HYDROELECTRIC POWER WORLDWIDE

INDUSTRY ANALYSIS AND FORECAST

AUGUST 2023

INTRODUCTION

- Hydropower is one of the oldest, largest, and most reliable sources of renewable energy and is larger than all other renewables combined (wind, solar, bioenergy and geothermal), although it is losing market share as growth in wind and solar generation expands.
- Of the total global power generation mix, hydropower ranks 3rd largest behind coal and natural gas, representing about 15% of the total.
- There are 3 types of hydro power:
  1. Impoundment, the most common type, is a facility that uses a dam to store river water.
  2. Diversion, more commonly known as run-of-river, channels a portion of the river using the natural decline of the riverbed
  3. Pumped Storage (PSH), acts like a battery as it stores power (water is pumped from a lower elevation to store at higher elevation) and releases it during periods high demand.
- Hydropower generation plants in developed countries are getting older (the average age in North American and Europe is approaching 50 years) and will need modernization so they can contribute to electricity security for years to come (hydro plants can run for up to 100 years).
- Incorrys does not expect big capacity increases and is forecasting global hydropower capacity to increase from under 1400 GW in 2022 to just over 1600 GW in 2030; an increase of 230 GW (17%), 2% annually.

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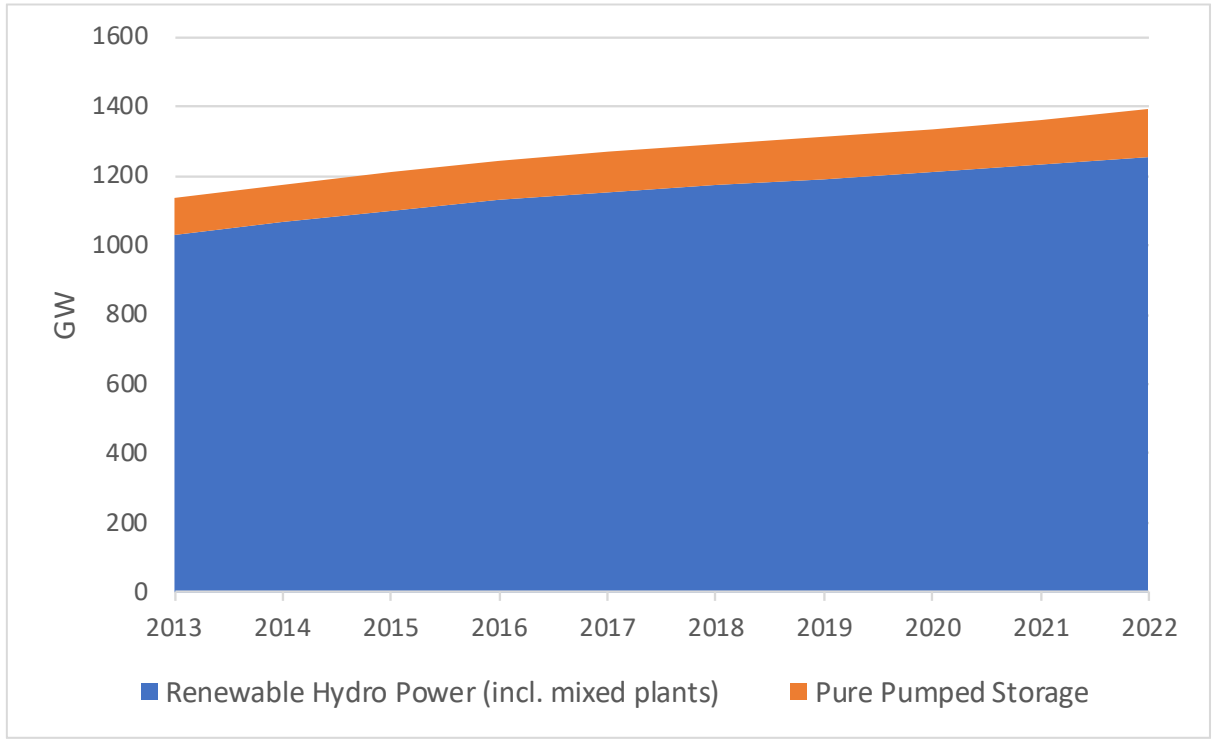
HYDROPOWER GENERATION CAPACITY 2013-2022

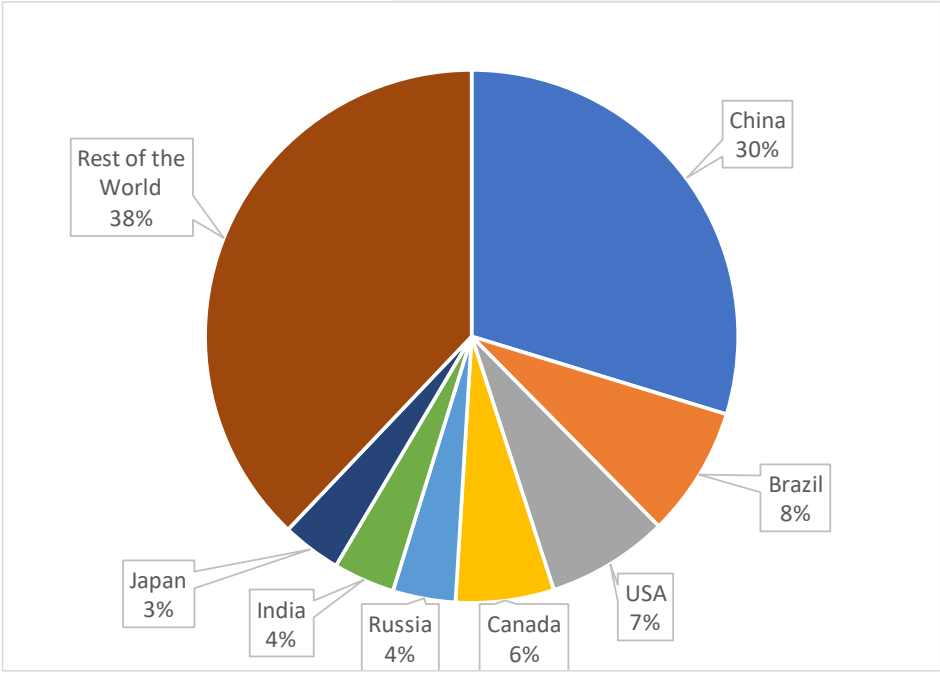


- Hydropower generating capacity has grown steadily since 2013 at an average annual rate of just under 2.5%; from 1150 GW to 1400 GW.
- Renewable hydro (including mixed plants; run-of-river, storage hydro, and small amount of offshore hydro) grew from 1000 GW to 1250 GW, just over 2%/year.
- Pure pumped storage, where water is pumped between upper and lower reservoirs providing peak-load supply, increased from 100 GW to 140 GW, a rate of 2.7% annually although the growth rate has accelerated over the past 2 years at over 6%/year. represents 10% of total capacity.

Source: International Renewable Energy Agency (Copyright © IRENA 2023)

- China accounted for about 30% of global 2022 hydropower generating capacity at over 400 GW.
- Following a distant second and third are Brazil and the US at 8% (110 GW) and 7% respectively (105 GW).
- Canada ranks fourth largest representing about 6% of the global total at just over 80 GW.

2022 Market Share



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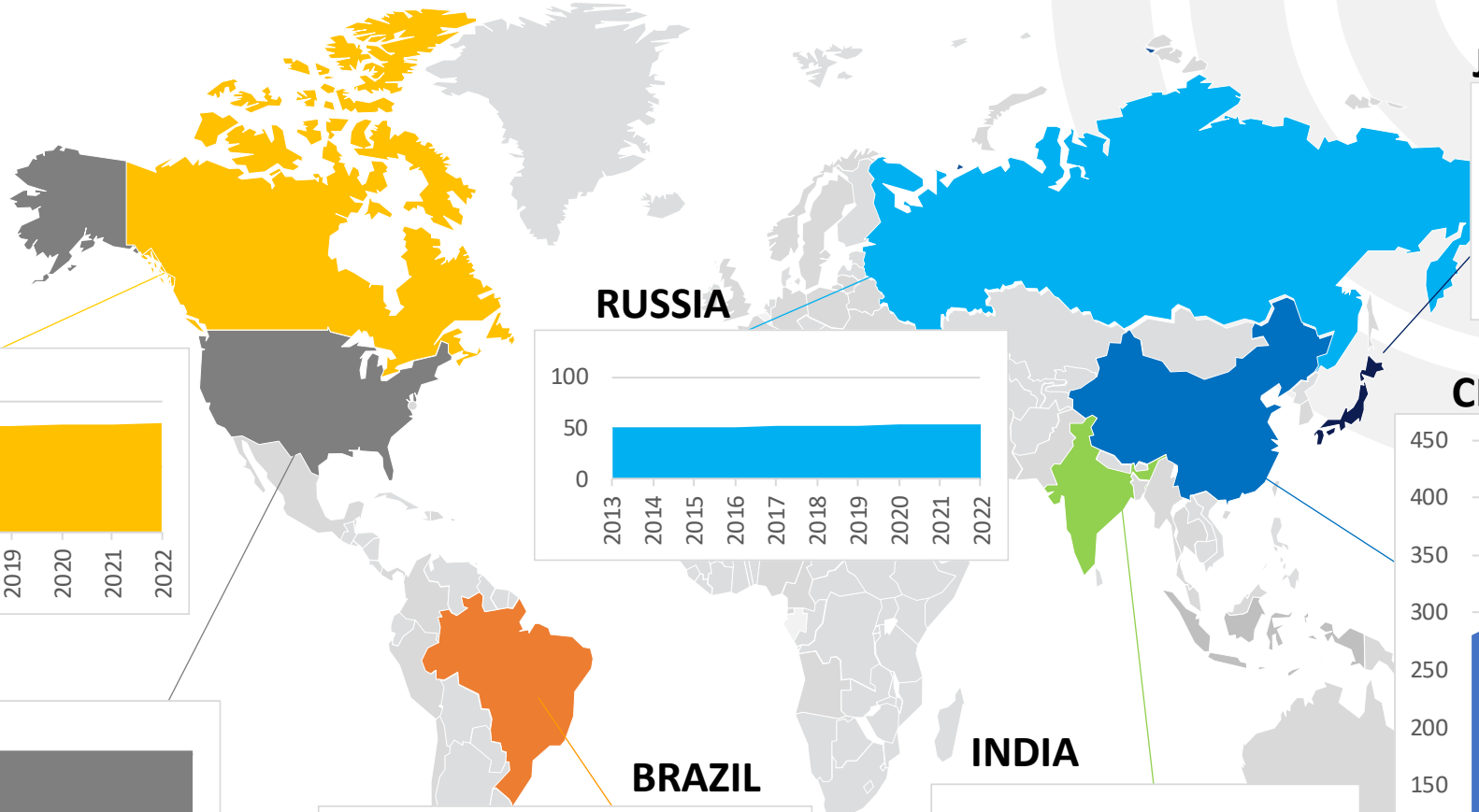
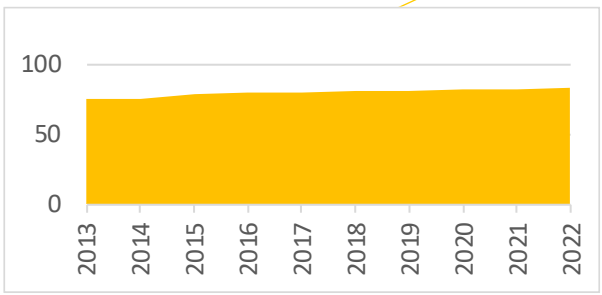
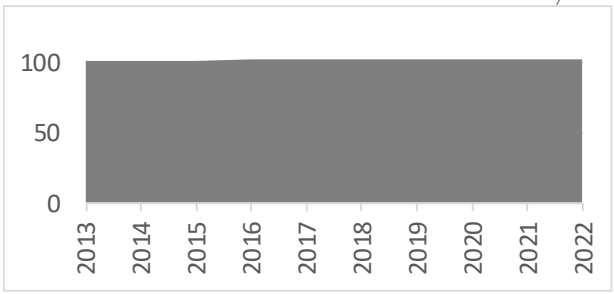
HYDRO GENERATION CAPACITY BY COUNTRY (GW) 2013-2022



CANADA

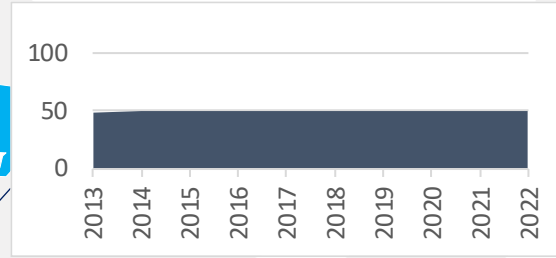


US

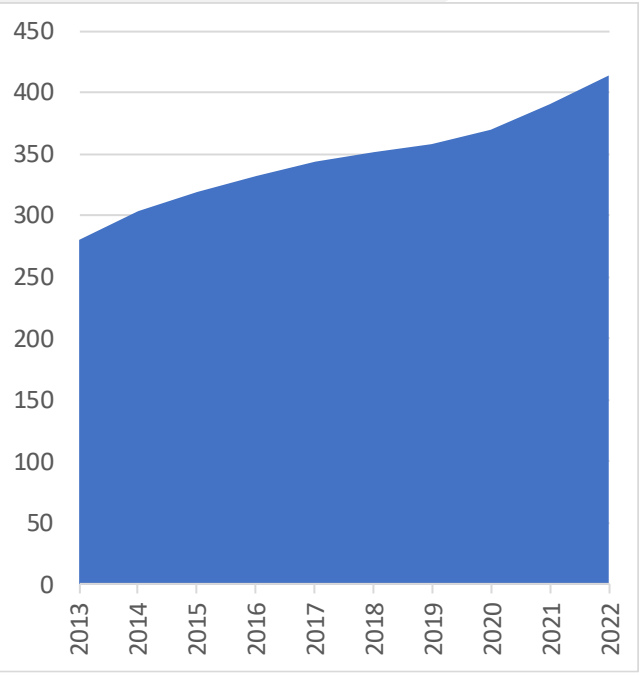


RUSSIA

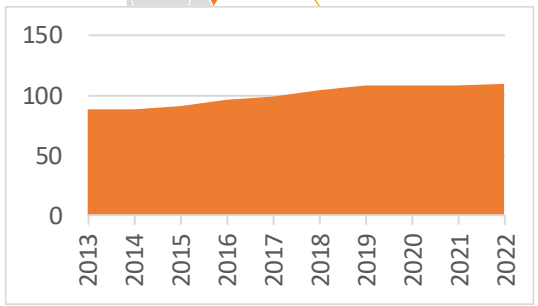
JAPAN



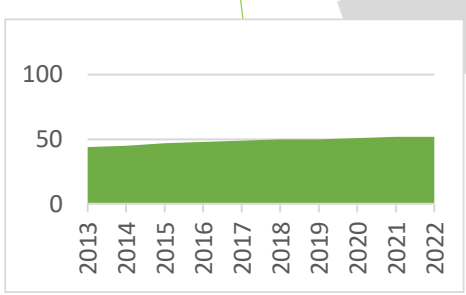
CHINA



BRAZIL



INDIA



Source: International Renewable Energy Agency

- China's hydro capacity grew by almost 50% from 2013 to 2022 followed by Brazil by almost 25% and India almost 20%.

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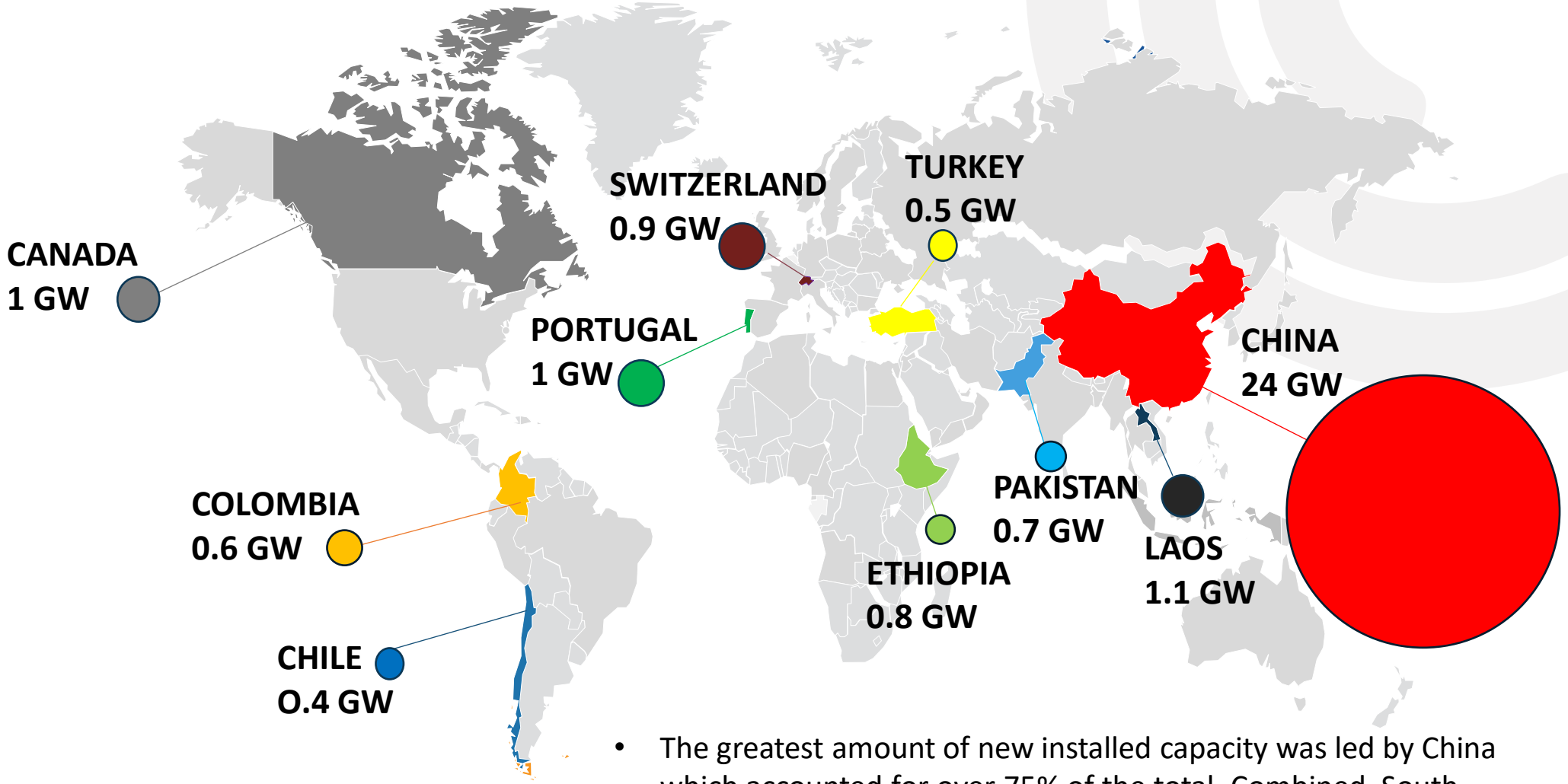
TOP 10 COUNTRIES BY NEW INSTALLED CAPACITY IN 2022



- The greatest amount of new installed capacity was led by China which accounted for over 75% of the total. Combined, South and East Asia (China, Laos and Pakistan) totaled 26 GW, almost 85% of the total.

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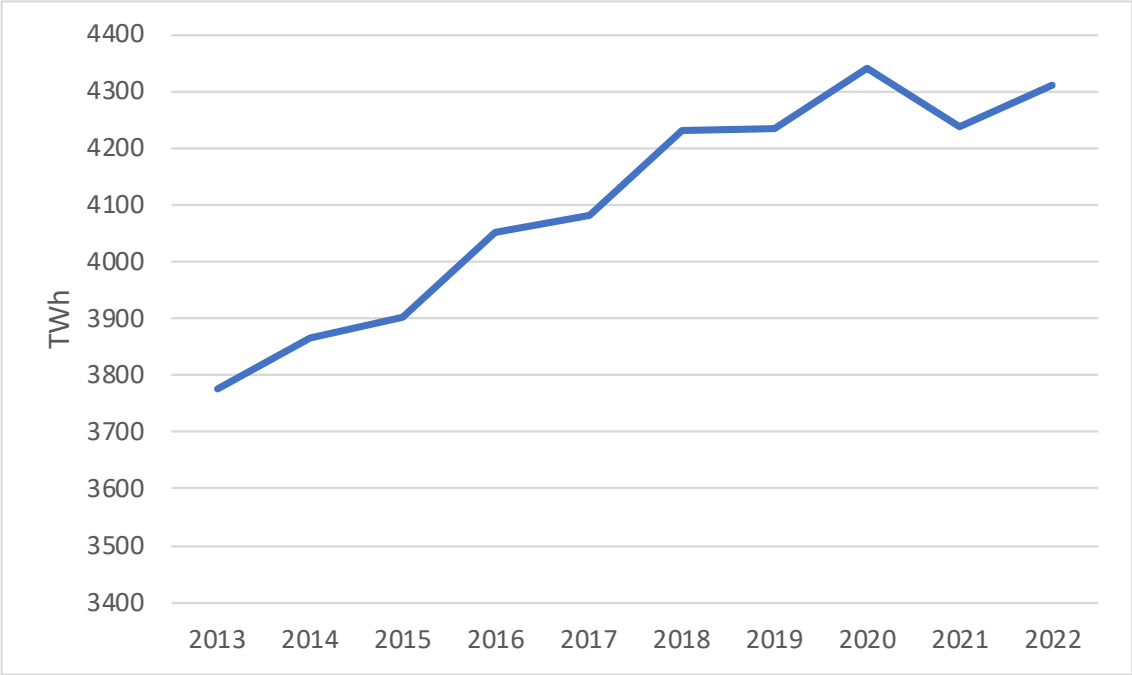
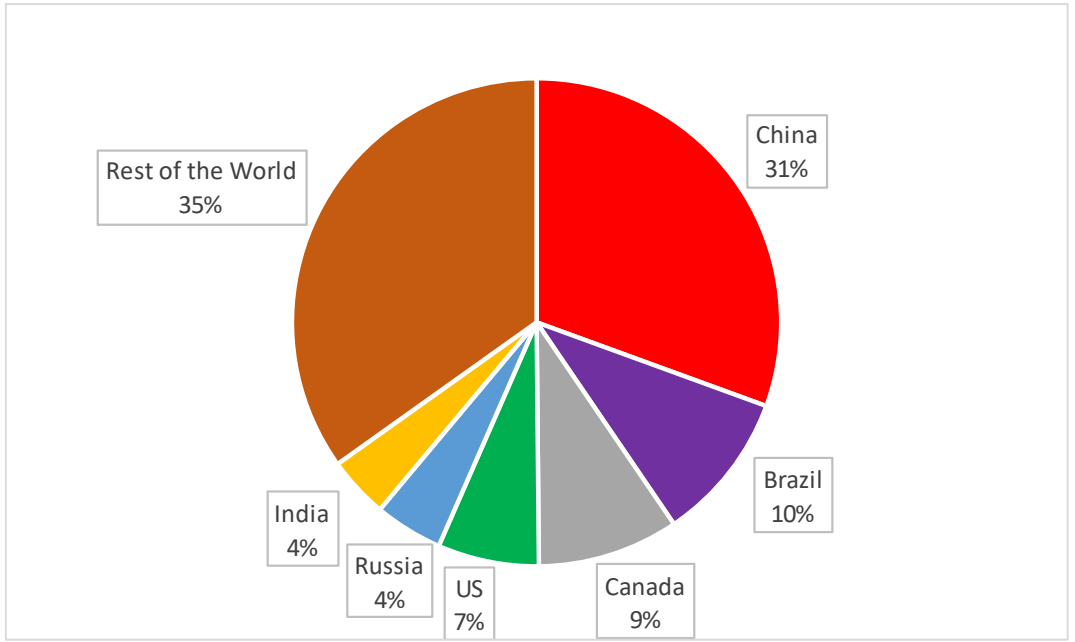
HYDROPOWER GENERATION 2010-2022



- Global hydroelectricity power generation has only increased 14% over the past 10 years (1.5% annual growth rate) from about 3800 TWh to over 4300 TWh in 2022. Considerably slower growth than other renewables like solar and wind
- Hydropower remains the single largest renewable source of electricity, generating more than all other renewable technologies combined.

- China, by far, is the largest generator of hydropower in the world accounting for almost 1/3 of the total; Brazil ranks second at 10%. These two countries have also dominated recent growth in hydro capacity additions.
- Canada ranks 3rd in the world at 9% followed closely by the US at 7%.
- Both Brazil and Canada boast capacity factors of almost 60% (2020) from hydro generation (56% and 59% respectively). Considerably higher than the US and Russia with capacity factors of just over 40% and China at just 37%.

2022 Market Share



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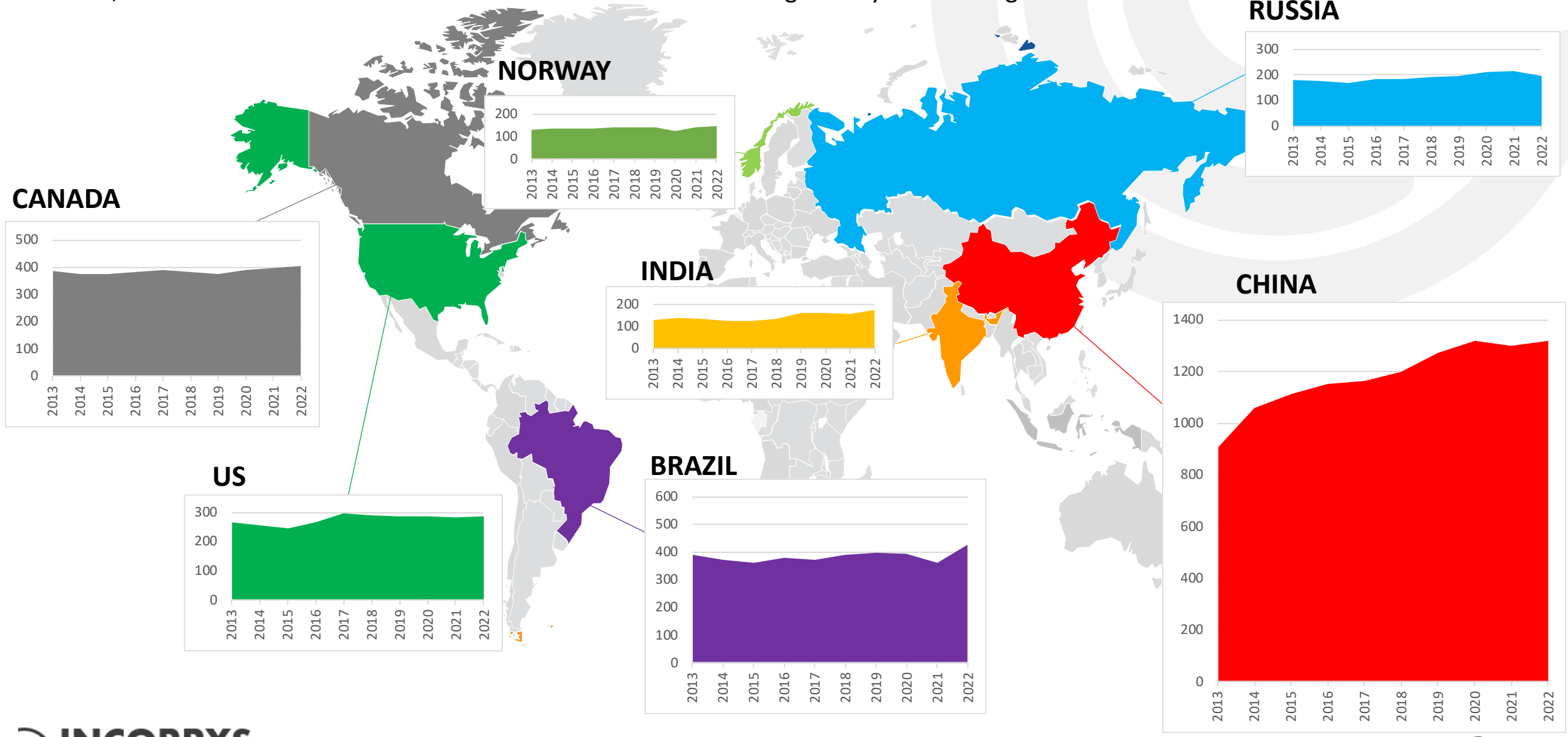
HYDROPOWER GENERATION BY COUNTRY (TWH)

Combined, these seven countries accounted for almost 70% of the total global hydroelectric generation in 2022.



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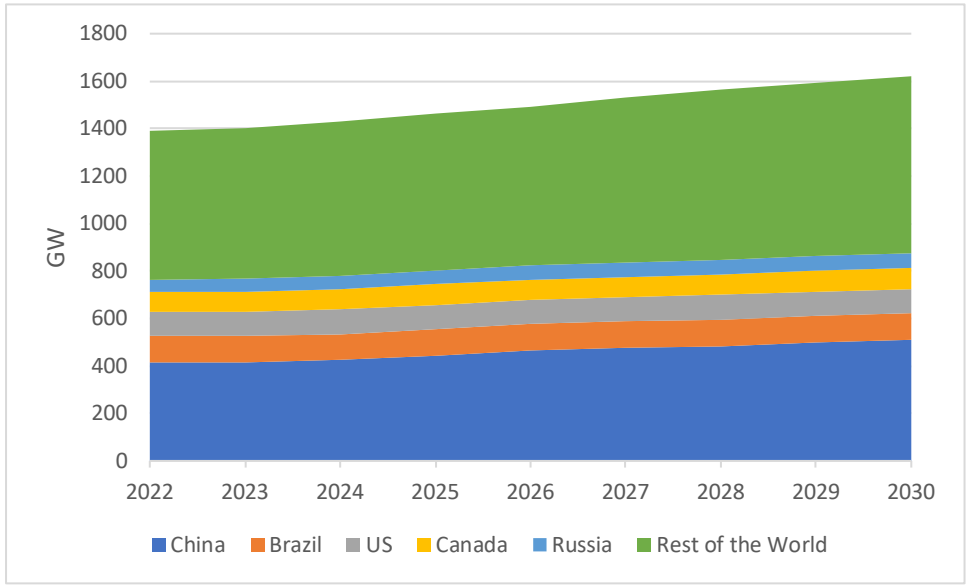
HYDROPOWER CAPACITY FORECAST 2022-2030



- Global hydropower capacity additions could be 40% higher through 2030 if governments addressed the hurdles to foster quicker deployment. However, Incorrys does not expect this to occur and is forecasting annual capacity increases of 30-40 GW (230 GW total) from under 1400 GW in 2022 to just over 1600 GW in 2030.
- Pumped-storage is expected to account for about 30% (about 60 GW) of the total capacity additions over the 2022-2030 time frame, the highest 10-year growth period ever recorded. The focus on PSH reflects the need for greater system flexibility and storage requirements in many areas.

- Although hydro facilities can operate up to 100 years, over 20% of the global fleet will be more than 50 years old where electromechanical equipment will need to be replaced at significant costs. It is estimated that USD $300 billion of investment is needed by 2030 to modernize all aging facilities. Projected spending on existing plants is not enough to meet the global hydropower fleet's modernization needs by 2030, investment will need to double to keep up.
- China will remain the single largest hydropower market through 2030 adding 95 GW of capacity, over 40% of global capacity growth. This is down from its peak of 60% from 2001-2010 due to growing concerns over the environmental impacts and lack of economically attractive sites.
- The Asia Pacific region (excluding China) is expected to add 65 GW by 2030. India, the world's 2nd largest growth market, has set new long-term targets and financial incentives that should unlock a long list of previously stalled projects.
- 75% of new worldwide hydropower capacity through 2030 is expected to come in the form of large-scale projects in Asia and Africa with sub-Saharan Africa adding about 20 GW. Over half of all new hydropower projects in sub-Saharan Africa , Southeast Asia and Latin America are set to be either built, financed, partially financed or owned by Chinese firms.

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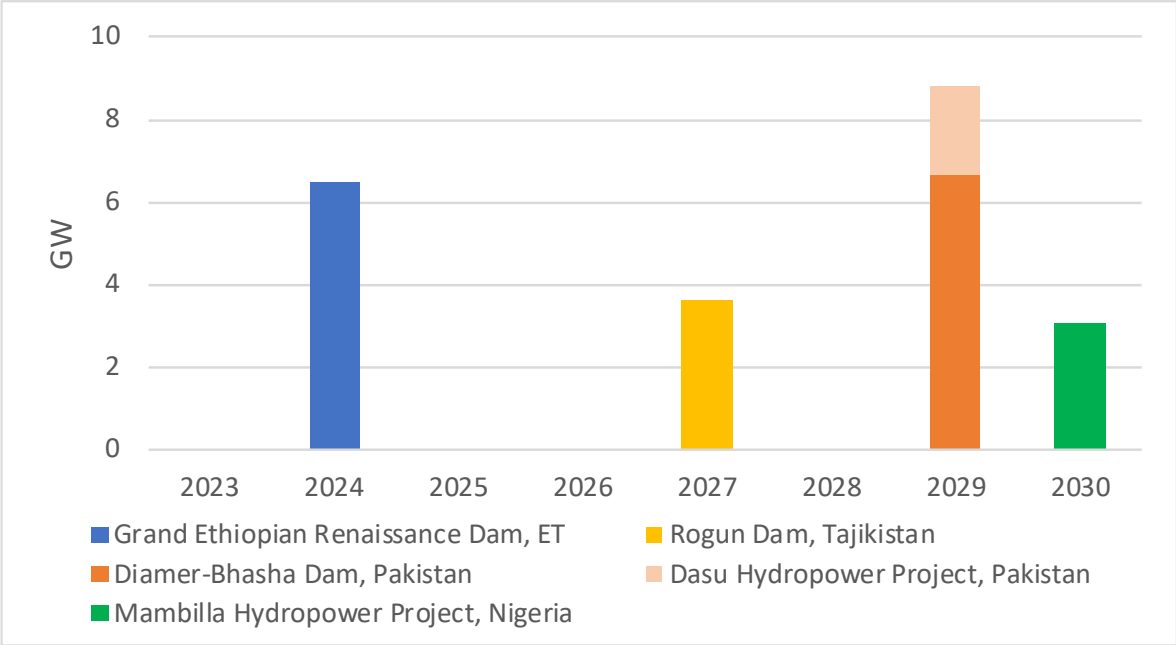
5 LARGEST HYDROELECTRIC PROJECTS UNDER CONSTRUCTION



- The 5 largest hydropower projects, with in-service dates before 2030, are expected to add over 20 GW of capacity. Two are in Pakistan and one each in Ethiopia, Tajikistan, and Nigeria.
- The first to come online (2024) is the 6.5 GW facility in Ethiopia.
- The largest of the 5 is the 6.7 GW facility in Pakistan slated to begin operations in 2029.

- According to the International Hydropower Association's (IHA), global installed hydropower capacity rose by over 25 GW in 2021 with about 80% of the new capacity being installed in China.
- The IHA also noted that almost 5 GW of pumped storage hydropower was added to the grid, triple the amount added in 2020.
- There is currently about 130 GW of hydropower under construction worldwide with another 500 GW in various stages of development, led by China and other countries with large risks surrounding electricity supply.
- The IHA suggests in a recent report (Hydropower 2050: Identifying the next 850+ GW towards Net Zero) that although there is 500 GW being developed worldwide, it is short by 300 GW to limit global warming to 2°C and by 600 GW to limit it at 1.5°C.
- One of the key factors hindering the growth of the global hydropower generation is the high capital and operating costs.
- There are currently 3 hydro projects in Canada:
  - Romaine River in Quebec (1.55 GW) was recently completed
  - Site C Dam in BC (1.1 GW) is near completion (2025)
  - Gull Island in Newfoundland & Labrador (2.25 GW) is planned with construction scheduled for 2028 and in-service by 2032.

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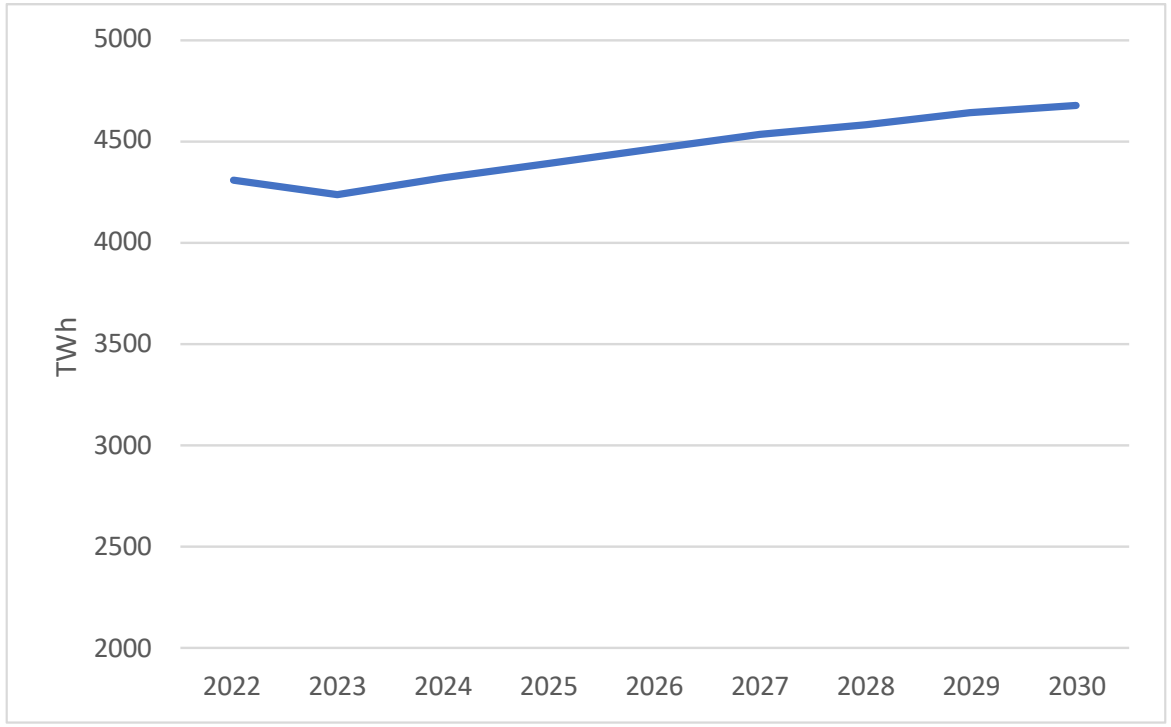
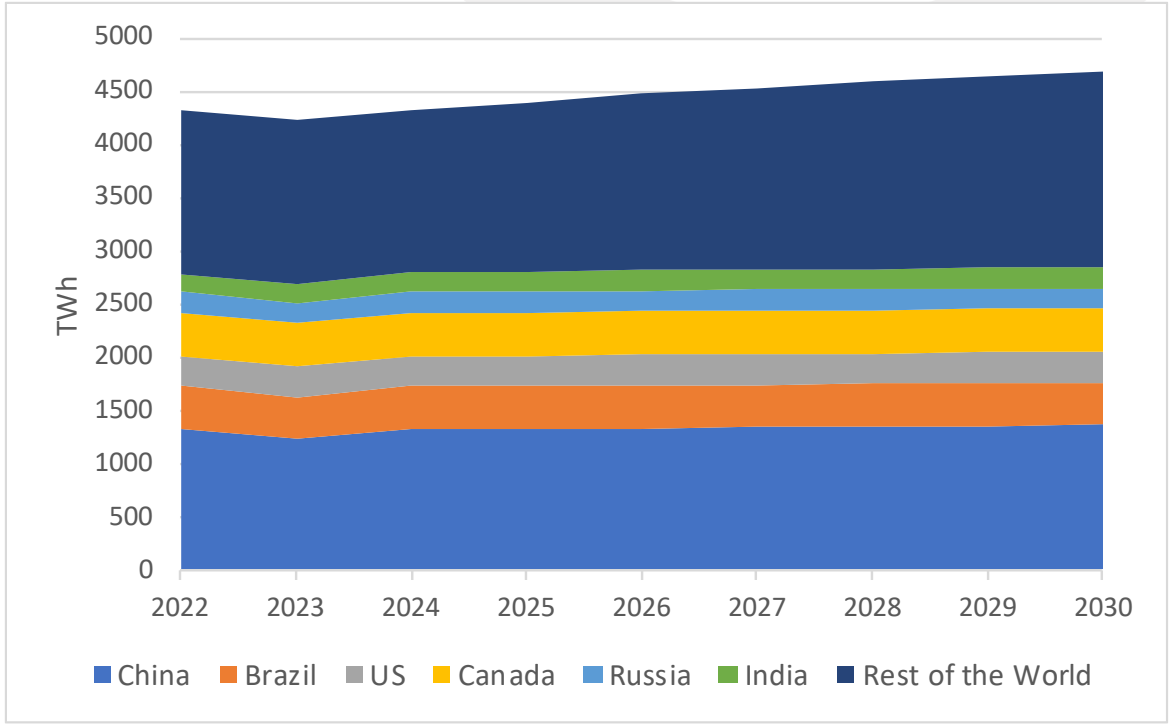
HYDROPOWER GENERATION FORECAST



- Global generation from hydropower is expected to decline by almost 2% (80 TWh) in 2023 primarily due to drought conditions in China, the largest hydropower producer.
- Incorrys expects that post 2023, under normal weather conditions, the global trend will return to positive, albeit at a modest 2% annually through 2030. Generation increases from about 4250 TWh in 2023 to 4650 TWh over that period.

- China alone accounts for about 30% of global hydro generation followed by Brazil at 9% and the US at 6%.
- All the largest hydro producing countries, except China and India, are expected to remain relatively flat over the forecast period. Both China and India see increases in hydro generation at 3% and 15% respectively.
- The rest of the world shows strong growth (30% from 2022-2030) led by Laos, Pakistan, Ethiopia and others.



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WHY INCORRYS INFORMATION SYSTEM

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ADVANCED ANALYTICS

Incorrys performs data analysis to ensure quality and consistency among different industries and jurisdictions

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