1,015
	Bulgaria	BG	276
	Croatia	HR	84
	Cyprus	CY	0
	Czech Rep.	CZ	1,051
	Denmark	DK	0
	Estonia	EE	0
	Finland	FI	0
	France	FR	5,306
	Germany	DE	6,169
	Greece	GR	16
	Hungary	HU	0
	Iceland	IS	0
	Ireland	IE	238
	Italy	IT	1,716

	Country	Code	[GWh]
	Latvia	LV	0
	Lithuania	LT	529
	Luxembourg	LU	1,244
	Malta	MT	0
	Norway	NO	713
	Poland	PL	417
	Portugal	PT	1,235
	Romania	RO	433
	Slovakia	SK	3
	Slovenia	SI	189
	Spain	ES	2,469
	Sweden	SE	40
	Switzerland	CH	1,554
	The Netherlands	NL	0
	Turkey	TR	0
	United Kingdom	UK	2,498



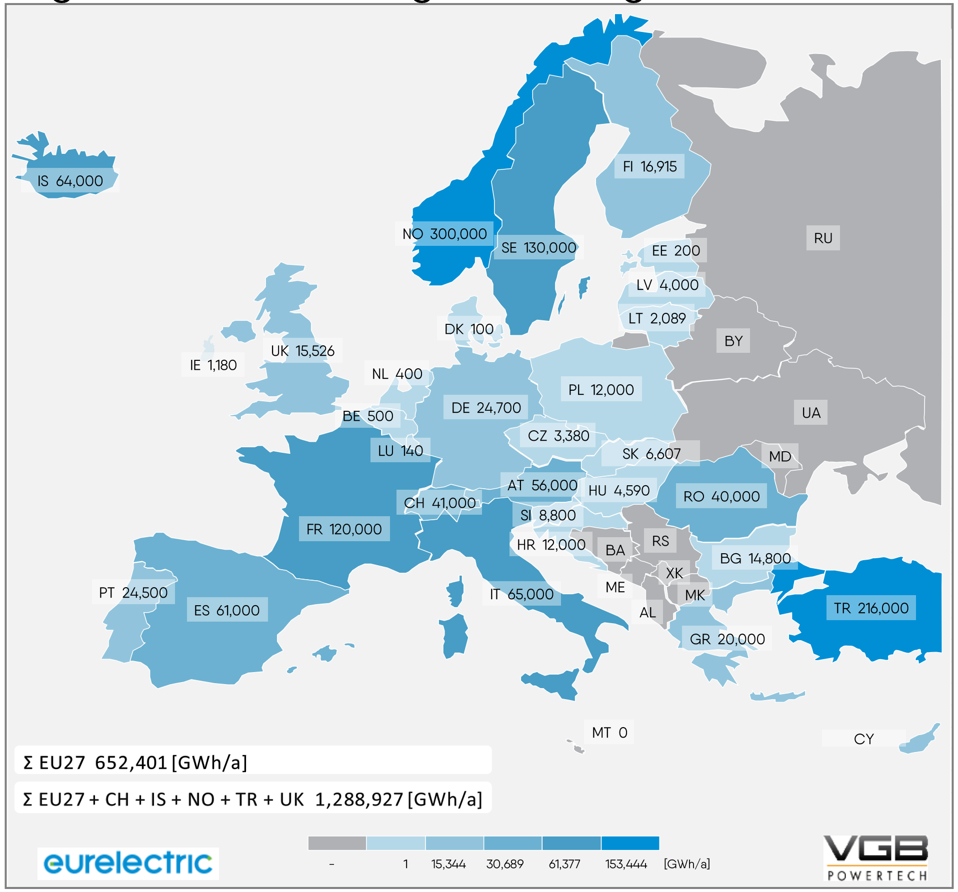
8 EUROSTAT 2020 - Gross and net production of electricity and derived heat by type of plant and operator [nrg_ind_peh]; Gross Electricity Generation Pumped = pump(main) + pump(auto)

Technically Feasible Hydropower Potential in 2018[9;10]

A considerable potential for hydropower exists but investments are stalled by market failures. A stable regulatory framework ensuring a level playing field for all generation and storage technologies is needed.

	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

	Country	Code	[GWh/a]
	Latvia	LV	4,000
	Lithuania	LT	2,089
	Luxembourg	LU	140
	Malta	MT	0
	Norway	NO	300,000
	Poland	PL	12,000
	Portugal	PT	24,500
	Romania	RO	40,000
	Slovakia	SK	6,607
	Slovenia	SI	8,800
	Spain	ES	61,000
	Sweden	SE	130,000
	Switzerland	CH	41,000
	The Netherlands	NL	400
	Turkey	TR	216,000
	United Kingdom	UK	15,526



[9] The technically feasible hydropower potential includes the already realised as well as the additionally technically feasible potential.
[10] Hydropower & Dams World Atlas, 2019

Outlook: Hydropower's Potential for Future Electricity Generation

Hydropower potential left

The latest publications and data clearly show that there is not only a gross theoretical hydropower potential but also a considerable economically feasible potential in Europe – mainly in Norway, Turkey, Sweden, France, Austria, Italy and in the Balkans. The technically feasible hydropower potential in the EU27 (652 TWh/a) plus Norway, Switzerland and Iceland equals to about 1,000 TWh/a[11], a number as high as the sum of France's, Italy's and Sweden's total gross electricity generation in 2018. Subtracting the already realised potential from the technically feasible hydropower potential, it becomes obvious that there is still considerable hydropower potential left in Europe. Only a small share of this feasible additional potential will be realised by 2030 within EU27, whereas the additional hydro built-out is estimated to about plus 9 GW[12] (only run-of-river and reservoir storage plants) by then.

A broad range of suitable sites for pumped storage plants

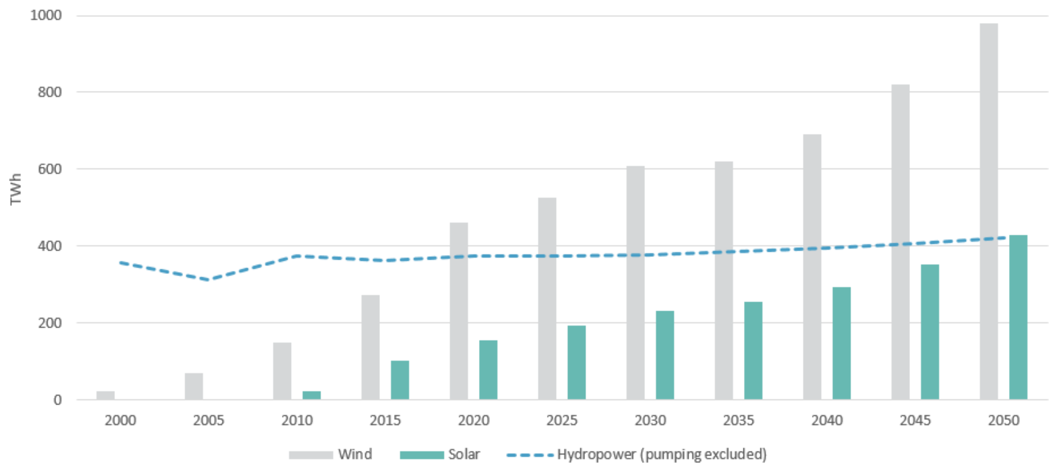
If planned with artificial reservoirs, pumped storage power plants can be built anywhere, in case the necessary height difference is available. They can be built e.g. on/in mountains, fjords, islands (where also the sea can be used as a lower reservoir), next to river systems with steep banks (river as lower basin), where the country is below the sea level (sea as upper reservoir), within old mines (closed water cycle), connecting or expanding existing storage power plants to new pumped storage facilities.

Hydropower facilitates the integration of wind and solar power

Hydropower provides significant amounts of balancing power, enabling the efficient integration of the constantly increasing shares of variable renewables such as wind and solar power. Due to the projected increase in variable renewables (see the grey and green columns in the graph below), the importance of hydropower will even rise in the future.

Hydropower will provide the future power system with storage and flexibility services, thus allowing for higher shares of wind and solar power without compromising security of supply and system stability.

Accelerated deployment of variable renewables:
Historical and projected net electricity generation in EU27 + UK[13]



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[11] Hydropower & Dams World Atlas, 2019

[12] Estimations based on the National Energy and Climate Plans as well as announced project developments.

[13] EU Reference Scenario 2016, based on PRIMES, GAINS

Hydropower Contributes to Reaching the EU Climate Objectives

The hydropower sector plays a key role in supporting Europe's clean energy transition to reach its international and European climate objectives. Hydropower is not only highly resource-efficient (with 85% to 95%) but is also crucial in fighting climate change.

With its low carbon footprint, hydropower can provide significant volumes of renewable low-carbon electricity, both for base and peak load. Once built, hydropower infrastructure can generate electricity for many decades, even for more than 100 years. For this reason, life-cycle assessments of hydropower provide a very good carbon footprint (defined as the total quantity of GHG emitted over the lifecycle) and energy efficiency profile. Lifecycle GHG emissions for different electricity generation technologies clearly show that hydropower plants have the lowest carbon footprint among all generation technologies.

Furthermore, hydropower even contributes to avoiding CO_2-emissions. Assuming that hydropower replaces the current generation mix, hydropower avoids about 180 Mt of CO_2 emissions in the EU27 + UK, equalling to 15% of total power sector emissions. Research even shows that each MWh of additional hydropower generation leads to savings between 0.3 to 0.7 t of CO_2.[14]

Moreover, hydropower shows the highest energy payback of all generation technologies. This means that hydropower has the best ratio between the total electricity output over its lifetime and the energy needed to build, operate, maintain and decommission a specific plant. During its long lifetime (up to 80 years and even longer), a hydropower plant can generate far more than 200 times the energy needed to build, maintain and operate it.

Low Carbon Footprint & High Resource-Efficiency

Hydropower efficiency rates (the highest of all technologies)	85% - 95%
Worldwide median lifecycle emissions[15]	24 $gCO2eq/kWh_{el}$
Avoidance of CO_2-emissions due to hydropower in the power sector in the EU28[14]	180 $MtCO_2$ (=15% of total CO_2-emissions of the power sector)
Savings of CO_2-emissions of each additional generated MWh by hydropower[14]	0.3 - 0.7 t of CO_2
Energy payback ratio (by far the highest of all electricity generation technologies)[16]	up to 267 for run-of-river plants and up to 205 for storage plants

Long Average Lifetimes of Hydropower Components

Generator	av. 25 - 45 years
Turbine	av. 35 - 45 years
Construction / building / dam	80 years and longer

[14] DNVGL, 2015: The Hydropower Sector's Contribution to a Sustainable and Prosperous Europe – Main Report

[15] Most recent UN's Intergovernmental Panel on Climate Change (IPCC) data: Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[16] Killingtveit 2019, Hydropower – in: Managing Global Warming, An Iterface of Technoogy and Human Issues

Hydropower Offers the Entire Range of Ancillary Services – Providing Security of Supply and Grid Stability

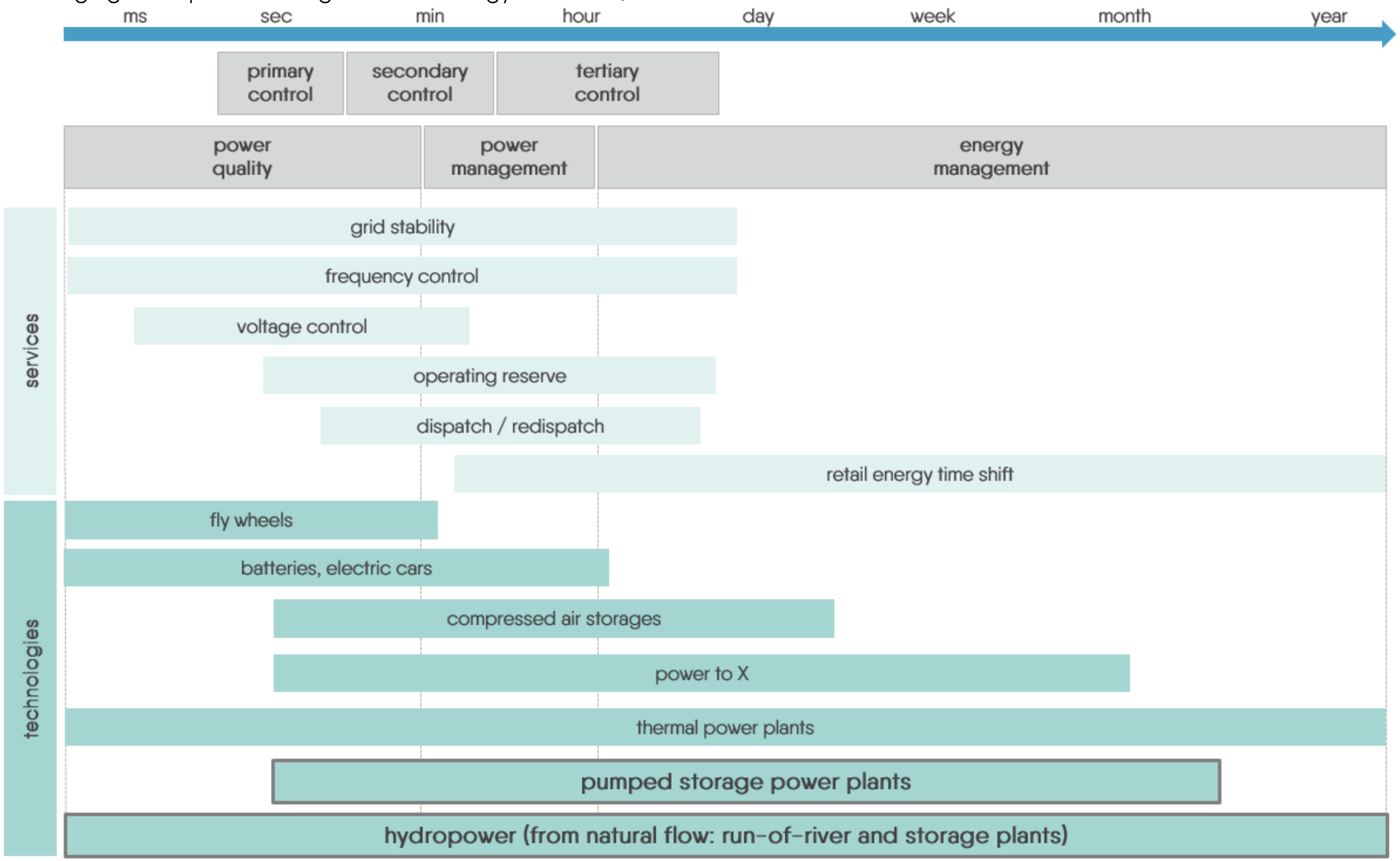
Services	Contribution to the power system
Back-up and reserve capacity	Hydropower offers back-up supply (generation can pick up load within an hour) and operating reserve capacity for bottleneck situations and longer imbalances.
Quick start capability	Hydropower is able to start operation within a few seconds enabling quick system stabilizations.
Black start capability	Hydropower is able to feed into the grid without help from outside after a blackout.
Dispatch / Redispatch	Hydropower helps to prevent an overload of the power grid. Especially PSPP provide redispatch capacity as they are able to adjust - even from standstill in positive or negative direction - the power they input in order to avoid or eliminate grid congestion.
Short-circuit power	Hydropower helps to maintain voltage stable and to protect the electrical grid.
Regulation and frequency response (control)	Hydropower contributes to maintain the frequency by continuous modulation of active power compensating moment-to-moment fluctuations in the system. Frequency control comprises the provision of balancing power for primary control (to be achieved within < 30 sec.), for secondary control (to be achieved within < 5 min.), for tertiary control (to be achieved within < 15 min.) and interruptible loads.

Services	Contribution to the power system
High change of capacity (load rate of change)	Hydropower can provide stability for grid frequency by transformation of the exceedance of capacity. Hydraulic-short-circuit management of PSPP can provide immediate capacity-flow change (taking-out or feeding-in). PSPP can support grid stability via fast and flexible switches making sure that power supply and power demand are constantly matched.
Peak load control	Hydropower generates less electricity during off-peak and quickly responds to peak demands via fast and flexible start and stops.
Synchronous condenser operation	Hydropower supports the dynamic behaviour of grid operation by providing inductive or capacitive reactive power during synchronous condenser operation (turbine runner is dewatered and rotates in air).
Rotating masses and spinning reserve	Hydropower provides spinning reserve (additional power supply that can be made available to the grid system in case of unexpected load changes in the grid).
Voltage support to control reactive power	Hydropower is able to 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.

Hydropower is Highly Flexible and operates at All Timescales

Hydropower operates at all timescales providing threefold support to the power system:

- **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: storing energy during periods when the retail electricity price (€/kWh) is low and discharging when prices are high – "retail energy time shift").



Enhanced Cooperation to Strengthen the Position of Hydropower in Europe

In 2017, Eurelectric and VGB renewed their commitment to advocate European policymakers to recognise the important role of hydropower, including the multipurpose function of hydropower infrastructure. The comprehensive expertise of the two associations will provide the basis to ensure a proper representation of hydropower at European level, with Eurelectric focusing on the political advocacy and VGB providing technical analysis and research.

Eurelectric

The Union of the Electricity Industry - Eurelectric is the sector association which represents the common interests of the electricity industry at pan-European level, plus its affiliates and associates on several other continents. We currently have over 34 full members, representing the electricity industry in 32 European countries (these are in the focus of this publication).

For a long time already, Eurelectric has a dedicated working group on hydropower ("WG Hydro"), whose core purpose is to closely monitor, influence and react on European policy initiatives as well as legislative proposals that have an impact on hydropower generation and development. The group facilitates business intelligence, technical knowledge & market developments insights in order to support positions, advocating and communication campaigns.

More information about **Eurelectric** http://www.eurelectric.org/

VGB PowerTech e.V.

VGB PowerTech e.V. is the international technical association for generation and storage of power and heat. VGB´s 424 members located in more than 33 countries represent a power plant capacity of 433,000 MW. The main focus of VGB's work is the development of technical competence and of operational services leading to the compilation of technical standards and the co-ordination of R&D projects.

VGB PowerTech I Hydro acts as the European platform for 74 operators, 19 equipment suppliers and 22 consultants and is the first address for solving techno-economic, ecological and strategic challenges for hydropower. Currently, more than 130 experts share experiences and knowledge on a high level of expertise actively participating in VGB´s hydropower committees being well embedded in the European hydropower network.

More information about **VGB PowerTech | Hydro** https://www.vgb.org/en/_hydro/

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