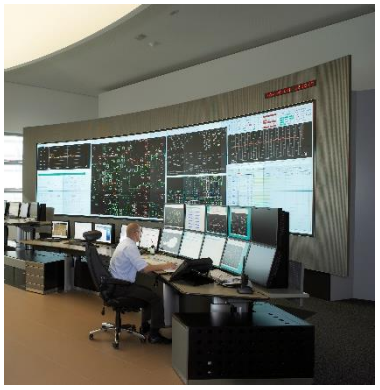
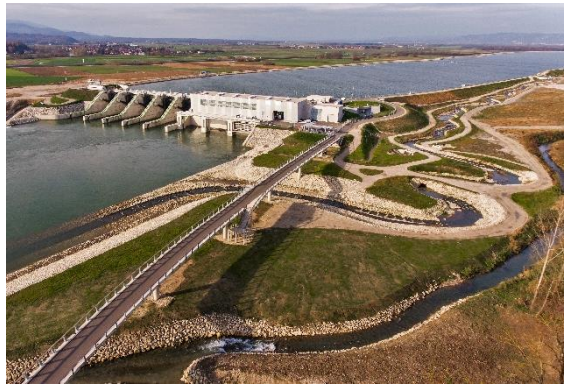
Facts of Hydropower in the EU

Renewable | Sustainable | Secure
Storable | Powerful | Projectable


Created by eurelectric in cooperation with VGB POWERTECH June 2018

Hydropower is indispensable for Europe

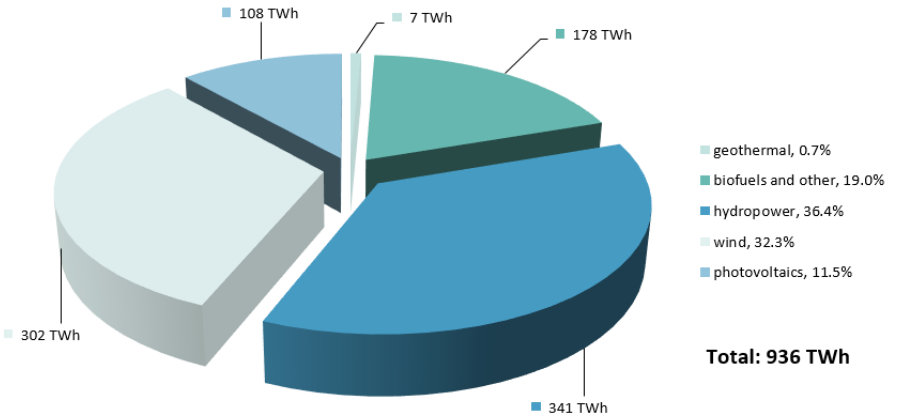
The EU has set binding targets to promote the expansion of renewable energy and decrease CO_2 emissions. The national renewable action plans indicate that renewables in the electricity sector will account for 34% of electricity generation by 2020 and at least for 45% by 2030.

So far, hydropower is the number one renewable energy source in Europe. With a total generation of more than 341 TWh per year equalling to about 36% of the electricity generated from renewable energy sources and 10% of the entire generation, hydropower contributes significantly to achieving the EU targets.

Installed capacity and annual generation of hydropower in the EU-28 and in the EU-28 + CH + NO + IS (in 2015)

Hydropower	EU-28	EU-28 + CH + NO + IS
Turbine capacity without pumping function	105 GW[1]	149 GW[1;2]
Turbine capacity with pumping function	47 GW[3]	51 GW[3]
Gross electricity generation from natural flow	341 TWh[4]	529 TWh[2;4;5]
Gross electricity generation from stored pumped water	30 TWh[6]	33 TWh[5;6]

Shares of renewable electricity generation in the EU-28 in 2015 (in TWh)[6]



Shares of hydropower capacity and generation in the EU-28 (in 2015)

Hydropower in the EU-28	Share of total capacity or generation	Share of total RES capacity or generation
Share of installed capacity run-of-river and storage plants[7]	11.2 % (of 934 GW)	28.1 % (of 374 GW)
Share of electricity generation run-of-river and storage plants[8]	10.5 % (of 3,234 TWh)	36.4 % (of 936 TWh)

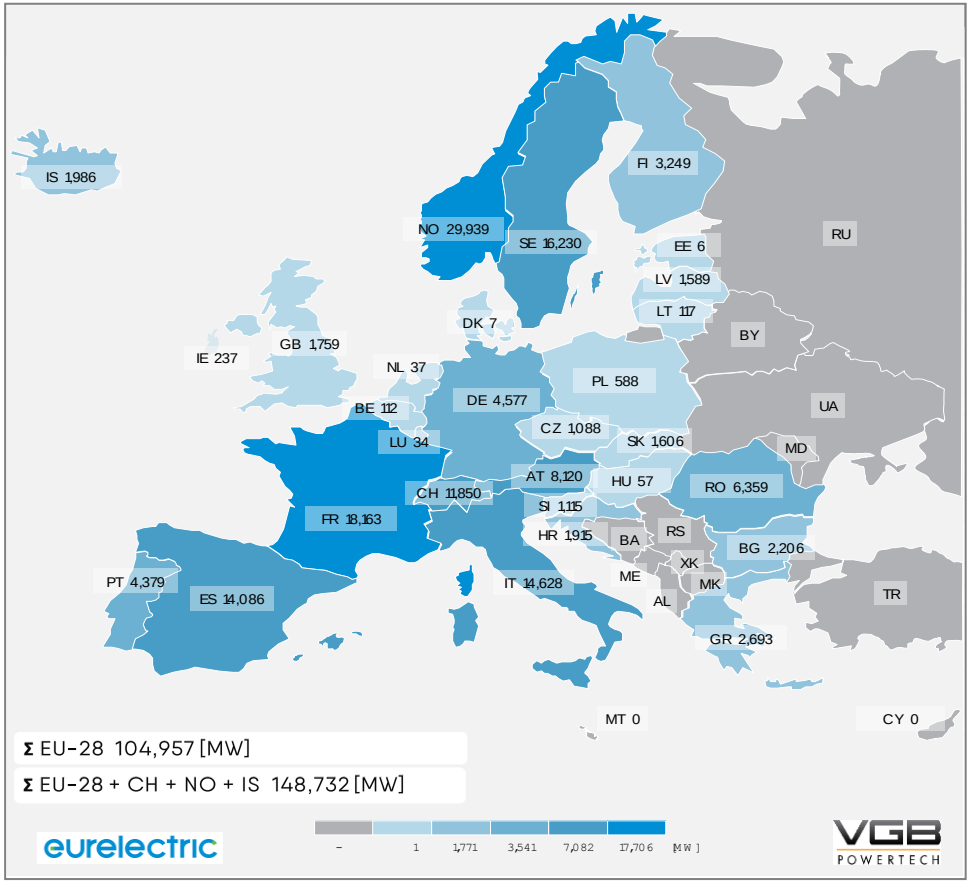
[1] EUROSTAT 2017 - Infrastructure - electricity - annual data [nrg_113a: 12_117615, 12_117616, 12_117617], data basis 2015
[2] ORKUSTOFNUN – Energy Statistics in Iceland 2015
[3] EUROSTAT 2017 - Infrastructure - electricity - annual data [nrg_113a: 12_1176061, 12_1176071, 12_1176072], data basis 2015
[4] EUROSTAT 2017 - Supply, transformation and consumption of electricity - annual data [nrg_105a: 14_1070341, 14_1070342, 14_1070343, 14_1070351, 14_1070352, 14_1070353], data basis 2015
[5] Bundesamt für Energie BFE, Stand der Wasserkraftnutzung in der Schweiz am 1. Januar 2015
[6] EUROSTAT 2017 - Supply, transformation and consumption of electricity - annual data [nrg_105a: 15_107036, 15_107037], data basis 2015
[7] EUROSTAT 2017 - Infrastructure - electricity - annual data [nrg_113a], data basis 2015
[8] EUROSTAT 2017 - Supply, transformation and consumption of electricity - annual data [nrg_105a], data basis 2015

Installed Turbine Capacity of Hydropower Plants without Pumping Function in the EU[9] + CH[10] + NO[1] + IS[2]

The installed turbine capacity of run-of-river hydropower plants and of storage power plants without pumping function varies significantly throughout Europe depending on water resources and available heads.

Flag	Country	Code	[MW]
	Austria	AT	8,120
	Belgium	BE	112
	Bulgaria	BG	2,206
	Croatia	HR	1,915
	Cyprus	CY	0
	Czech Rep.	CZ	1,088
	Denmark	DK	7
	Estonia	EE	6
	Finland	FI	3,249
	France	FR	18,163
	Germany	DE	4,577
	Greece	GR	2,693
	Hungary	HU	57
	Iceland	IS	1,986
	Ireland	IE	237
	Italy	IT	14,628

Flag	Country	Code	[MW]
	Latvia	LV	1,589
	Lithuania	LT	117
	Luxembourg	LU	34
	Malta	MT	0
	Netherlands	NL	37
	Norway	NO	29,939
	Poland	PL	588
	Portugal	PT	4,379
	Romania	RO	6,359
	Slovakia	SK	1,606
	Slovenia	SI	1,115
	Spain	ES	14,086
	Sweden	SE	16,230
	Switzerland	CH	11,850
	United Kingdom	GB	1,759
		Total [MW]	**148,732**



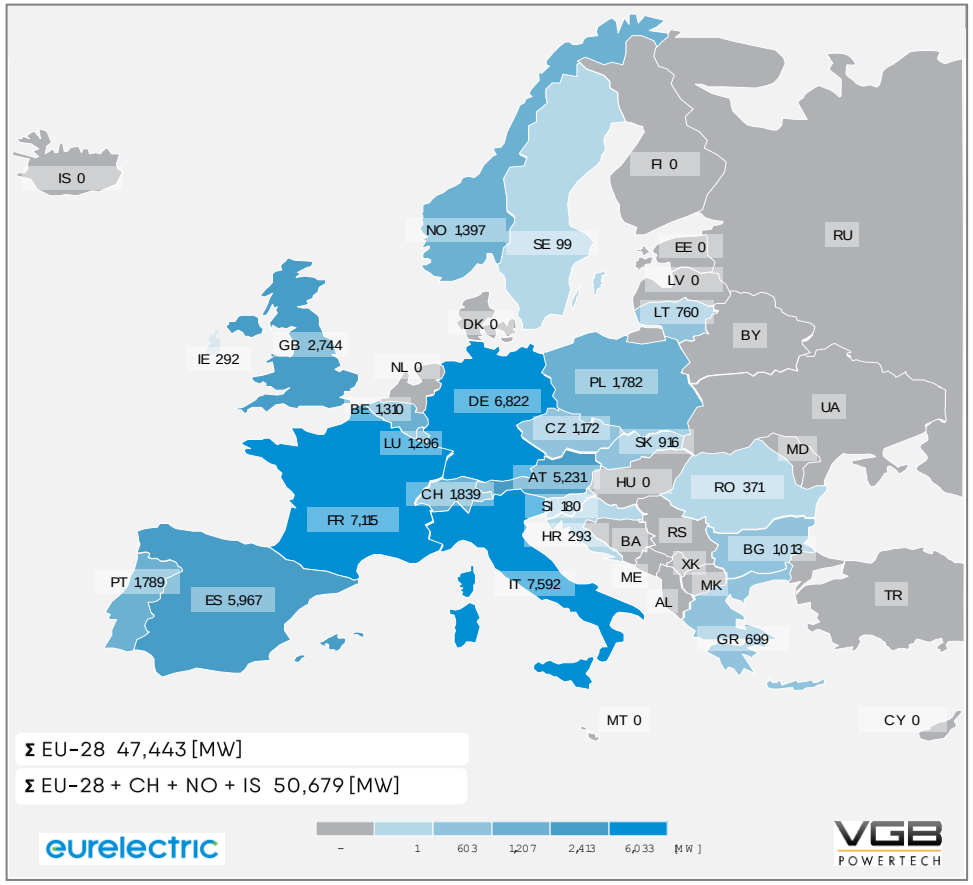
[9] EUROSTAT 2017 - Infrastructure - electricity - annual data [nrg_113a: 12_117615, 12_117616, 12_117617], data basis 2015
[10] Bundesamt für Energie BFE, Stand der Wasserkraftnutzung in der Schweiz am 1. Januar 2015

Installed Turbine Capacity of Hydropower Plants with Pumping Function in the EU[11]+ CH[12] + NO[1] + IS[2]

Reversible pump-turbine/motor-generator assemblies can act as both pumps and turbines and are installed in a numerous of storage and all pumped storage hydropower plants. Italy, France and Germany are the top three countries for installed storage and pumped storage capacities.

Flag	Country	Code	[MW]
	Austria	AT	5,231
	Belgium	BE	1,310
	Bulgaria	BG	1,013
	Croatia	HR	293
	Cyprus	CY	0
	Czech Rep.	CZ	1,172
	Denmark	DK	0
	Estonia	EE	0
	Finland	FI	0
	France	FR	7,115
	Germany	DE	6,822
	Greece	GR	699
	Hungary	HU	0
	Iceland	IS	0
	Ireland	IE	292
	Italy	IT	7,592

Flag	Country	Code	[MW]
	Latvia	LV	0
	Lithuania	LT	760
	Luxembourg	LU	1,296
	Malta	MT	0
	Netherlands	NL	0
	Norway	NO	1,397
	Poland	PL	1,782
	Portugal	PT	1,789
	Romania	RO	371
	Slovakia	SK	916
	Slovenia	SI	180
	Spain	ES	5,967
	Sweden	SE	99
	Switzerland	CH	1,839
	United Kingdom	GB	2,744
		Total [MW]	**50,679**



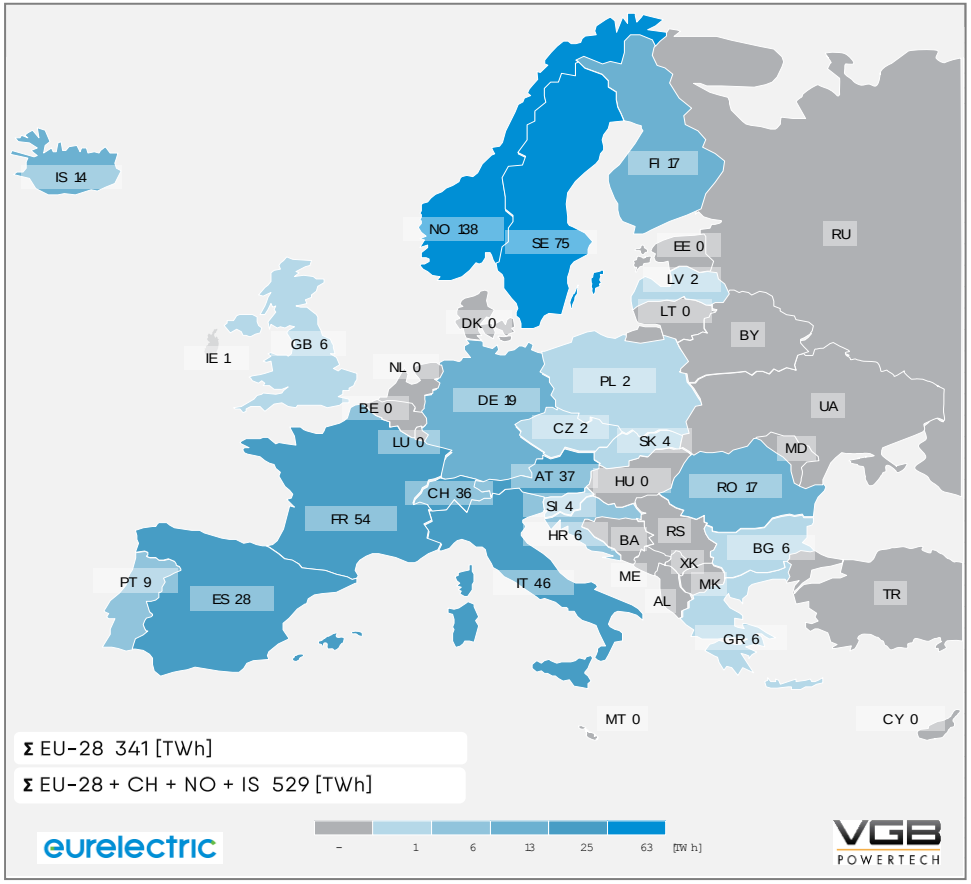
[11] EUROSTAT 2017 - Infrastructure - electricity - annual data [nrg_113a: 12_1176061, 12_1176071, 12_1176072], data basis 2015
[12] Bundesamt für Energie BFE, Stand der Wasserkraftnutzung in der Schweiz am 1. Januar 2015

Gross Electricity Generation of Hydropower Plants from Natural Flow in the EU[13] + CH[14] + NO[1] + IS[2]

The gross electricity generation from storage hydropower plants generated by natural flow and from run-of-river hydropower plants plays a significant role across Europe and in meeting a carbon-free emission energy system in Europe. This electricity is reliable and generally without major fluctuations.

Flag	Country	Code	[TWh]
	Austria	AT	37.06
	Belgium	BE	0.32
	Bulgaria	BG	5.66
	Croatia	HR	6.39
	Cyprus	CY	0.00
	Czech Rep.	CZ	1.80
	Denmark	DK	0.02
	Estonia	EE	0.03
	Finland	FI	16.77
	France	FR	54.44
	Germany	DE	18.98
	Greece	GR	6.10
	Hungary	HU	0.23
	Iceland	IS	13.78
	Ireland	IE	0.81
	Italy	IT	45.54

Flag	Country	Code	[TWh]
	Latvia	LV	1.86
	Lithuania	LT	0.35
	Luxembourg	LU	0.10
	Malta	MT	0.00
	Netherlands	NL	0.09
	Norway	NO	137.91
	Poland	PL	1.83
	Portugal	PT	8.66
	Romania	RO	16.63
	Slovakia	SK	3.87
	Slovenia	SI	3.81
	Spain	ES	28.14
	Sweden	SE	75.31
	Switzerland	CH	36.00
	United Kingdom	GB	6.29
			Total [TWh] 529



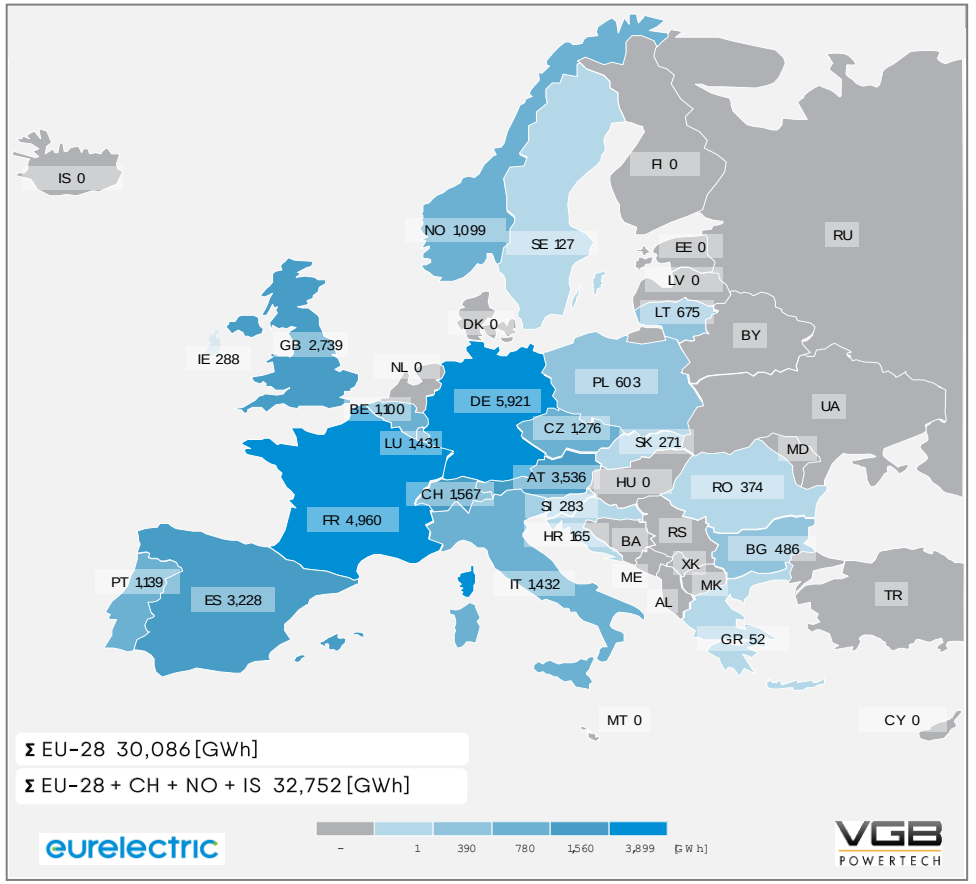
[13] EUROSTAT 2017 - Supply, transformation and consumption of electricity - annual data [nrg_105a: 14_1070341, 14_1070342, 14_1070343, 14_1070351, 14_1070352, 14_1070353], data basis 2015
[14] Bundesamt für Energie BFE, Stand der Wasserkraftnutzung in der Schweiz am 1. Januar 2015

Gross Electricity Generation from Stored Pumped Energy in the EU[15] + CH[16] + NO[1] + IS[2]

Pumped storage hydropower plants as well as storage hydropower plants, having additional a natural flow, store energy in the form of water in an upper reservoir, pumped from another reservoir at a lower elevation. The highest generation exclusively from pumping can be observed in Germany, France and Austria.

Flag	Country	Code	[GWh]
	Austria	AT	3,536
	Belgium	BE	1,100
	Bulgaria	BG	486
	Croatia	HR	165
	Cyprus	CY	0
	Czech Rep.	CZ	1,276
	Denmark	DK	0
	Estonia	EE	0
	Finland	FI	0
	France	FR	4,960
	Germany	DE	5,921
	Greece	GR	52
	Hungary	HU	0
	Iceland	IS	0
	Ireland	IE	288
	Italy	IT	1,432

Flag	Country	Code	[GWh]
	Latvia	LV	0
	Lithuania	LT	675
	Luxembourg	LU	1,431
	Malta	MT	0
	Netherlands	NL	0
	Norway	NO	1,099
	Poland	PL	603
	Portugal	PT	1,139
	Romania	RO	374
	Slovakia	SK	271
	Slovenia	SI	283
	Spain	ES	3,228
	Sweden	SE	127
	Switzerland	CH	1,567
	United Kingdom	GB	2,739
		Total [GWh]	**32,752**



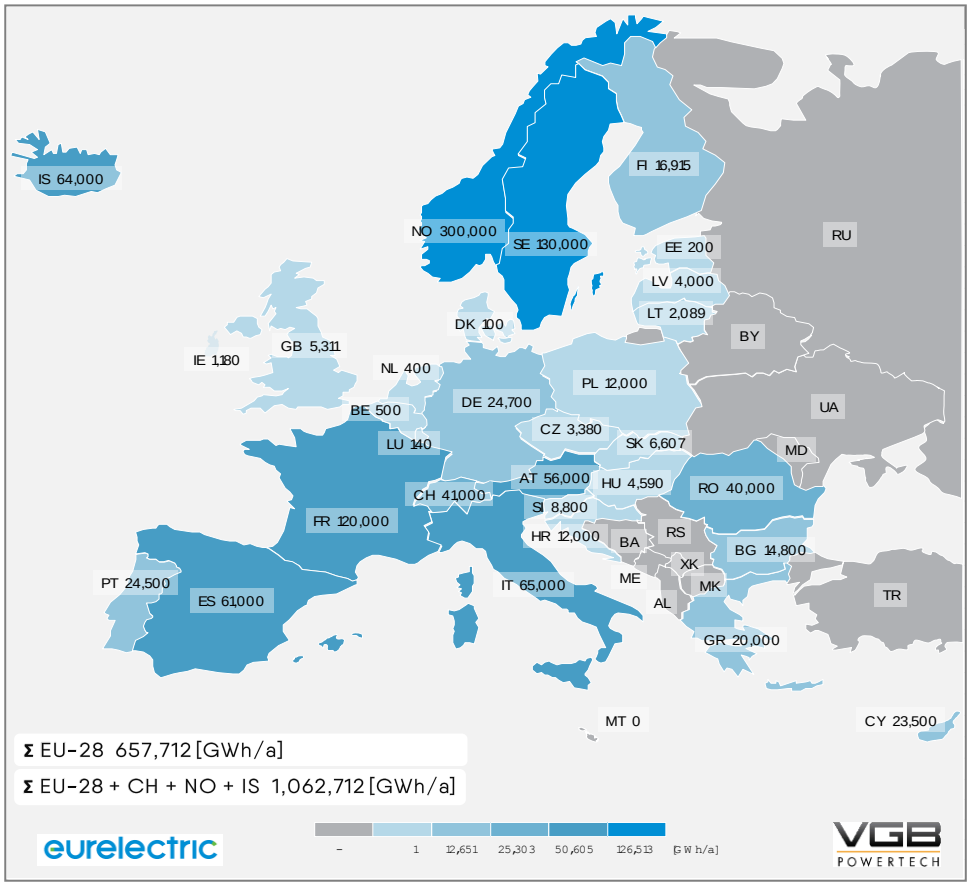
[15] EUROSTAT 2017 - Supply, transformation and consumption of electricity - annual data [nrg_105a: 15_107036, 15_107037], data basis 2015
[16] Bundesamt für Energie BFE, Stand der Wasserkraftnutzung in der Schweiz am 1. Januar 2015

Technically Feasible Hydropower Potential[17] in the EU[18] + CH[1] + NO[1] + IS[2]

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.

Flag	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

Flag	Country	Code	[GWh/a]
	Latvia	LV	4,000
	Lithuania	LT	2,089
	Luxembourg	LU	140
	Malta	MT	0
	Netherlands	NL	400
	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
	United Kingdom	GB	5,311
		Total [GWh/a]	**1,062,712**



[17] The technically feasible hydropower potential includes the already realised as well as the additionally technically feasible potential.
[18] Hydropower & Dams World Atlas, 2017

Outlook: Hydropower's Potential for Future Electricity Generation

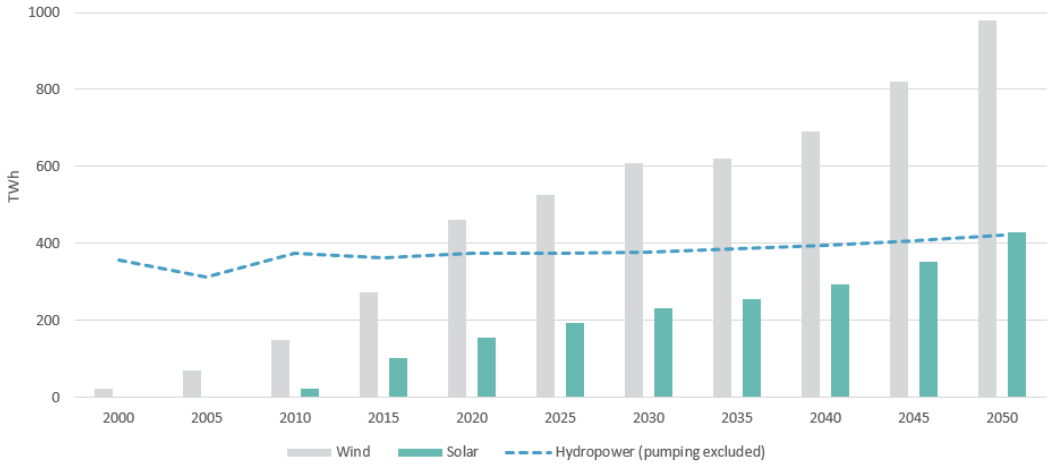
Some hydropower potential left

The latest publications and data clearly show that there is not only a gross theoretical hydropower potential[17] but also a considerable economically feasible potential in Europe – mainly in Norway, Sweden, France, Austria, Italy and in the Balkans[18]. The technically feasible hydropower potential in the EU-28 (658 TWh/a[18]) plus Norway, Switzerland and Iceland equals to about 1,000 TWh/a[18], a number as high as the sum of Germany's and the UK's total gross electricity generation in 2017. Subtracting the already realised potential from the technically feasible hydropower potential, it becomes obvious that there is still some hydropower potential left in Europe.

Hydropower facilitates the integration of wind and solar power

Hydropower has provided significant amounts of balancing power, facilitating 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 graph on accelerated deployment of variable renewables), the importance of hydropower will rise in the future, even though today's predictions foresee hydropower generation to remain roughly constant. 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 the EU-28[19]



[19] 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 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 would be replaced by the current generation mix, hydropower avoids about 180 Mt of CO_2 emissions in the EU-28, 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.[20]

Moreover, hydropower shows the highest energy payback of all generation technologies. This means that hydropower has the lowest 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%
CO_2-Emission factor[21] (among the lowest values of all technologies)	2.702 g CO_2-eq/kWh_{el}
Avoidance of CO_2-emissions due to hydropower in the power sector in the EU-28[20]	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[20]	0.3 - 0.7 t of CO_2
Energy payback ratio (the highest of all technologies)	170 - 280

Long Average Lifetimes of Hydropower Components

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

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

[21] According to Umweltbundesamt Deutschland, 2018

Hydropower Offers a Wide Range of Ancillary Services – Providing Security of Supply and Grid Stability

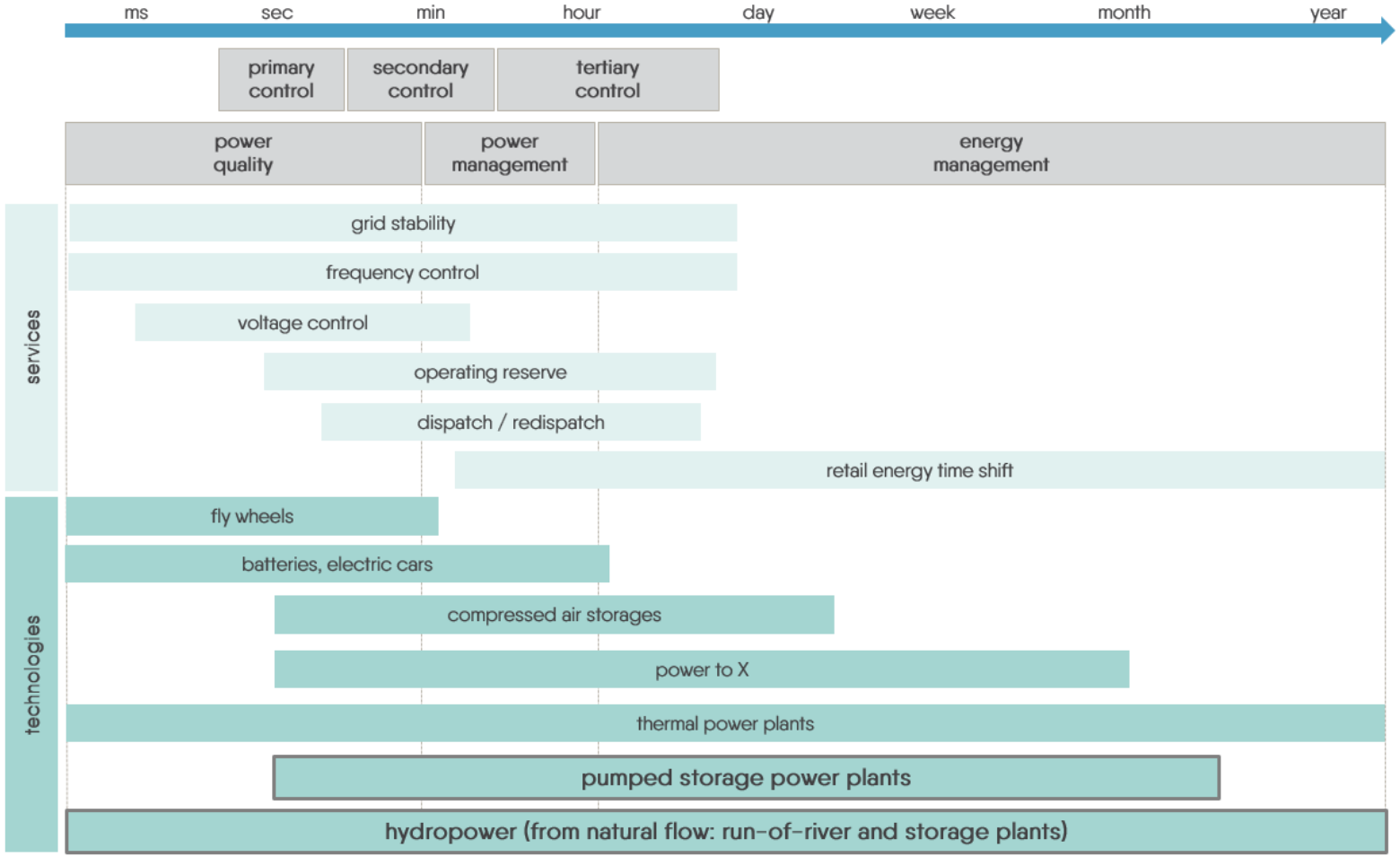
Services	Contribution to the power system
Back-up and reserve capacity	Hydropower offers back-up supply (generation can pick up load within an hour) and operating reserve capacity for bottleneck situations and longer imbalances.
Quick start capability	Hydropower is able to start operation within a few 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, Operating 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: 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

Eurelectric represents the common interests of the electricity industry at pan-European level. Our current members represent the electricity industry in over 30 European countries, including all EU Member States. We also have affiliates and associates on several other continents.

Our well-defined structure of expertise ensures that input to our policy positions, statements and in-depth reports comes from several hundred active experts working for power generators, supply companies or distribution network operators (DSOs).

We have a permanent secretariat based in Brussels, which is responsible for the overall organization and coordination of Eurelectric's activities.

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

VGB PowerTech e.V.

VGB PowerTech e.V. is the Technical Association for Generation and Storage of Power and Heat and represents all generation technologies. VGB's technological field "Hydro" provides Europe's largest platform for hydropower operators, as well as for hydropower equipment manufacturers and service providers of hydroelectric facilities.

Currently, the association represents 74 hydropower operators from 19 countries representing an installed capacity of more than 64,000 MW and some large European hydropower equipment manufacturers. More than 100 experts are actively participating in the numerous committees and groups dealing with all technological, operational and environmental aspects of hydropower plants.

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

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