

Hydropower

Lecture 3



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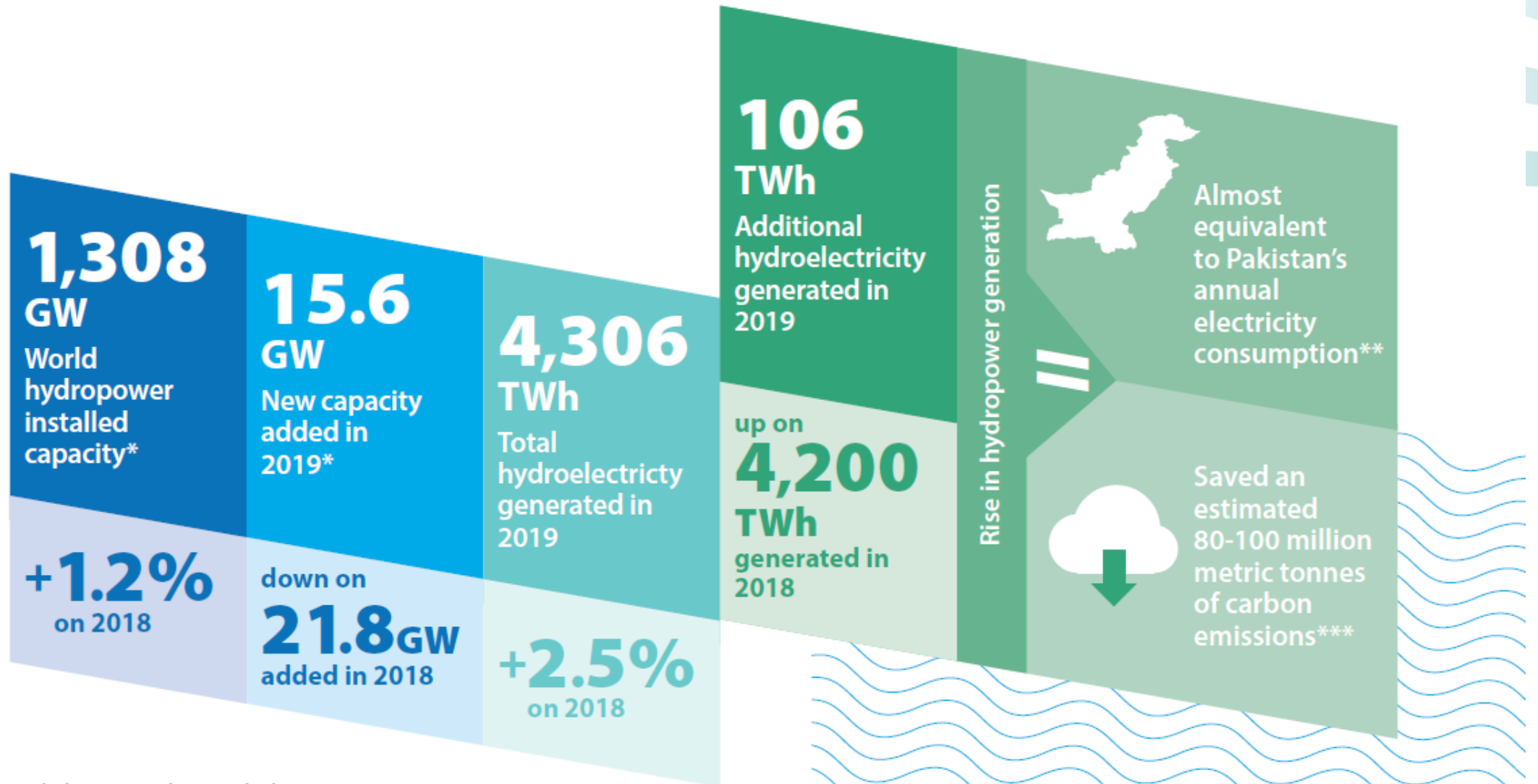
Where are we in terms of Hydropower?



Source: <https://www.globaltimes.cn/page/202107/1228661.shtml>

The Three Gorges Dam in central China's Hubei Province.

Clean electricity generation from hydropower achieved a record 4,306 TWh in 2020.



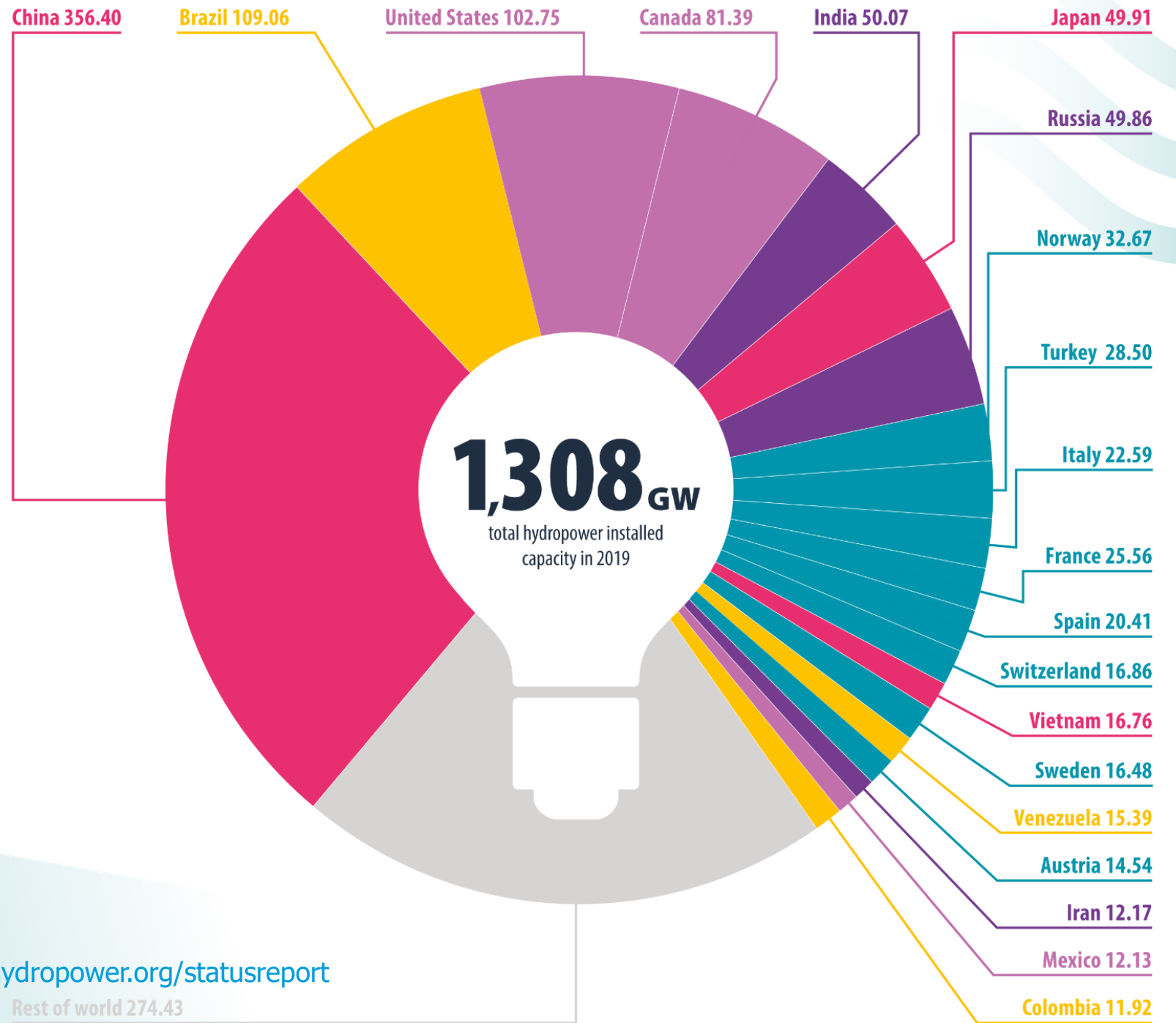
*Including pumped storage hydropower.

**Approximate based on Pakistan's total electricity consumption of 110 TWh in 2018 (IEA).

***IHA calculation if additional 106 TWh on 2018 had been generated instead by coal.

Global hydropower installed capacity

Total global hydropower installed capacity reached 1.308 (GW) in 2020. This represents an annual rise of 1.2%



Source: hydropower.org/statusreport

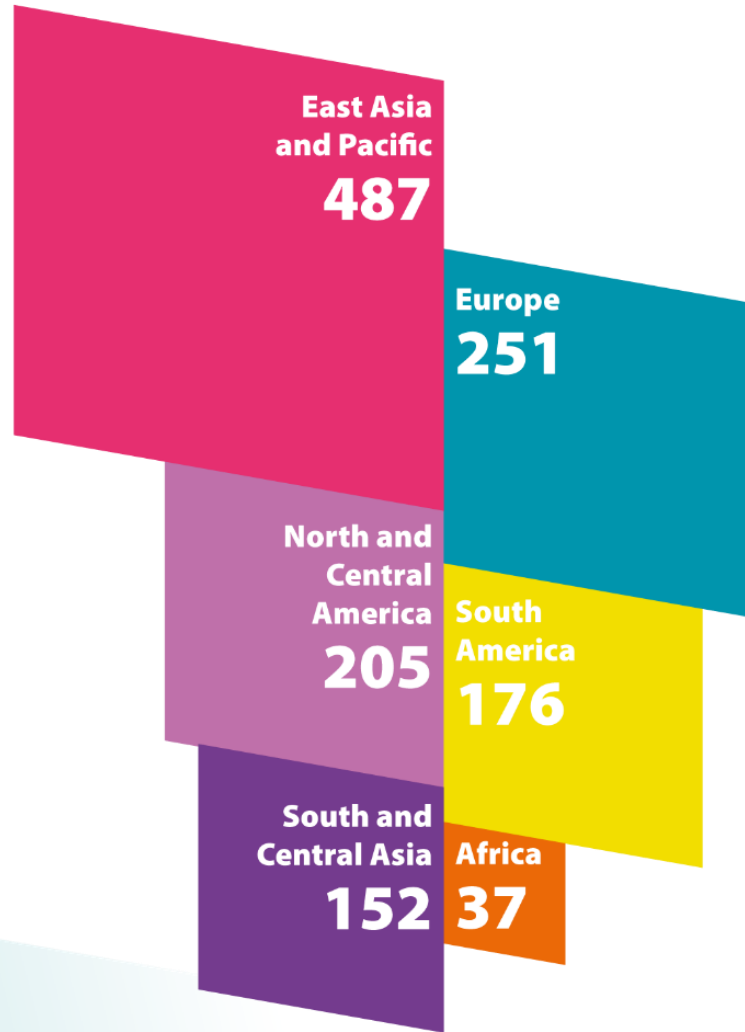
Rest of world 274.43

Hydropower capacity & generation by region

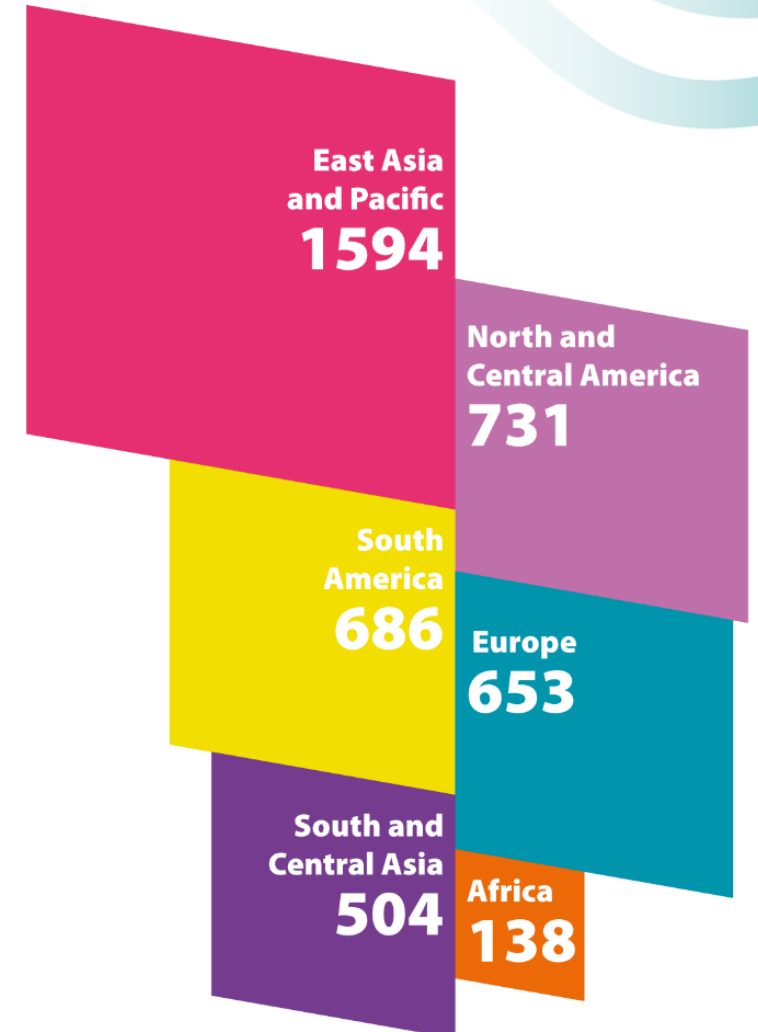
East Asia and the Pacific, thanks to the vast contribution of Chinese hydropower, remains the largest region by installed capacity at 487 GW.

Africa by contrast with its large untapped hydropower potential has the smallest installed capacity at 37 GW.

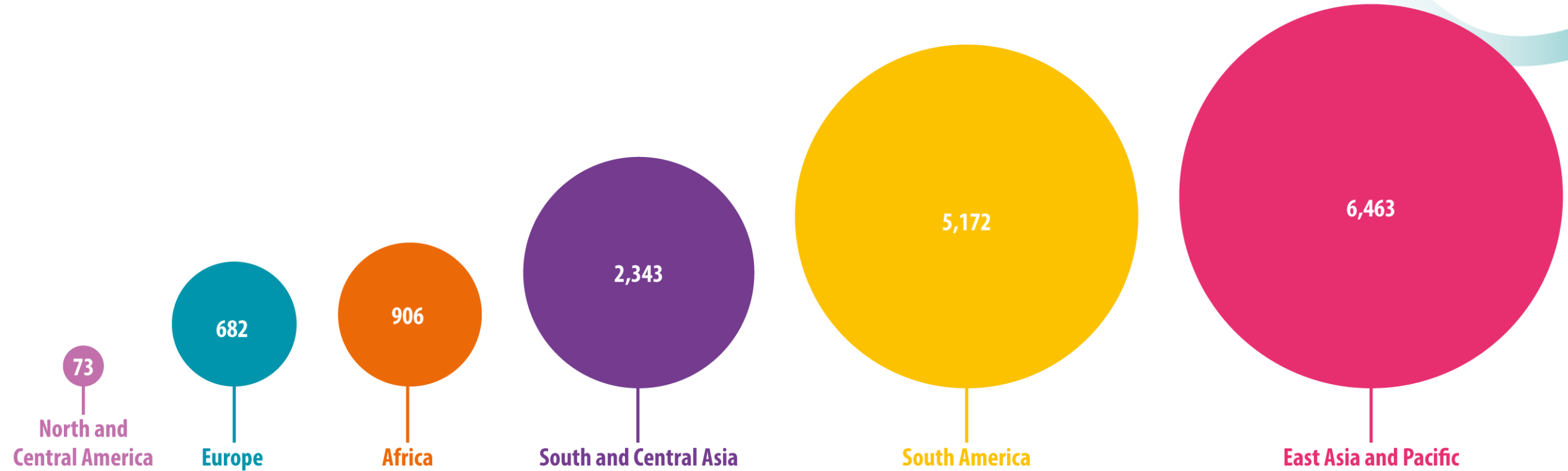
Installed capacity in GW



Estimated generation in TWh



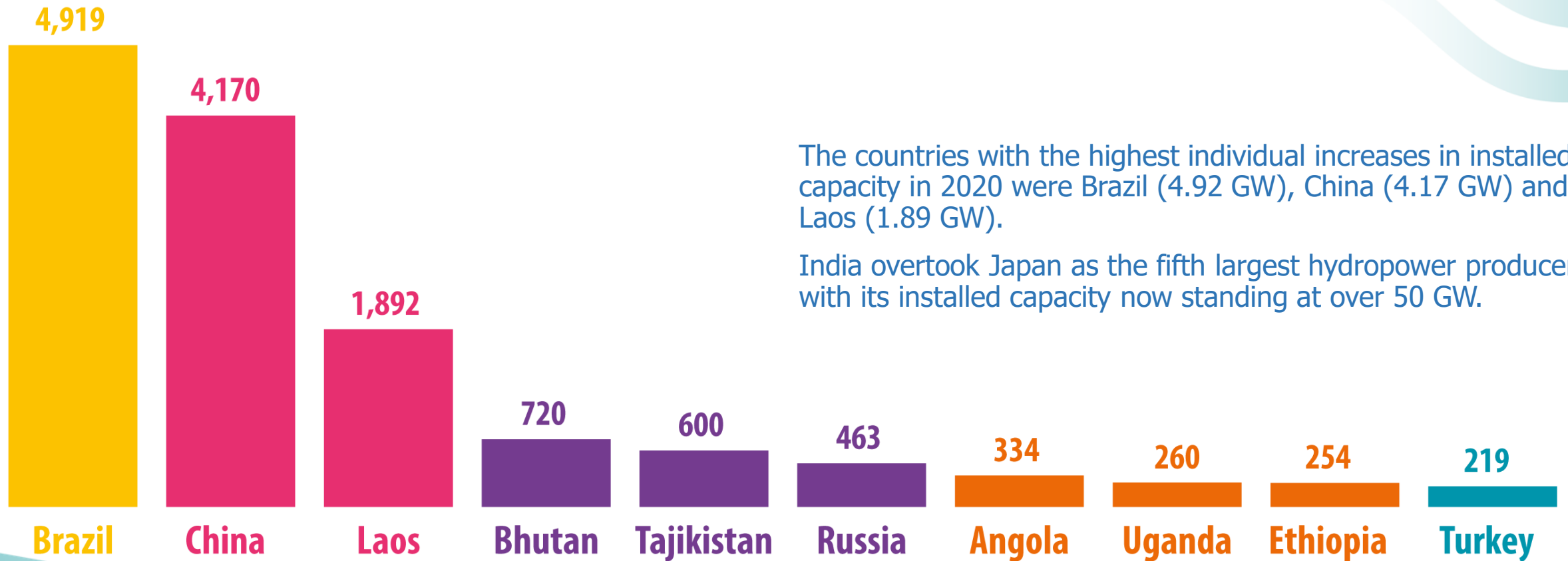
New installed capacity by region (MW)



In 2019, 50 countries added hydropower installed capacity.

The region to add the most capacity was East Asia and the Pacific, followed by South America and then South and Central Asia.

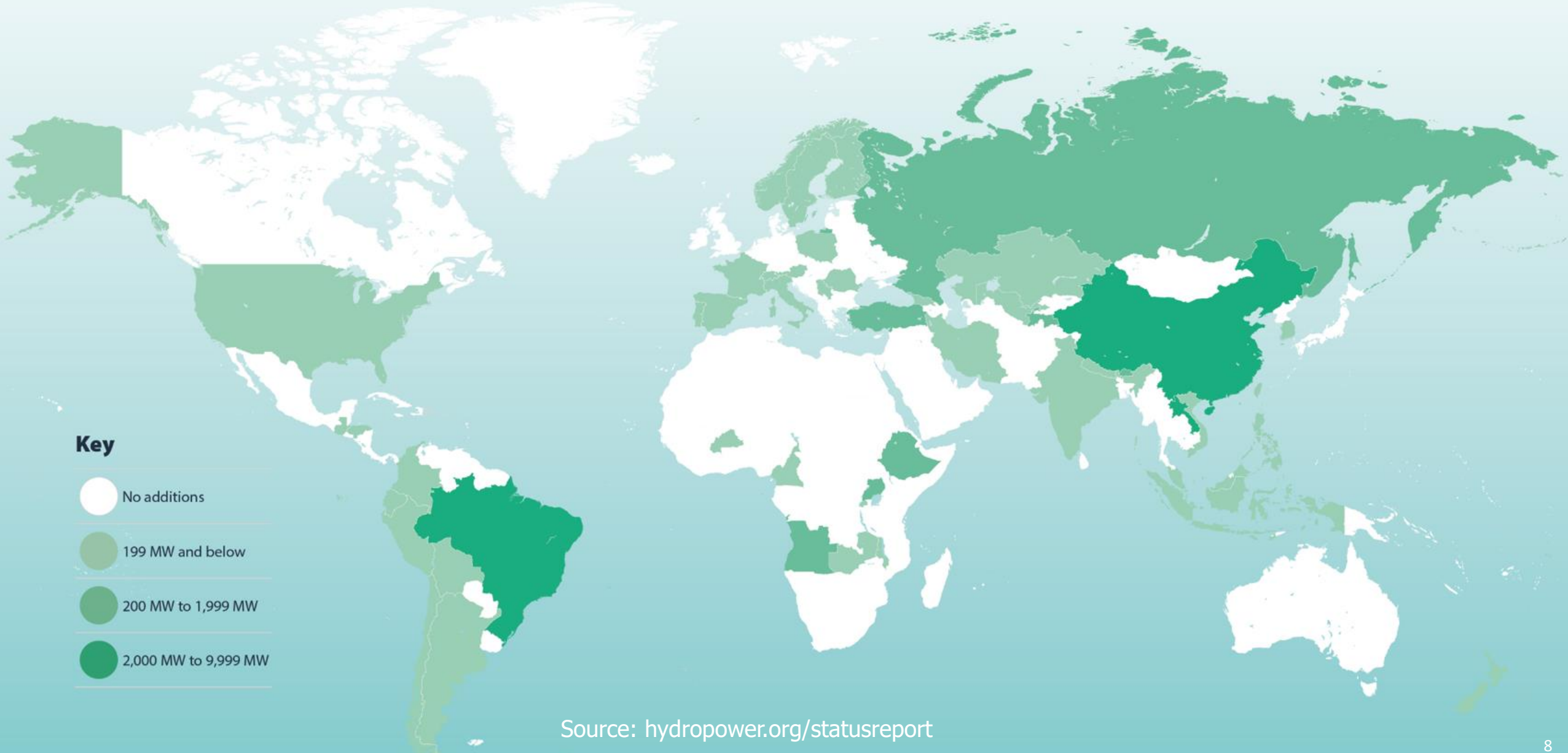
New installed capacity by country (MW)



The countries with the highest individual increases in installed capacity in 2020 were Brazil (4.92 GW), China (4.17 GW) and Laos (1.89 GW).

India overtook Japan as the fifth largest hydropower producer with its installed capacity now standing at over 50 GW.

Where has hydropower capacity been added in 2020?



Source: [hydropower.org/statusreport](https://www.hydropower.org/statusreport)

Top 20 countries by newly installed capacity

Ranking	Country	Capacity added (MW)
1	Brazil	4919
2	China	4170
3	Laos	1892
4	Bhutan	720
5	Tajikistan	600
6	Russia	463
7	Angola	334
8	Uganda	260
9	Ethiopia	254
10	Turkey	219

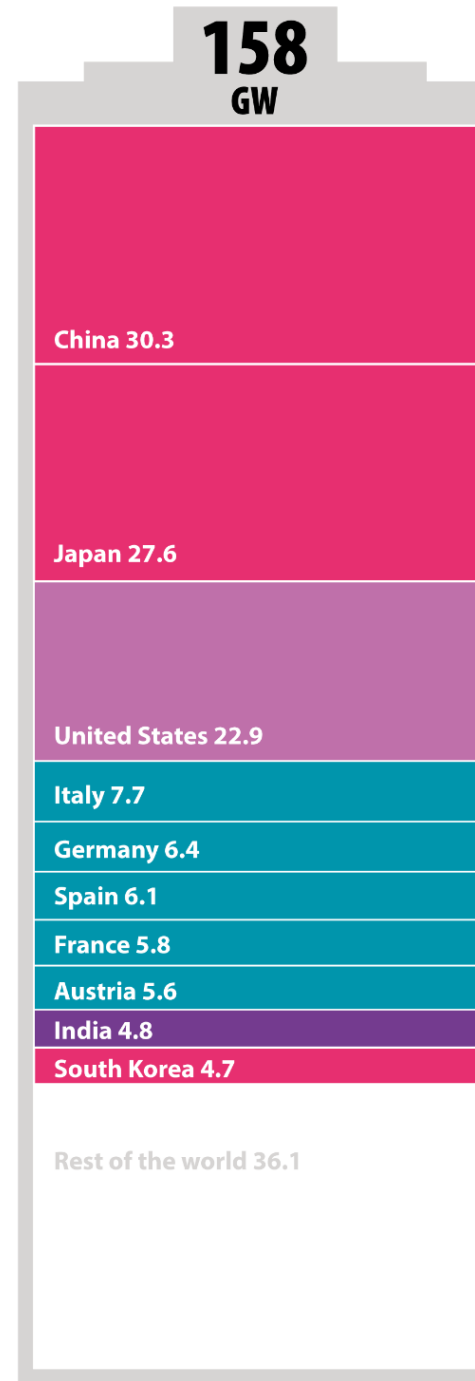
Ranking	Country	Capacity added (MW)
11	Nepal	176
12	India	154
13	Iran	150
14	Indonesia	144
15	Norway	134
16	Italy	95
17	Colombia	81
18	Malaysia	80
19	Vietnam	80
20	Bolivia	77

Global pumped storage installed capacity

Energy storage in the form of pumped storage hydropower (PSH), the world's 'water battery', supports the needs of changing power systems.

PSH currently accounts for over 94% of installed global energy storage capacity, and over 96% of energy stored in grid scale applications.

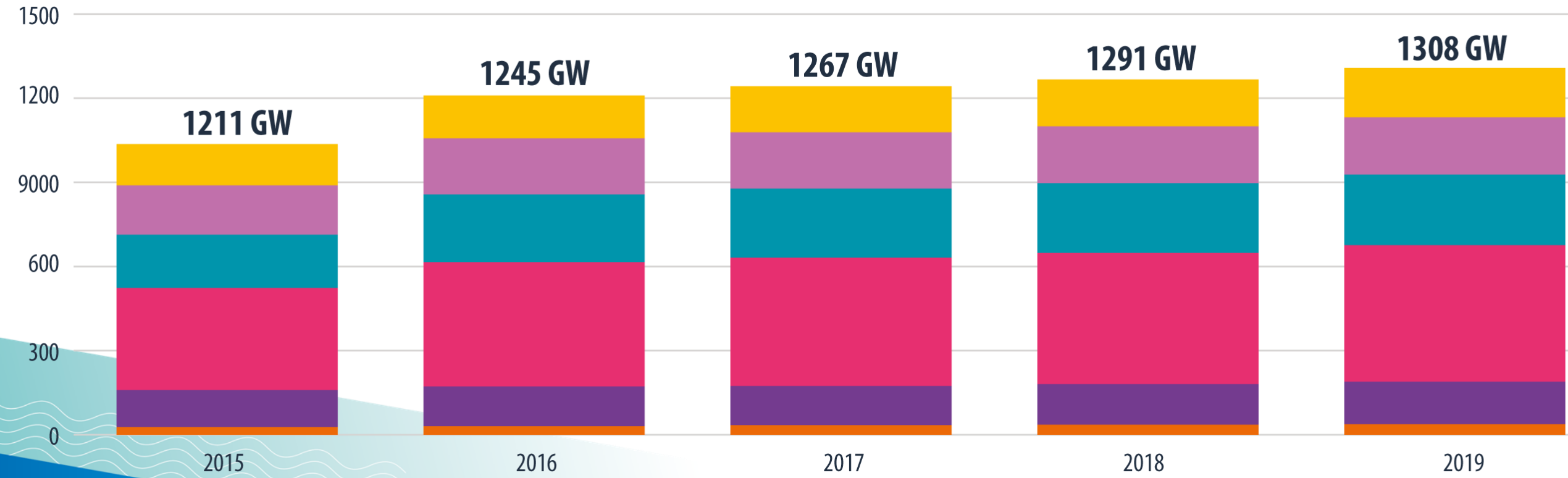
During 2019, worldwide pumped storage hydropower installed capacity grew by 304 MW.



Hydropower installed capacity growth, 2015-2020

The 2019 growth in global hydropower installed capacity to 1,308 GW represented a 1.2% annual rise.

This is down on the five-year annual average of 2.1% and well below an estimated 2.0% growth rate required to meet Paris Agreement targets.

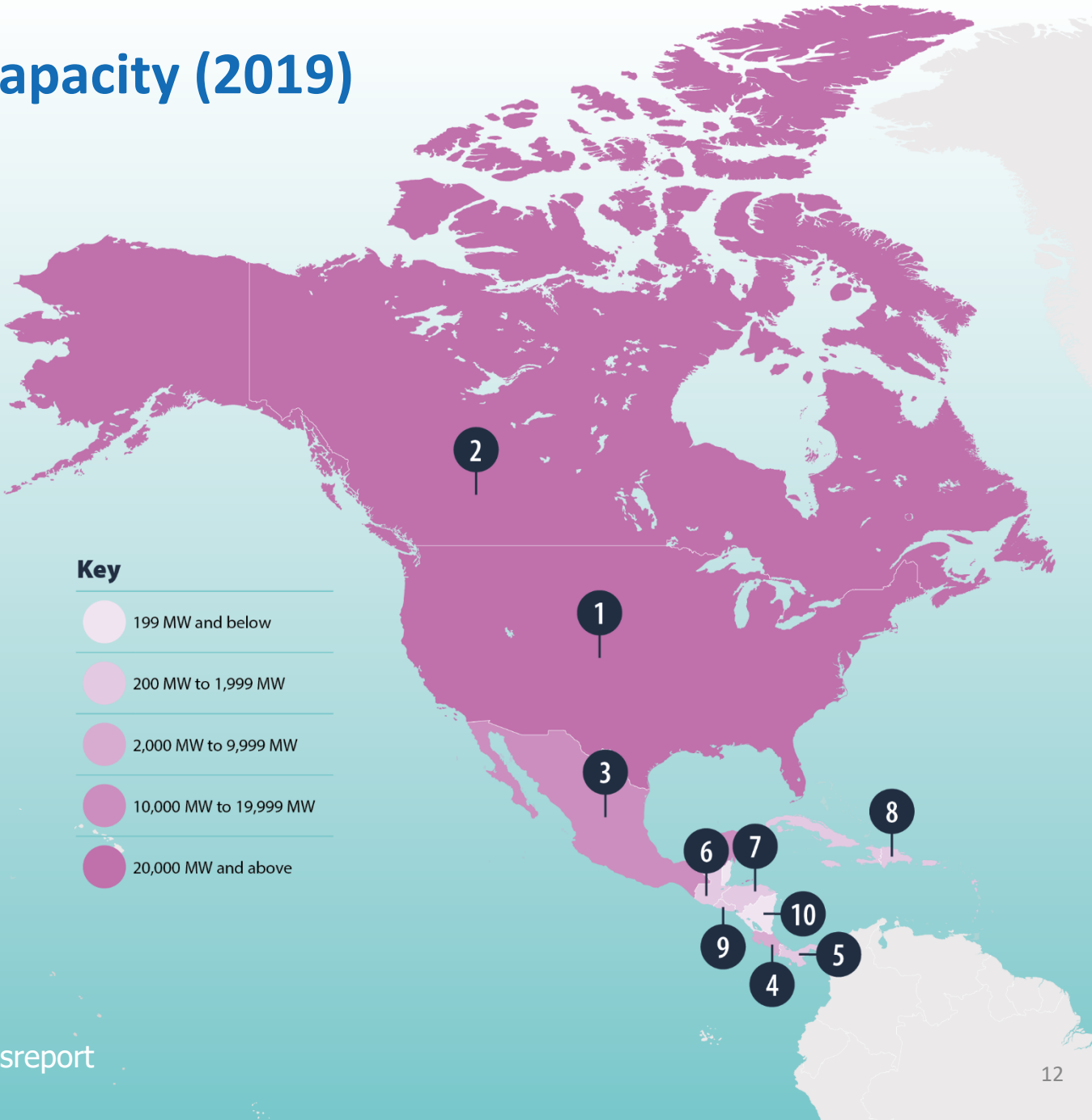
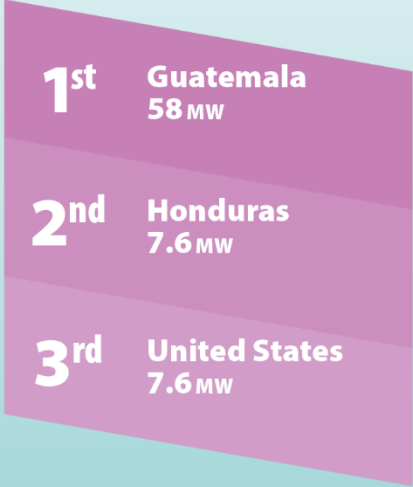


North and Central America installed capacity (2019)

North and Central America capacity by country

Rank	Country	Total installed capacity (MW)
1	United States	103,000
2	Canada	82,000
3	Mexico	12,126
4	Costa Rica	2,343
5	Panama	1,786
6	Guatemala	1,559
7	Honduras	713
8	Dominican Republic	616
9	El Salvador	575
10	Nicaragua	157

Top 3 countries by capacity added in 2019



Source: hydropower.org/statusreport

South America installed capacity (2020)

South America capacity by country

Rank	Country	Total installed capacity (MW)
1	Brazil	109,058
2	Venezuela	15,393
3	Colombia	11,918
4	Argentina	11,310
5	Paraguay	8,810
6	Chile	6,739
7	Peru	5,396
8	Ecuador	5,074
9	Uruguay	1,538
10	Bolivia	735

Top 5 countries by capacity added in 2019



Key

- 199 MW and below
- 200 MW to 1,999 MW
- 2,000 MW to 9,999 MW
- 10,000 MW to 19,999 MW
- 20,000 MW and above



Europe installed capacity (2020)

Europe capacity by country

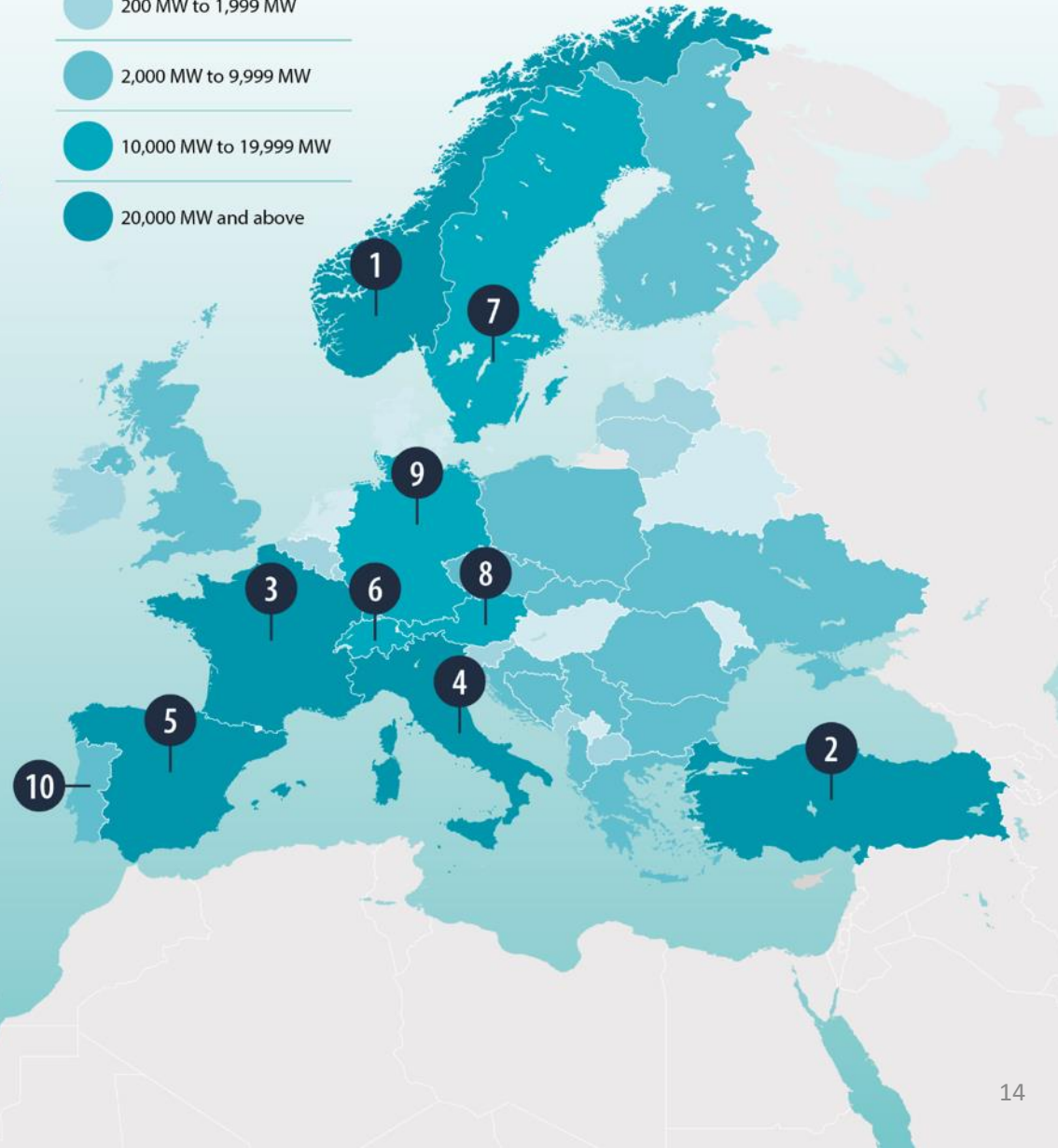
Rank	Country	Total installed capacity (MW)
1	Norway	32,671
2	Turkey	28,503
3	France	25,557
4	Italy	22,593
5	Spain	20,414
6	Switzerland	16,863
7	Sweden	16,478
8	Austria	14,545
9	Germany	11,022
10	Portugal	7,193

Top 5 countries by capacity added in 2019



Key

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-  20,000 MW and above

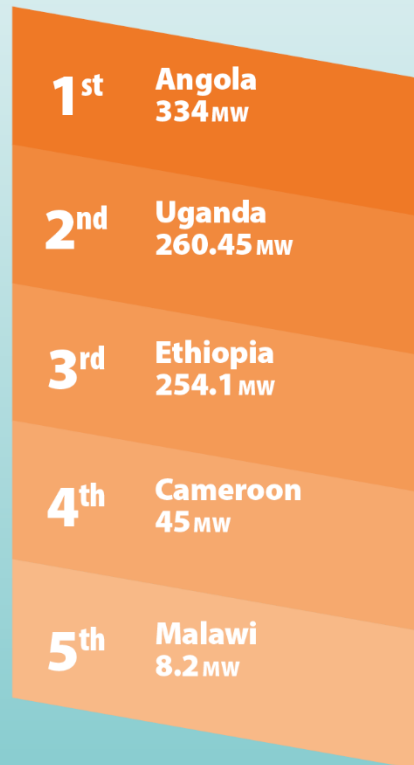


Africa installed capacity (2020)

Africa capacity by country

Rank	Country	Total installed capacity (MW)
1	Ethiopia	4,074
2	South Africa	3,596
3	Angola	3,435
4	Egypt	2,876
5	Democratic Republic of the Congo	2,750
6	Zambia	2,400
7	Mozambique	2,216
8	Nigeria	2,110
9	Sudan	1,923
10	Morocco	1,770

Top 5 countries by capacity added in 2019



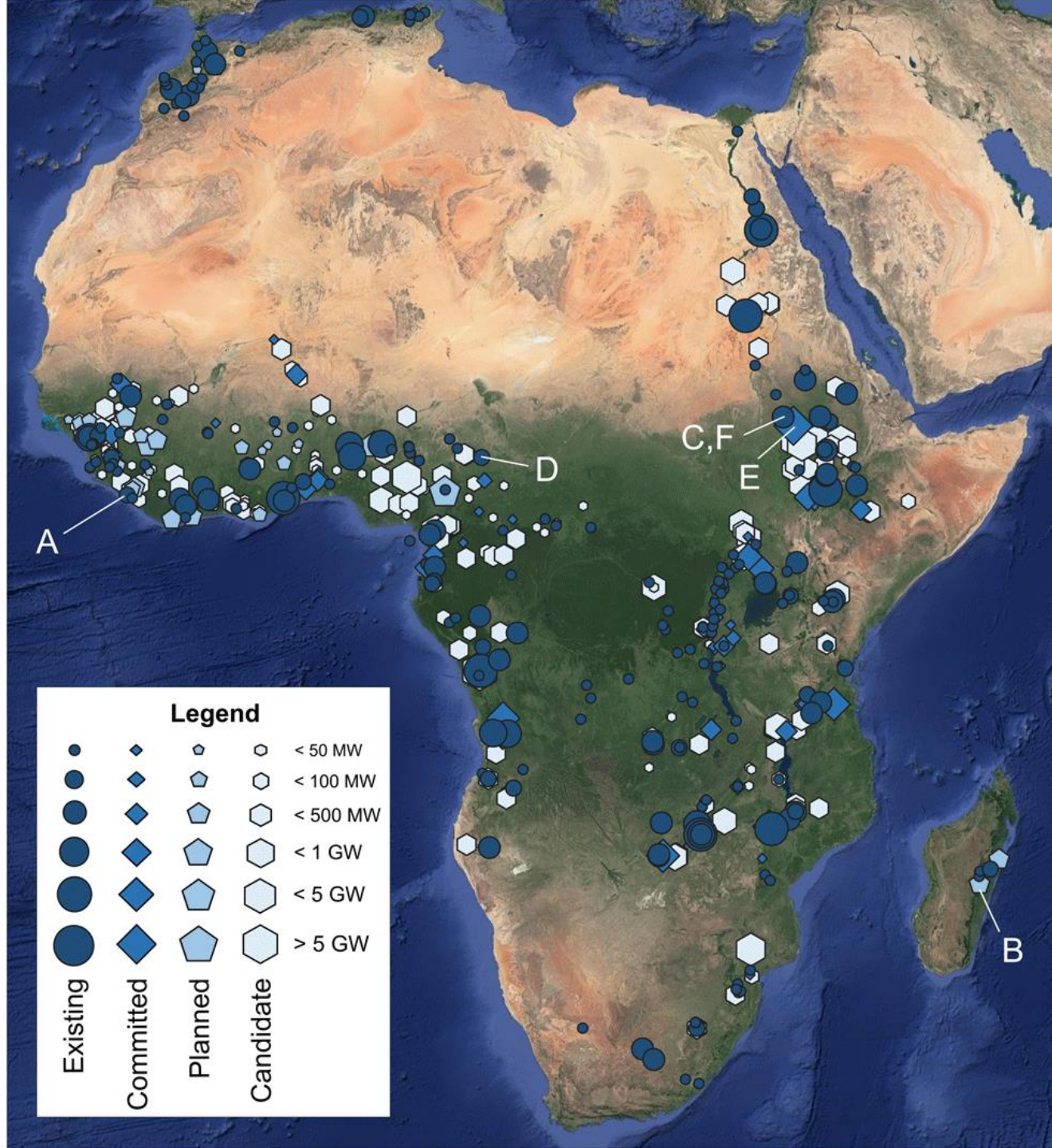
Key



Africa current & future situation

An overview of the georeferenced African hydropower plants by category

Source: doi: 10.12688/openreseurope.13392.2

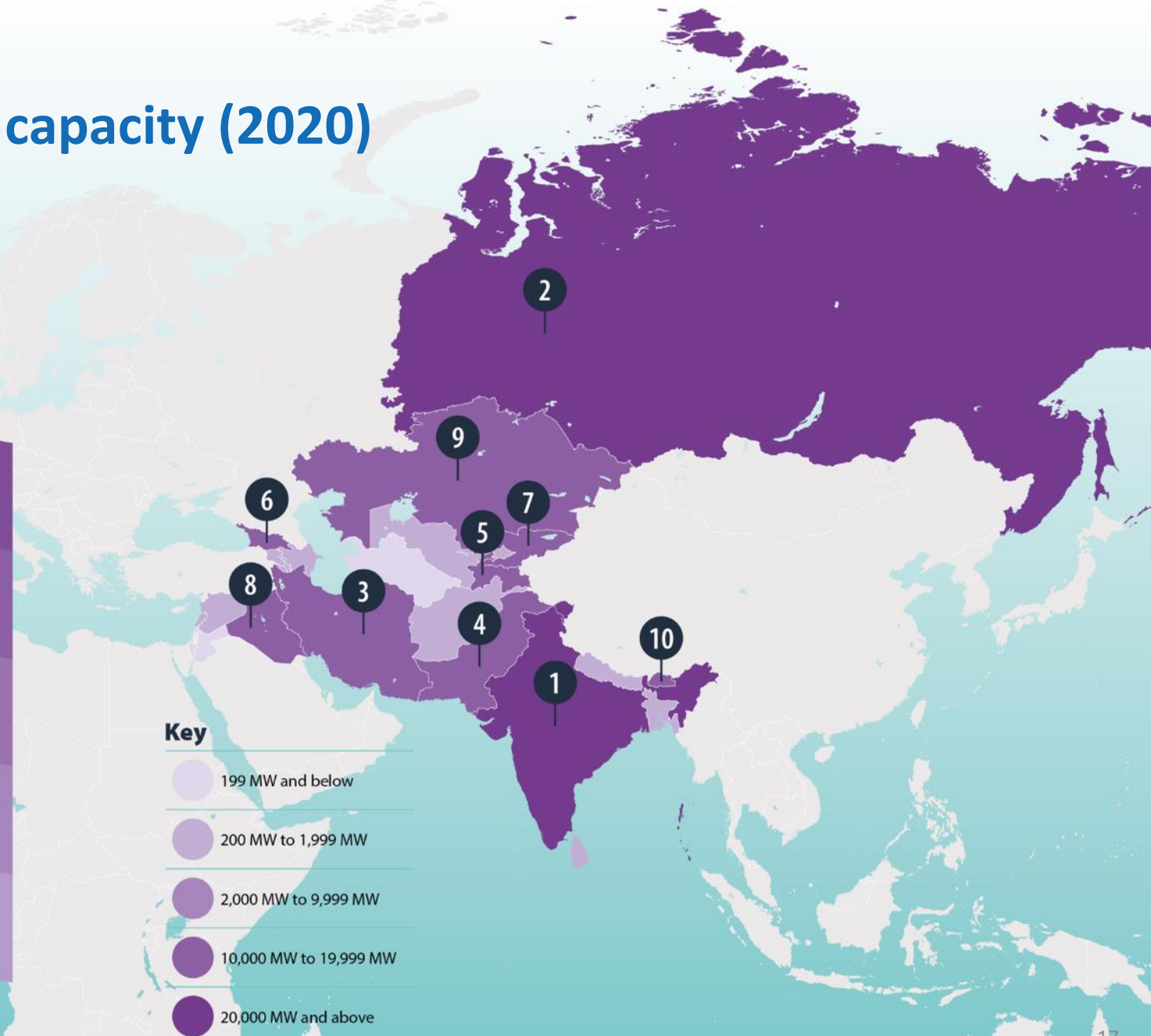


South and Central Asia installed capacity (2020)

South and Central Asia capacity by country

Rank	Country	Total capacity in 2019 (MW)
1	India	50,070
2	Russia	49,859
3	Iran	12,169
4	Pakistan	9,827
5	Tajikistan	6,395
6	Georgia	3,271
7	Kyrgyzstan	3,070
8	Iraq	2,753
9	Kazakhstan	2,598
10	Bhutan	2,326

Top 5 countries by capacity added in 2019



East Asia and Pacific installed capacity (2020)

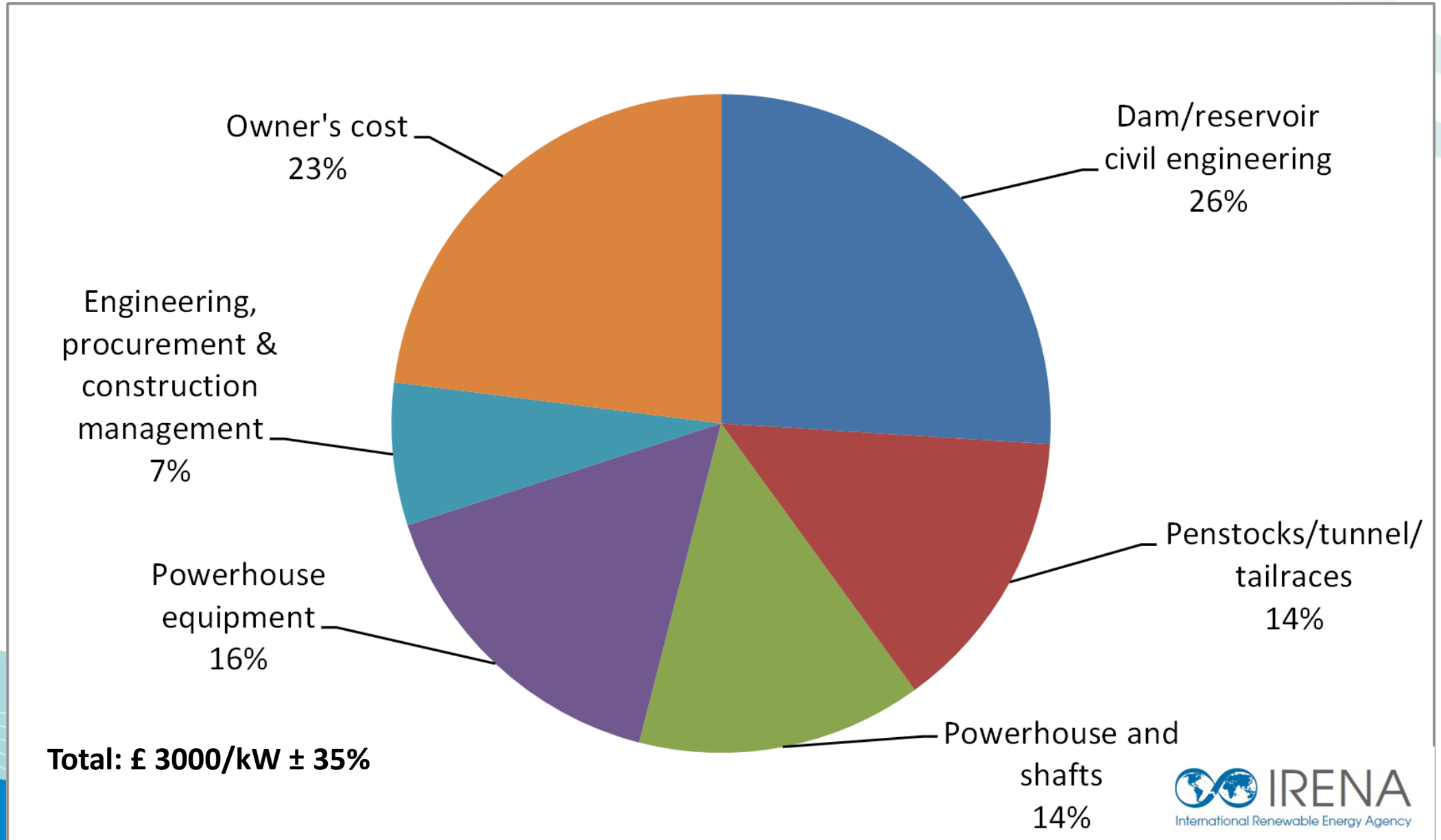
East Asia and Pacific capacity by country

Rank	Country	Total installed capacity (MW)
1	China	3,56400
2	Japan	4,9905
3	Vietnam	1,6759
4	Australia	8,790
5	Laos	7,200
6	South Korea	6,508
7	Malaysia	6,174
8	Indonesia	5886
9	New Zealand	5,354
10	North Korea	5,010

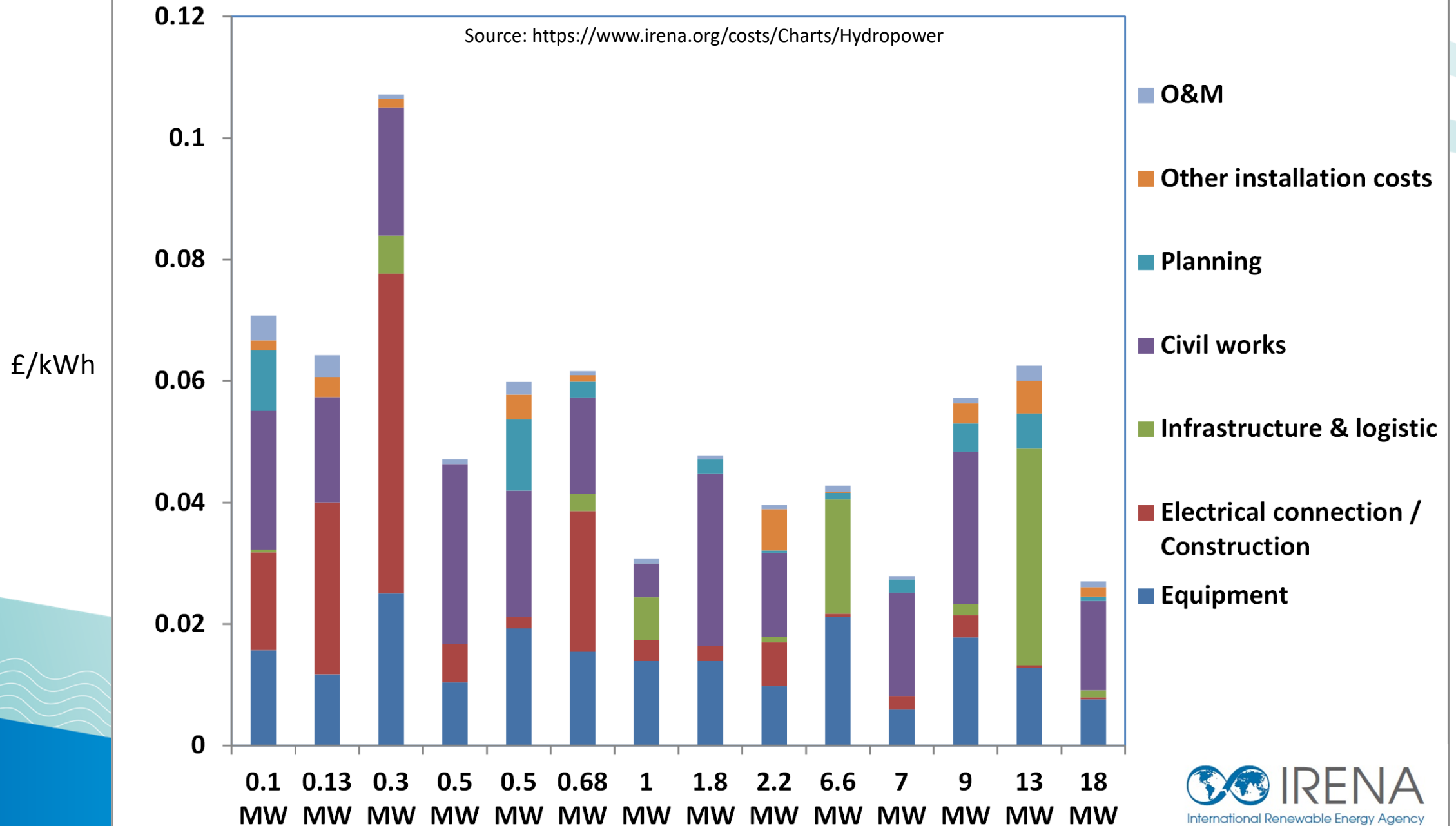
Top 5 countries by capacity added in 2019



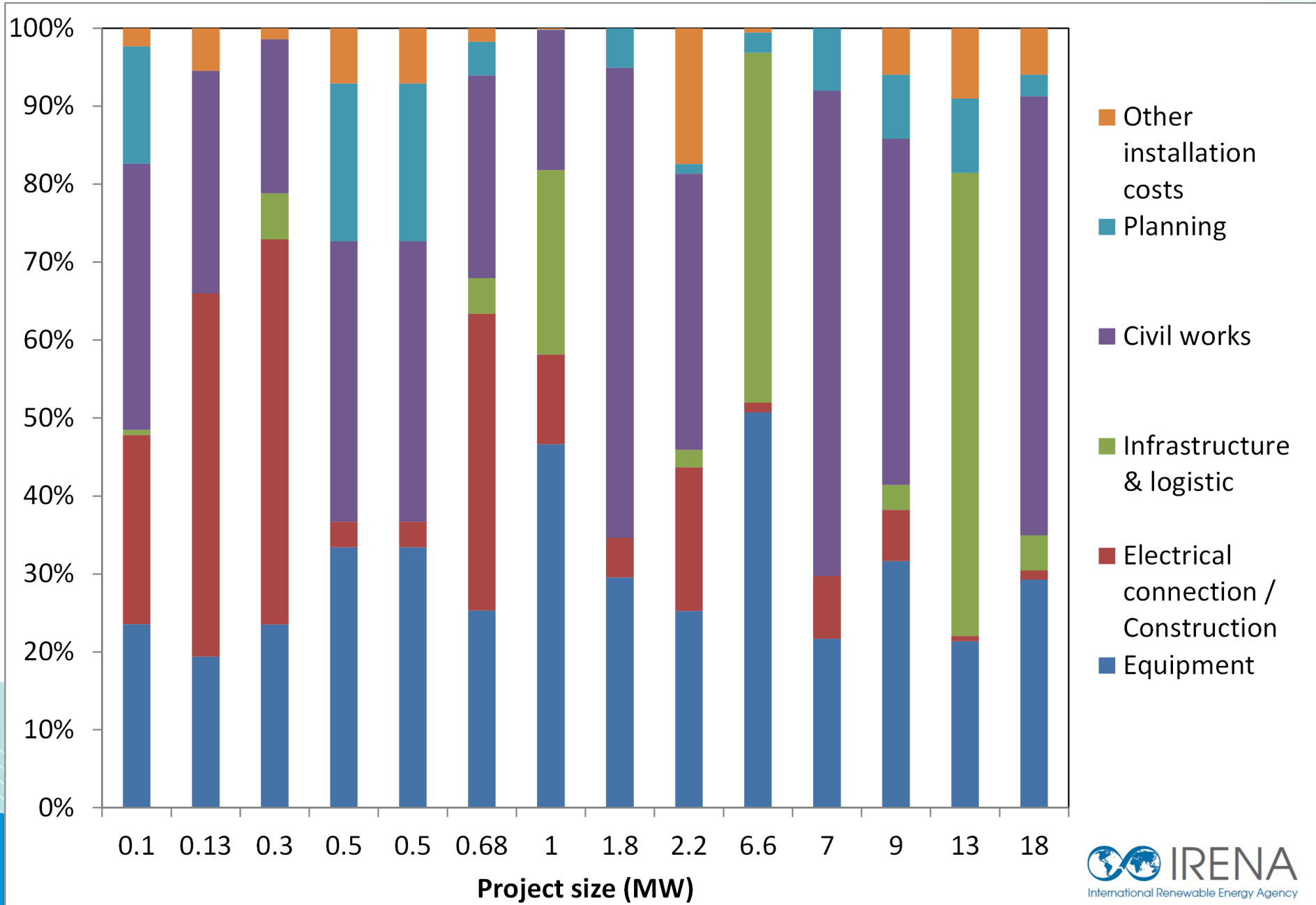
Cost breakdown of an indicative 500 MW greenfield hydropower project



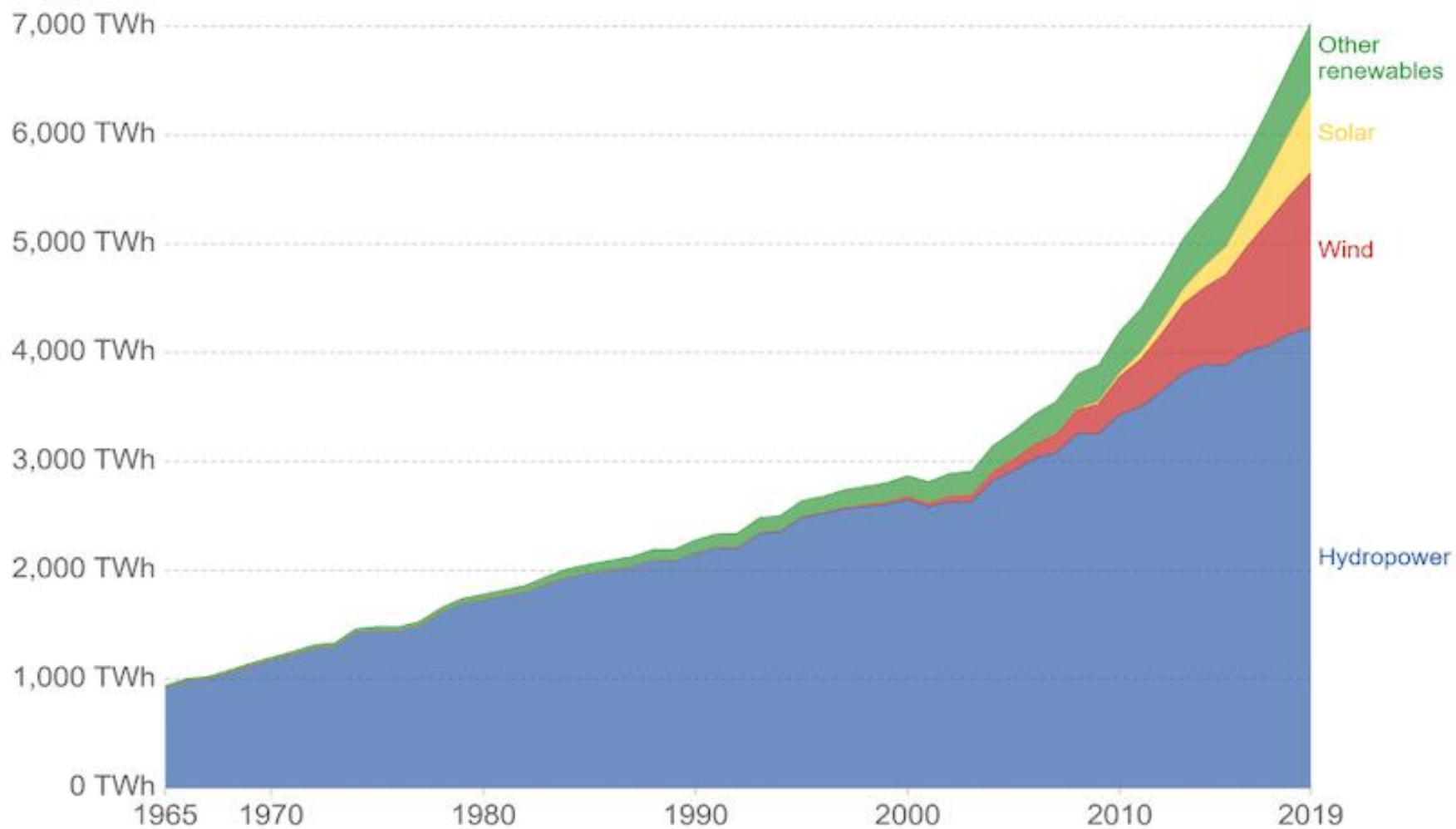
LCOE of small hydropower projects in developing countries



Capital cost breakdown of small-scale hydro projects in Africa



Renewable Energy Generation World



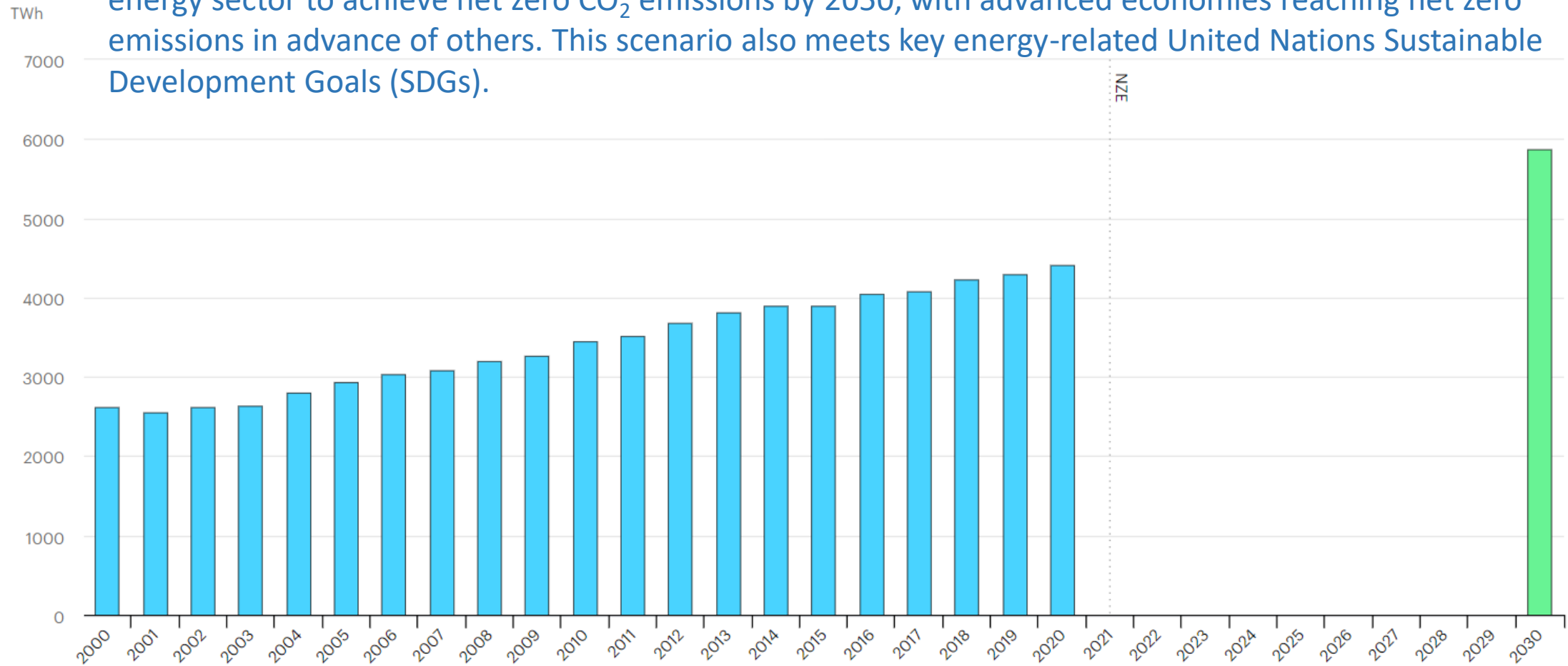
Source: BP Statistical Review of Global Energy

OurWorldInData.org/renewable-energy • CC BY

Note: 'Other renewables' refers to renewable sources including geothermal, biomass, waste, wave and tidal. Traditional biomass is not included.

Hydropower generation & Energy policies

The Net Zero Emissions by 2050 Scenario (NZE). This is a narrow but achievable pathway for the global energy sector to achieve net zero CO₂ emissions by 2050, with advanced economies reaching net zero emissions in advance of others. This scenario also meets key energy-related United Nations Sustainable Development Goals (SDGs).



Source: <https://www.iea.org/data-and-statistics/charts/hydropower-generation-in-the-net-zero-scenario-2000-2030>

International Environmental Protocols

- Montreal Protocol (1989)
- United Nation Convention on Climate Change (1992)
- Berlin Mandate (COP 1, 1995)
- Kyoto Protocol (COP 3, 1997)
- The Hague Convention (COP 6, 2000), Bonn (COP 6, 2001) and Marrakech (COP 7, 2001)
- Paris Agreement (2015)
- UN Climate Change Conference, Glasgow (COP 26, 2021)



1. Secure global net zero by mid-century and keep 1.5 degrees within reach.
2. Adapt to protect communities and natural habitats.
3. Mobilise finance (at least \$100bn in climate finance per year by 2030).
4. Work together to deliver.

“Climate Change and Nuclear War are the two most dangerous threats to the human species” Noam Chomsky, MIT

UN's Sustainable Development Goals



UN's Sustainable Development Goals

SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all



Targets	Indicators
<p>7.1. By 2030, ensure universal access to affordable, reliable and modern energy services</p>	<p>7.1.1. Proportion of population with access to electricity</p> <p>7.1.2. Proportion of population with primary reliance on clean fuels and technology</p>
<p>7.2. By 2030, increase substantially the share of renewable energy in the global energy mix</p>	<p>7.2.1. Renewable energy share in the total final energy consumption</p>
<p>7.3. By 2030, double the global rate of improvement in energy efficiency</p>	<p>7.3.1. Energy intensity measured in terms of primary energy and GDP</p>
<p>7.A. By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology</p>	<p>7.A.1. Mobilized amount of United States dollars per year starting in 2020 accountable towards the \$100 billion commitment</p>
<p>7.B. By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support</p>	<p>7.B.1. Investments in energy efficiency as a percentage of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services</p>

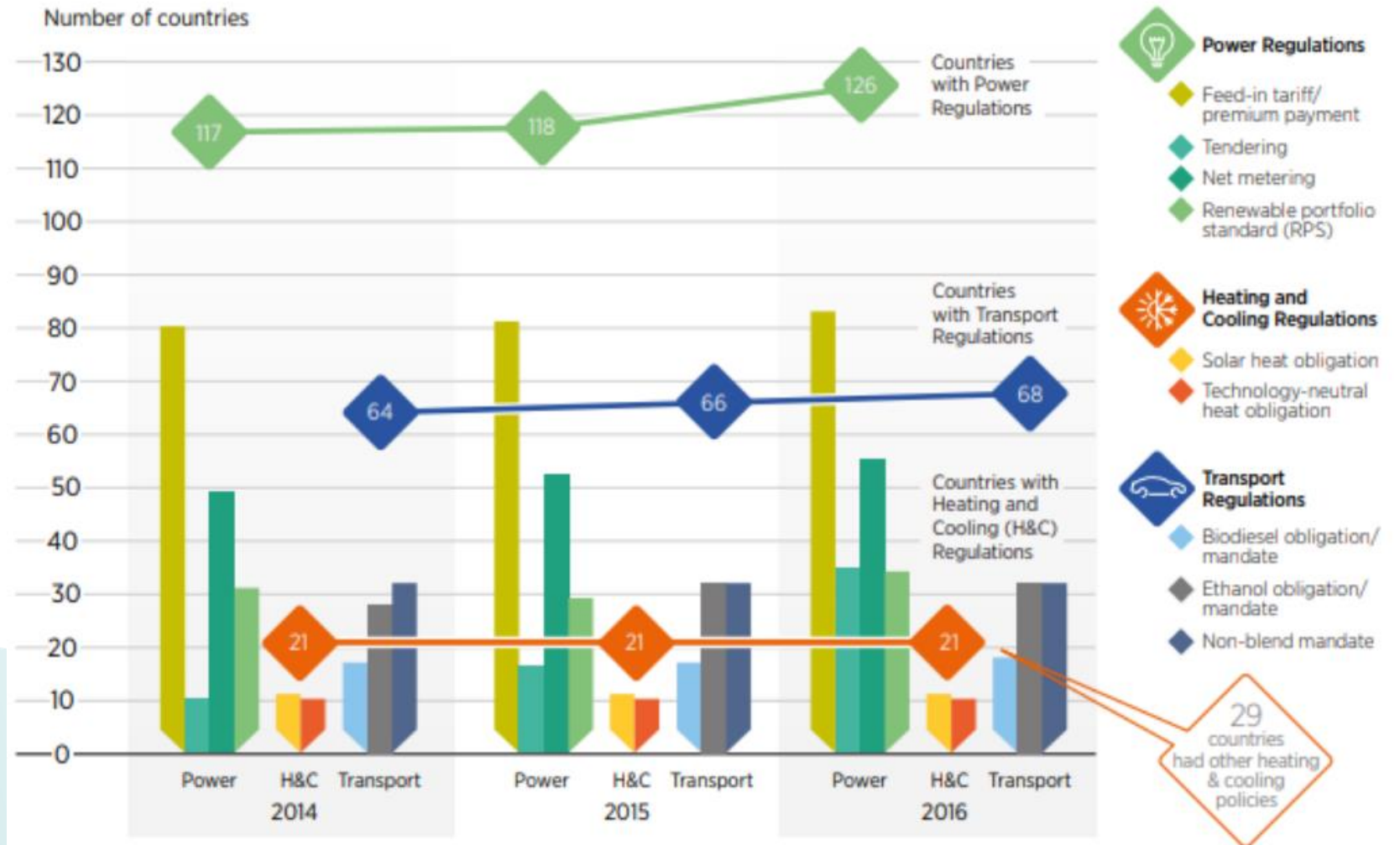
Key RE Policy Types

Regulatory Policies

- Feed-in Tariffs (FITs)/ Net metering
- Electric Utility Quota Obligation/Renewable Obligation Certificates (ROCs)
- Biofuel Obligation Mandate

Financial Policies

- Capital subsidies & grants
- Energy production payment/FIT
- Production tax credits



Key RE Policy Types

Renewable Heat Incentive (RHI)

Eligibility criteria

Ownership

Use of heat

Metering

MCS* accreditation (Microgeneration Certification Scheme).

Eligible technologies

Size limits

- Solar heating (water) 19.74 p/kWh
- Biomass > 1MWth 1 p/kWh
- Biomass < 1MWth
 - Tier 1 (up to 1314 hours) 5.0 – 8.6 p/kWh
 - Tier 2 (over 1314 hours) 2.1 – 2.2 p/kWh
- Biogas 7.3 p/kWh
- GSHP (Heat Pumps) 3.5 – 4.8 p/kWh

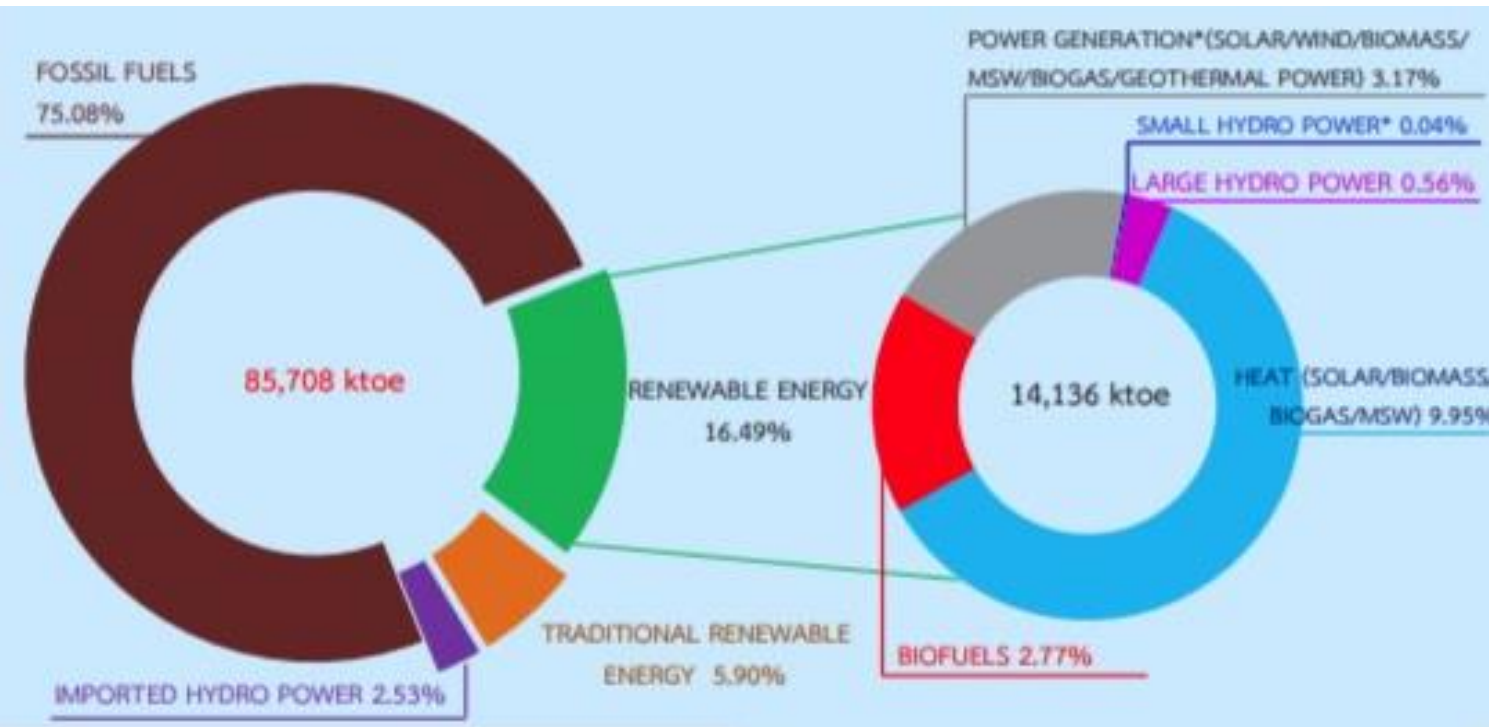
Tariffs according to technology and size

Domestic and non-domestic

0.82 p/kWh to 19.7 p/kWh

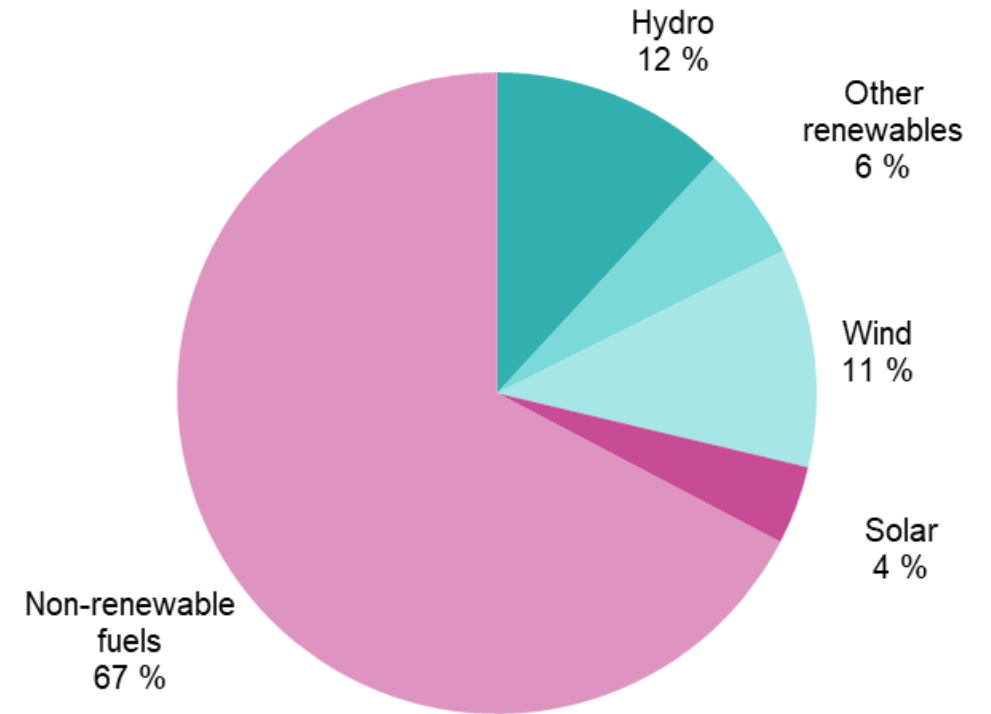
*MCS is an industry-led quality assurance scheme, which demonstrates the quality and reliability of approved products and installation companies

Share of RES in total gross electricity production



In Thailand 2019 (GWh)

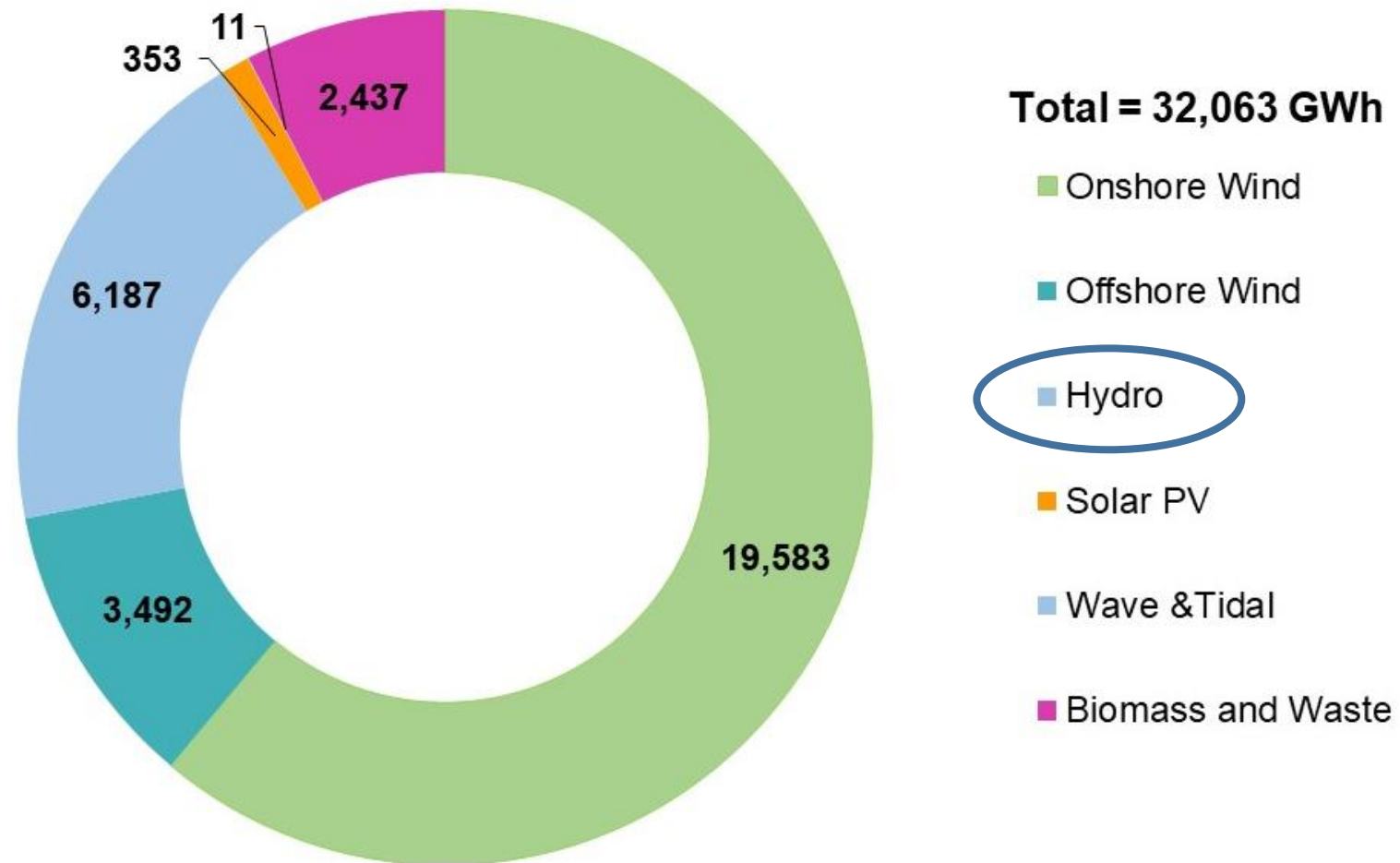
Source: <https://www.trade.gov/energy-resource-guide-thailand-renewable-energy>



In EU-27 in 2020 (GWh)

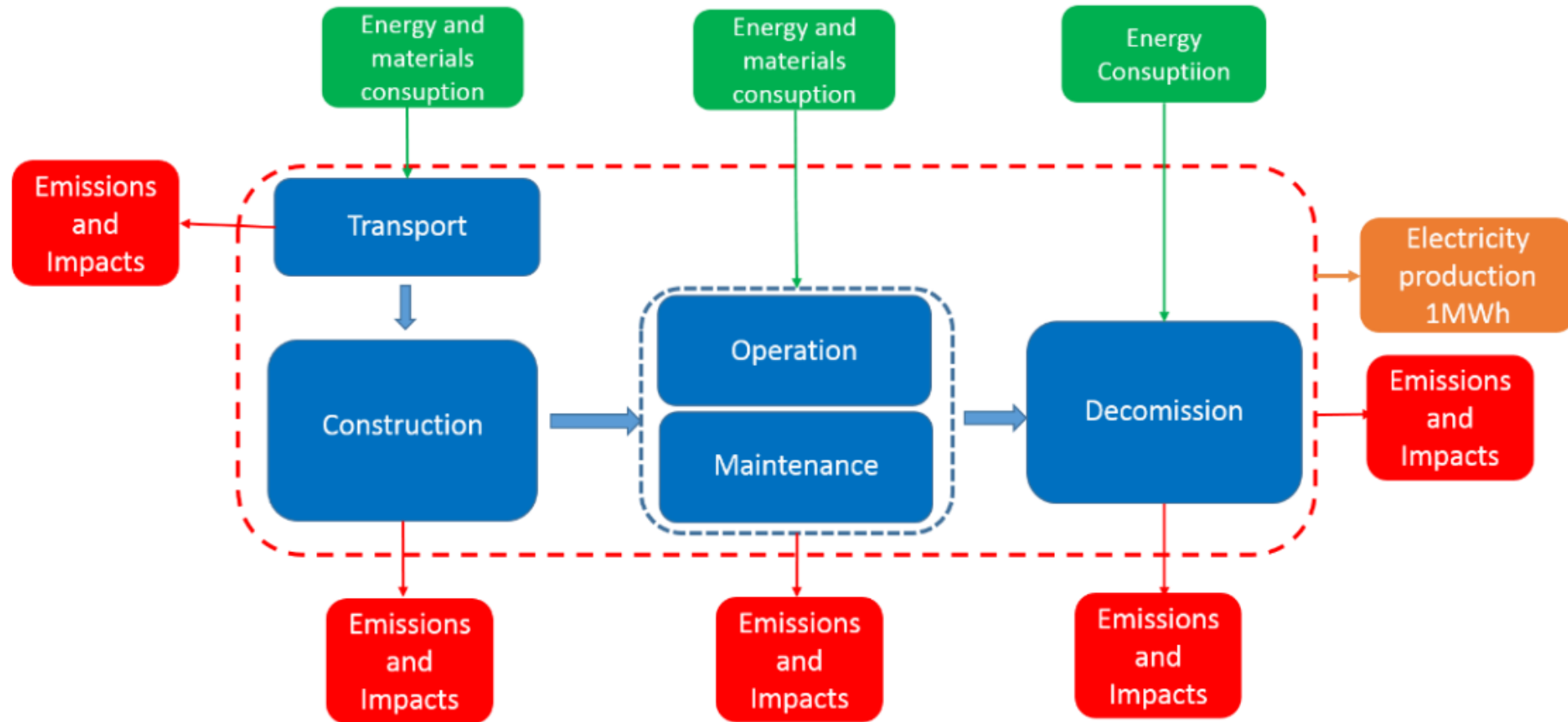
Source: Eurostat

Electricity output by RE technology 2020 (GWh)



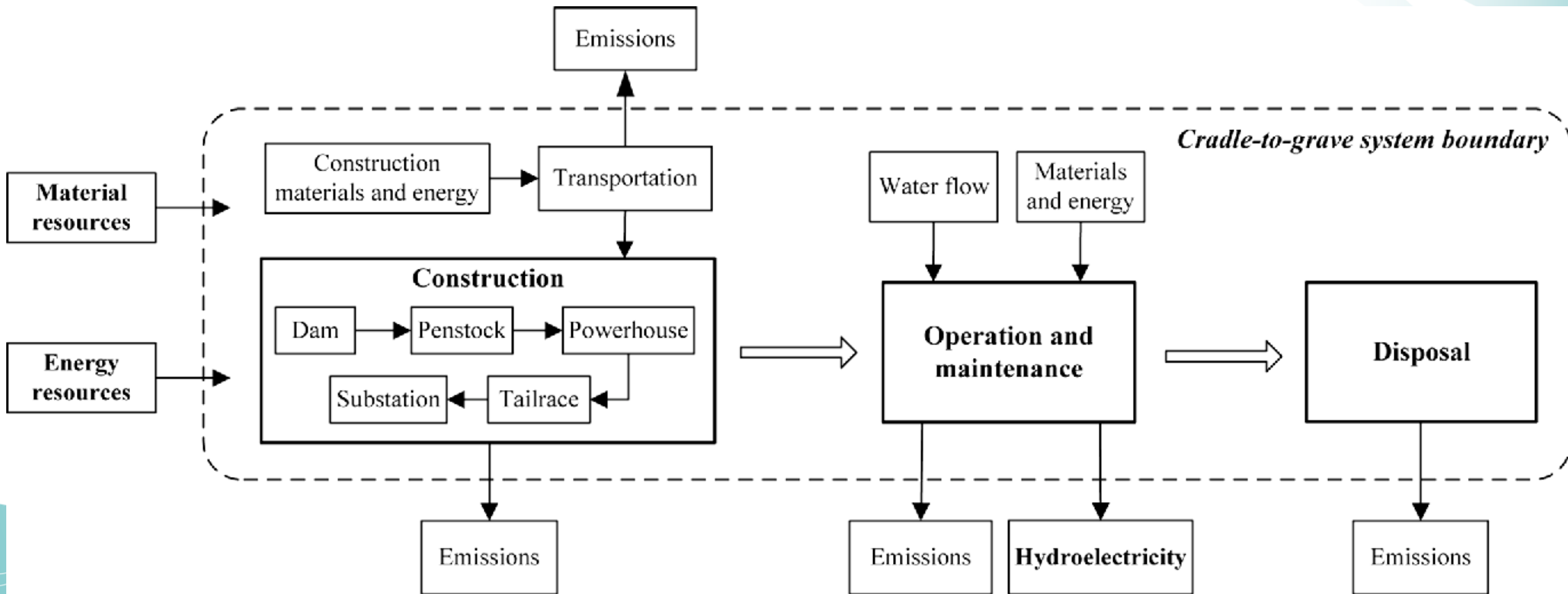
Note: Biomass and Waste includes biomass (1,996 GWh), landfill gas (407 GWh) and sewage sludge digestion (34 GWh).

Life cycle of hydropower plants



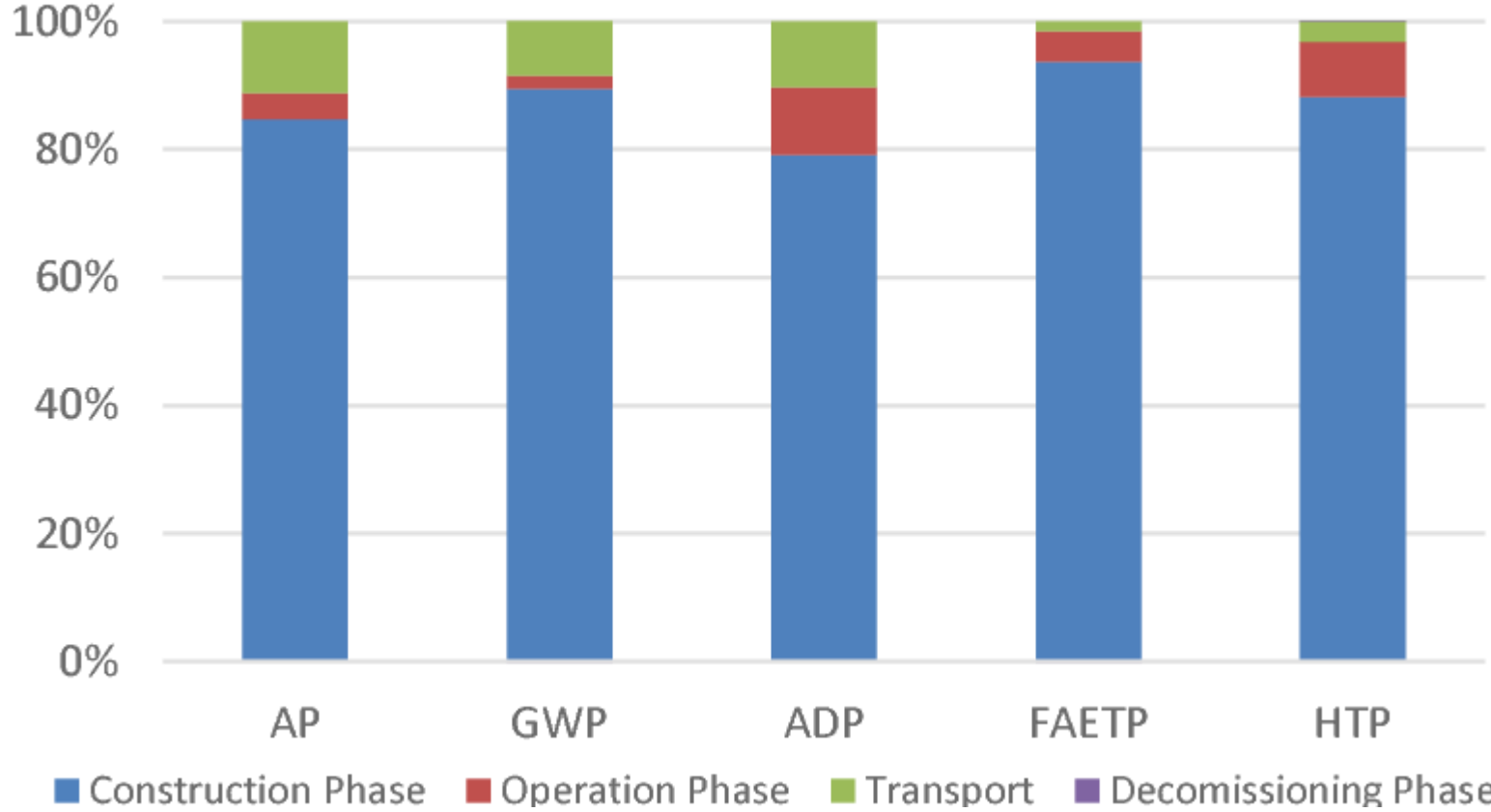
Source: <https://www.semanticscholar.org/paper/Life-Cycle-Assessment-of-a-Small-Hydropower-Plant-Geller-Meneses/09b5436247cbf9f26aedd957db3b1d8bd5cc9565/figure/1>

Life cycle of hydropower plants



Source: <https://www.semanticscholar.org/paper/Environmental-life-cycle-assessment-of-a-small-in-Pang-Zhang/523b599b34ce00440faba372ccf5cc35fbb6e76b>

Life cycle of hydropower plants



Life Cycle Impacts Assessment (LCIA)

- (AP) Acidification Potential
- (GWP) Global Warming Potential -100 years
- (ADP) Abiotic Depletion Resources
- (FAETP) Freshwater Aquatic Ecotoxicity Potential
- (HTP) Human Toxicity Potential

↓
dams are not removed, but abandoned or replaced

Life Cycle Impacts Assessment (LCIA)

Acidification Potential (AP). Acidification results of the sulphur dioxide (SO₂), ammonia (NH₄) or nitrogen oxides (NO_x) reaction with water, causing the “acid rain”. It is expressed using the reference unit, kg SO₂

Global Warming Potential (GWP – 100 years). Potential global warming expresses the climate changes referent to the global temperature caused by “greenhouse gases” released by human activity. GWP is expressed as over the time horizon of different years, being the most common 100 years (GWP100), measured in the reference unit, kg CO₂

Abiotic Depletion Resources (ADP). This impact category refers to the consumption of non-biological resources such as fossil fuels, minerals, metals, water, etc

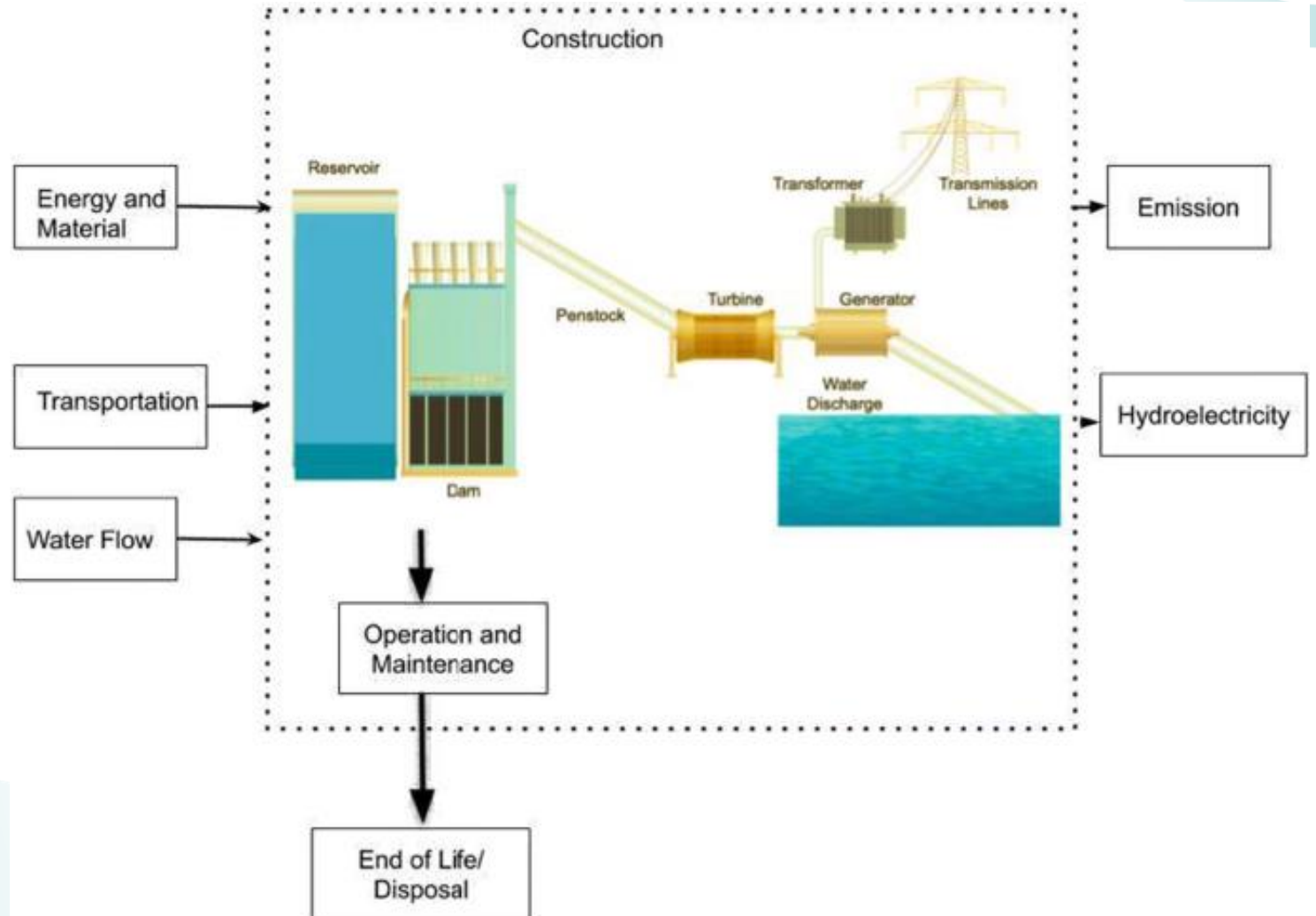
Freshwater Aquatic Ecotoxicity Potential (FAETP). Environmental toxicity is the toxic effects of chemical on an ecosystem, in this case in the freshwater, causing biodiversity loss and/or species extinction

Human Toxicity Potential (HTP). The HTP is considered the toxic effects of chemicals on humans. It reflects the potential harm of a unit of chemical released into the environment that are caused, for the most part, by electricity production from fossil sources

Impact category	Reference unit	Complete life cycle 29,976,720 MWh normal level (100y)	Complete life cycle 22,110,240 MWh low level (100y)
Acidification potential – AP	[kg SO ₂ eq]	0.0223	0.0321
Climate change – GWP 100a	[kg CO ₂ eq]	5.4659	7.6228
Depletion of abiotic resources – ADP	[kg antimony eq]	0.0312	0.0489
Freshwater aquatic ecotoxicity – FAETP	[kg 1.4-DCB eq]	2.4505	3.3790
Human toxicity – HTP 100a	[kg 1.4-DCB eq]	7.2858	9.9819

Simplified product system boundary for a hydropower plant

In LCA studies, the disposal stage of a hydropower station is essential. It is assumed that 30% of the equipment, materials, are being recycled and the rest are sent to a nearby landfill for disposal.



Impact of hydropower



Source: Diego Gelmetti

VS



Source: Esmail Babaeil