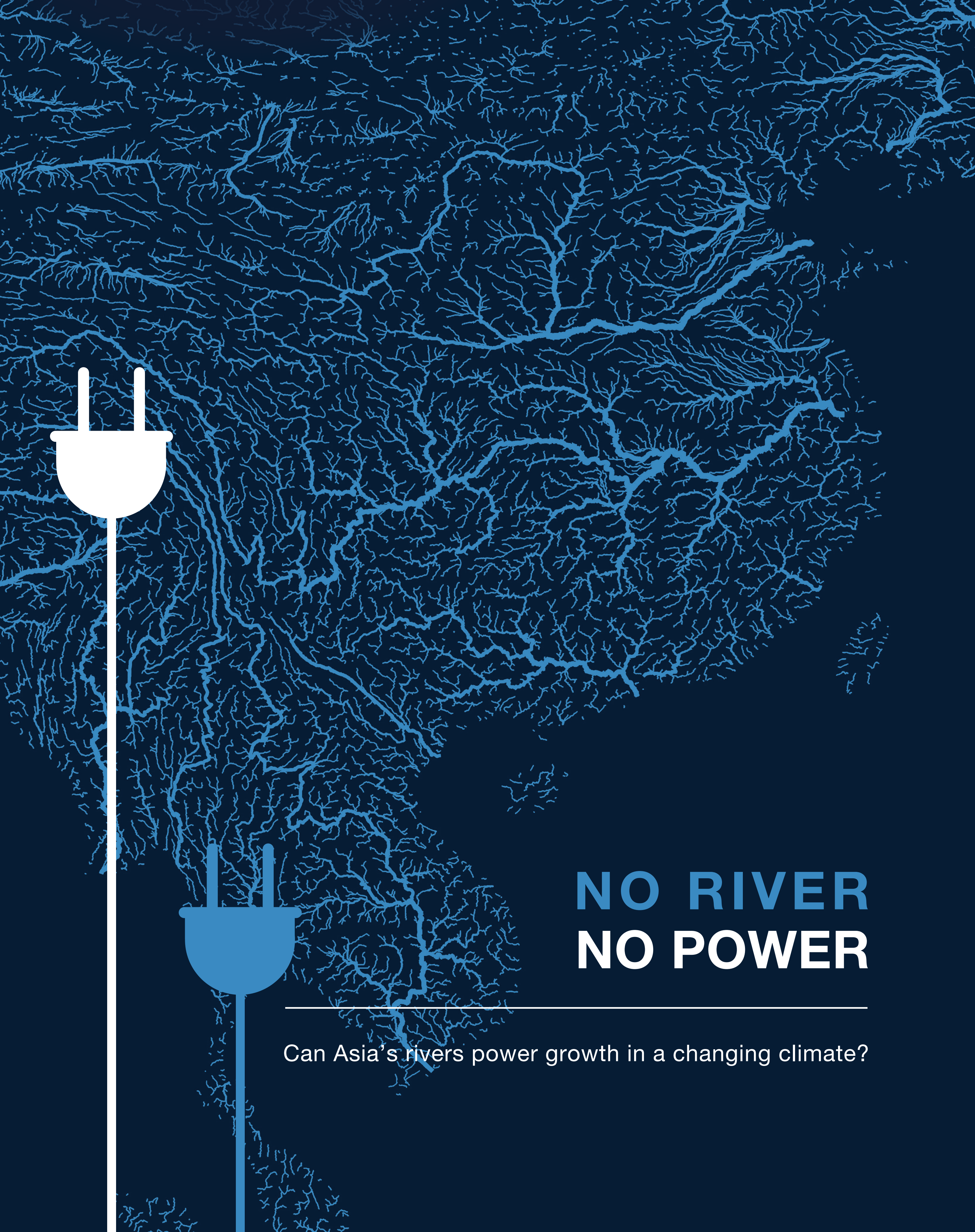
CWR



NO RIVER NO POWER

Can Asia's rivers power growth in a changing climate?

CWR

No River, No Power

Can Asia's rivers power growth in a changing climate?

Authors:
Debra Tan, Dr. CT Low

Published by:
China Water Risk (CWR)

Publication Date:
May 2023

Graphics & layout:
ROKO Studio
www.rokostudio.com

Contact:
For any enquiry, please contact:
info@chinawaterrisk.org

Asia faces serious and urgent water challenges ahead. Mighty rivers that flow through 16 countries are Asia's cradles of civilisation and power economies along the Yangtze, Yellow, Ganges, Indus, Irrawaddy and Mekong. These are all impacted by climate change. From the Hindu Kush Himalaya Water Towers source region to the ocean, every component of river flow is affected – glacier & snow melt have accelerated, rain/snowfall are changing as are monsoon patterns; at the deltas, seas are rising. Lives and livelihoods are at stake – one in two Asians live in 10 river basins where over US$4.3trn of GDP is generated annually.

Recent extreme floods and droughts have shown that they can displace population as well as disrupt power generation. Yet, Asia is heavily reliant on and still expanding its coal-fired power fleet, which only accelerates climate change and exacerbates water scarcity. Perversely, coal-fired power generation requires water for cooling and driving steam turbines, so rising uncertainty in the availability of water can strand existing coal assets and threaten energy security as well as disrupt development.

The devastating floods along the Indus that displaced 33mn people in Pakistan and affected up to 10% of the country's GDP was a rude wake up call. It is time to ask important questions – will using coal to fuel development further impact river flows and future growth? Do Asia's rivers have enough water to support coal-fired power expansion? Or will a future that is powered with less coal ensure the future of its mighty rivers?

This report aims to illustrate Asia's tight water-energy-climate nexus so that the 16 countries that rely on the 10 rivers can make better decisions today for water tomorrow when planning power expansion to fuel development. Such power growth must not jeopardise Asia's future water, energy, food and economic security.

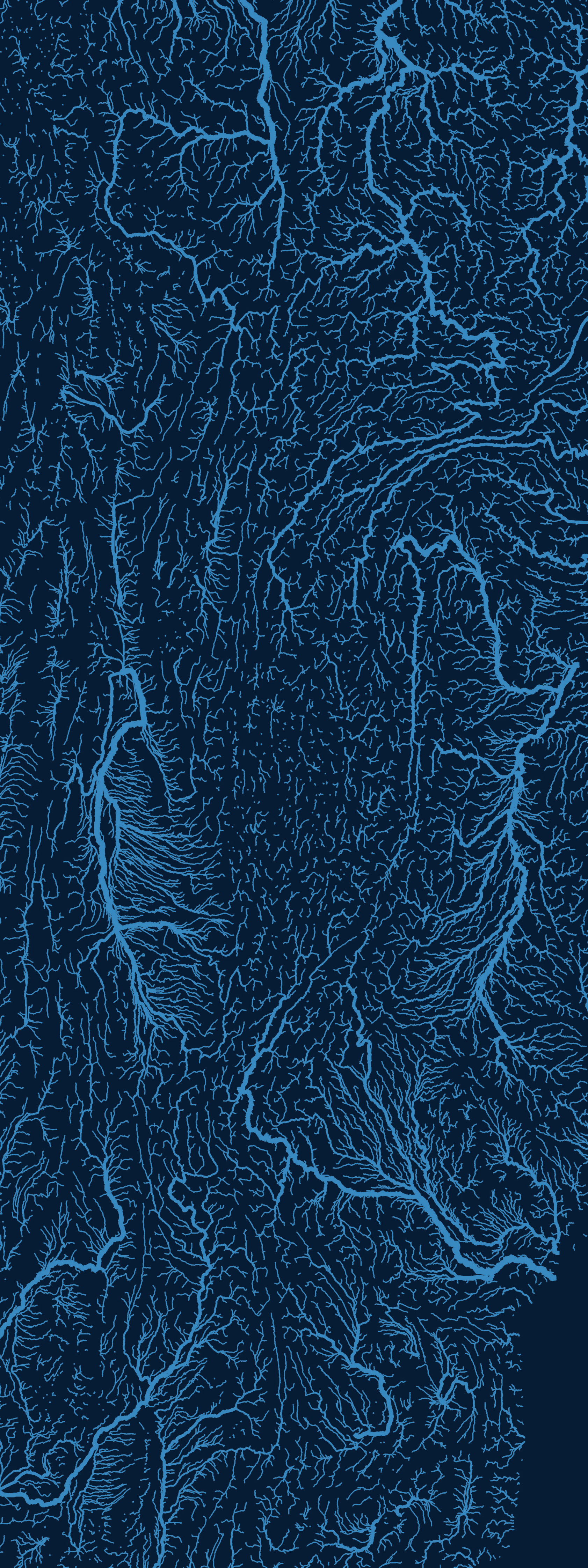
About China Water Risk (CWR)

CWR is a non-profit think tank that aims to create a world where water and climate risks are embedded in business & finance. Since its launch in 2011, it has worked from its Hong Kong base to engage with global business and investment communities in understanding and managing various types of water risks in China and across Asia. CWR's collaborative reports with financial institutions, IGOs, scientists as well as government related bodies have been considered ground-breaking and instrumental in understanding Asia's water challenges. They have helped inform better decision-making today for a water secure tomorrow. Join the conversation at www.chinawaterrisk.org

Acknowledgements

CWR is grateful to the Growald Climate Fund for the funding of this report.
CWR would also like to acknowledge the contributions of Yuanchao Xu and Sophie Kutsunai Lam.

CWR



"No man ever steps
in the same river twice,
for it's not the same river
and he's not the same man"

Heraclitus

Our climate and rivers are changing,
so must we.

Now is the time for Asia
to put in place sensible energy policies
that will protect and not destroy our rivers.

For if we do not fail our rivers,
our rivers will not fail us.

Dip into this report and you'll never look at
power & rivers in the same way again…

The future of Asia's 10 mighty rivers is at stake…
…no water means no power and no growth

Power generation needs water and delivering clean water needs power.

Coal-fired power, the traditional cornerstone of energy security for many Asian economies will accelerate climate change, which in turn exacerbates water scarcity. This not only impacts the ability to generate power but could also impact economies and livelihoods as over US$4.3trn of GDP as well up to 1 in 2 Asians lives in 10 major river basins that share the same source: the Hindu Kush Himalaya Water Towers.

Solutions are also compromised – cooling technologies that can generate power without water increase emissions while carbon capture to reduce emissions is water intensive.

Managing these interdependencies are especially challenging for power hungry Asia as it has limited water resources for development. This tight water-energy-climate nexus means that the future of Asia's energy and water policies are intertwined. As the second largest user of water after agriculture, the power mix must be considered given its ability to accelerate climate change.

For a future with water, energy and water security must be considered together with economic development planning to ensure a prosperous Asia.

This is especially urgent as we have already warmed by 1.2°C today, 80% of the way to the aspirational 1.5°C global warming target under the Paris Agreement. Since there is *"no credible pathway to 1.5°C in place"*, it is safe to say that our 2100 climate future is right here, right now. We are all late in adapting.

Photo by ArtHouse Studio on Pexels.com

"We are on a highway to climate hell with one foot on the accelerator"

António Guterres
Secretary-General of the United Nations

"Between 3 and 4 billion people are projected to be exposed to physical water scarcity at 2°C and 4°C"

IPCC Climate Change 2022: Impacts, Adaptation and Vulnerability

Time to rethink power mix…
…Asia must lead energy transition for a future with water

Current global policies in place with no additional action are projected to result in 2.8°C of warming by 2100 – this will be disastrous for Asia's mighty rivers and the billions of people that live in and trillions of dollars that are generated in their basins. Asia has traditionally looked to the Global North for leadership on climate change, yet G7 leaders continue to disappoint in the fulfilment of their climate pledges and COP27 did not yield any new meaningful pledges. While renewables saw aggressive expansion in 2022, so did oil – over US$1trn was invested in fossil fuel infrastructure and extraction in 2022 alone, including numerous new "carbon bomb" projects.

Worse still, global geopolitics seem to have put us on a path of the "Regional Rivalry Scenario" which the IPCC warned can lead to >4°C. Already at 3°C, the Hindu Kush Himalaya Water Towers' will see ice and snow losses of 90%. This certainly does not bode well for Asia's water future. Sadly, climate change does not pause for "exceptional circumstances" such as the Russia-Ukraine war.

Pakistan's devastating floods and major rivers running dry around the world (the Rhine, Po, Colorado & Yangtze) last year provided us with a glimpse of what's to come. With the future of Asia's 10 mighty rivers at stake, the 16 countries which rely on their waters cannot afford to wait. Asia's leaders must fill the global leadership void in climate action; China and India especially must take the lead.

The window of opportunity to rein in climate change is narrowing. The time is now for Asia to step up to rethink its energy security with water in mind. The continent can and must lead the way in fast tracking transition to net zero emissions for a future with water.

CWR

The 10 HKH River Basins

These 10 HKH Rivers which flow through 16 countries holds 865GW of power generation installed capacity. This is for around half the total installed capacity of the 16 countries.

Tarim
River Length: 1,321 km

Basin area:
0.93-1.15 million km²

Share of ice & snow melt in the upper reach:
42%

Annual flow:
10-43 billion m³

Countries involved:
China, Kyrgyzstan

Brahmaputra
River Length: 2,896 km

Basin area:
0.53-0.65 million km²

Share of ice & snow melt in the upper reach:
25 - 35%

Annual flow:
538-815 billion m³

Countries involved:
China, India, Bhutan, Bangladesh

Yellow
River Length: 5,400 km

Basin area:
0.76-1.07 million km²

Share of ice & snow melt in the upper reach:
23%

Annual flow:
50-107 billion m³

Countries involved:
China

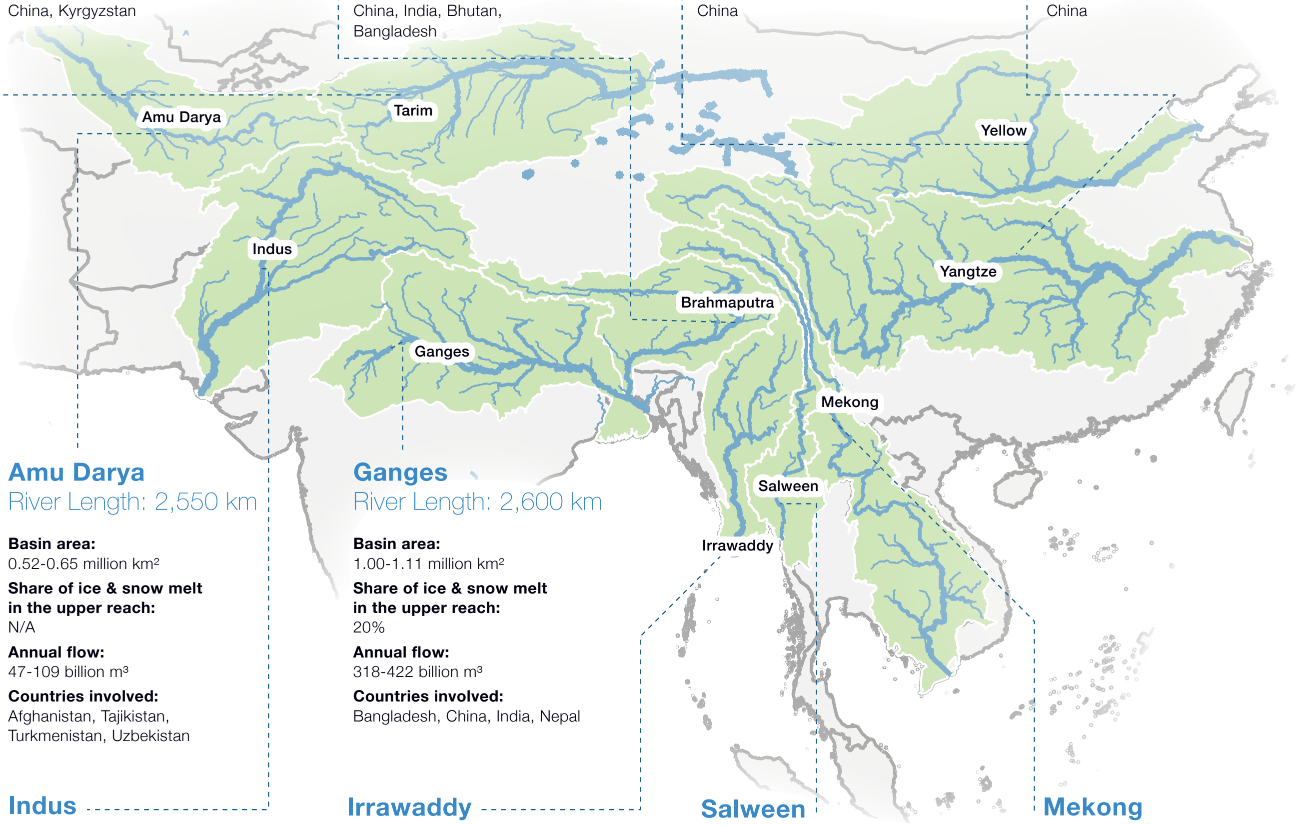
Yangtze
River Length: 6,300 km

Basin area:
1.72-2.07 million km²

Share of ice & snow melt in the upper reach:
29%

Annual flow:
666-971 billion m³

Countries involved:
China



Amu Darya
River Length: 2,550 km

Basin area:
0.52-0.65 million km²

Share of ice & snow melt in the upper reach:
N/A

Annual flow:
47-109 billion m³

Countries involved:
Afghanistan, Tajikistan, Turkmenistan, Uzbekistan

Ganges
River Length: 2,600 km

Basin area:
1.00-1.11 million km²

Share of ice & snow melt in the upper reach:
20%

Annual flow:
318-422 billion m³

Countries involved:
Bangladesh, China, India, Nepal

Indus
River Length: 2,880 km

Basin area:
1.08-1.26 million km²

Share of ice & snow melt in the upper reach:
62 - 79%

Annual flow:
146-197 billion m³

Countries involved:
Afghanistan, China, India, Pakistan

Irrawaddy
River Length: 2,300 km

Basin area:
0.40-0.43 million km²

Share of ice & snow melt in the upper reach:
N/A

Annual flow:
343-566 billion m³

Countries involved:
China, India, Myanmar

Salween
River Length: 2,400 km

Basin area:
0.27-0.36 million km²

Share of ice & snow melt in the upper reach:
25 - 36%

Annual flow:
114-207 billion m³

Countries involved:
China, Myanmar, Thailand

Mekong
River Length: 4,800 km

Basin area:
0.81-0.90 million km²

Share of ice & snow melt in the upper reach:
22-33%

Annual flow:
390-492 billion m³

Countries involved:
Cambodia, China, Laos, Myanmar, Thailand, Vietnam

River Basins ■ Major Rivers ■ ■

- *Infographic based on CWR's report "No Water, No Growth - Does Asia have enough water to develop?", 2018.*

Definitions

HKH = The Hindu Kush Himalayas (HKH) generally refers to the region where the majestic Himalayas, Hindu Kush, Karakorum mountains are located as well as the Tibetan Plateau. It is also often called the 'Third Pole' or 'Asia's Water Towers' as it is the source of ten major rivers.

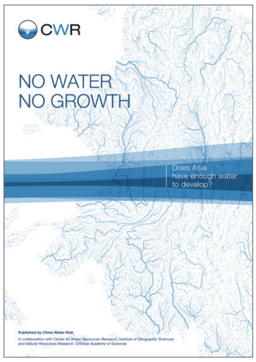
10 HKH Rivers = 10 major rivers flow from the HKH – they are the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze and Yellow Rivers (collectively the "HKH Rivers").

16 HKH Countries = The 16 countries that the rivers flow through before emptying into respective seas or ending in desert in the case of Tarim. They are Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Kyrgyzstan, Laos, Myanmar, Nepal, Pakistan, Tajikistan, Thailand, Turkmenistan, Uzbekistan and Vietnam.

Why we are writing this report

Rivers are important to Asia. The Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze and Yellow are the continent's cradles of civilisation. Much of Asia's population and economy are clustered there. Yet, climate change, evident in their common source region, the Hindu Kush Himalayas (HKH), threatens their upper watershed; other components of river flow such as snow/rainfall and monsoon patterns are also affected. All these impact the flow of the 10 mighty rivers that provide water to 16 countries: Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Kyrgyzstan, Laos, Myanmar, Nepal, Pakistan, Tajikistan, Thailand, Turkmenistan, Uzbekistan and Vietnam (HKH 16). **One in two Asians live along these rivers and over US$4.3trn is generated in these 10 river basins**, but there is little conversation on the threats to Asia's Water Towers or water and climate risks faced by these rivers.

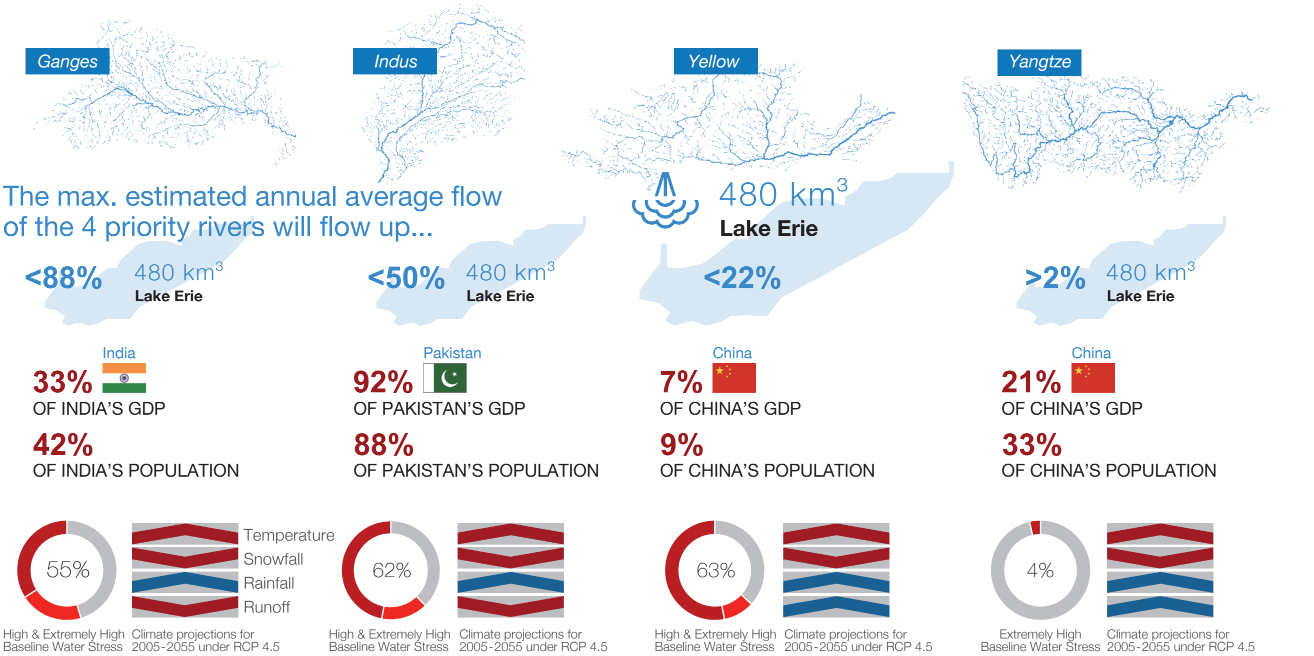
To kickstart the conversation CWR collaborated with the Center for Water Resources Research, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences to synthesise research and conduct analysis on the impacts of climate change on the water resources and economy in the ten major river basins that originate from the HKH.



These results were published in the report *"No Water, No Growth – Does Asia have enough water to develop?" (NWNG)* in 2018. The report findings were sobering. Water resources from these ten rivers are clearly vital to the social and economic development of continental Asia and the current water-intensive export-led growth model is not sustainable. The report highlighted the clustered exposure of GDP in these basins – see graphic below. It also revealed the significant impact of climate change on each of the rivers in terms of temperature, rain, snowfall as well as river flows.

As a first-of-its kind waternomic report for the region, NWNG was well received. CWR was invited to present at the 6th APAC Climate Change Adaptation Forum, The First Hindu Kush Himalaya Science-Policy Forum, the Greater Mekong Forum on Water, Food and Energy as well as the ASEAN-China Cooperation on Energy Transition & Climate-resilient Development to share our findings. We also engaged with the institutional investors, banks and central bankers; credit rating agencies even reached out to us acknowledging that river basin risks & clustered GDP exposure have implications for sovereign risk ratings. Interestingly, the insurance sector shared with us that such basin risks highlighted in NWNG were not included in their assessments of acute water risk.

CWR | VERY LITTLE WATER SUPPORTS A LOT OF PEOPLE & GDP FOR THE 4 "PRIORITY RIVERS"



Source: CWR analyses based on "No Water, No Growth - Does Asia have enough water to develop?", 2018
Infographic © China Water Risk 2023, all rights reserved. The report identifies four "Priority Rivers" that require urgent attention

Chronic basin risks are now recognised by the NGFS to the IPCC. With underlying chronic basin risks now recognised by the NGFS, a group of 100+ central banks[1] and supervisors, as key physical risks for the financial industry, the focus is on their valuation. More recently, we were pleased to see waternomics highlighted in NWNG included as a chapter in a Springer Nature book on "Water Security & Climate Change" as well as NWNG cited in the Asia Chapter of the IPCC AR6 Working Group 2 report on "Climate Change 2022: Impacts, Adaptation & Vulnerabilities & Impact".

Choosing the right type of power in the water-energy-climate nexus was one of NWNG's 8 broad strategic recommendations (see graphic below). This report thus builds on NWNG by deep diving into the various types of power generation located in the 10 river basins with particular attention to coal-fired power as it also accelerates climate change and water scarcity. How much of this is water reliant? Will energy security be threatened as coal-fired power plants could be stranded by uncertain water availability? Cooling technologies used are also explored – do they help or exacerbate scarcity?

Policymakers must rethink energy security given rising uncertainties in water availability due to climate change. By adding an energy security facet to the waternomics of these rivers, we hope that this helps policymakers, businesses and investors "see" the tightness of Asia's water-energy-climate nexus to rethink energy security. This is an urgent conversation as current global transition policies in place with no additional action point to 2.8°C[2] which will be disastrous for Asia's mighty rivers. Billions of lives that live in and trillions of dollars that are generated in their basins are at risk. Climate driven events can cause whole countries to fail today not tomorrow – floods in the Indus last year is case in point.

Lack of global leadership on climate change increases risks for Asia's rivers. Nearly 200 countries promised to update their NDCs at COP26, but only 24 countries actually did by COP27.[3] G7 leaders also disappointed: while the USA has passed the pro-climate Inflation Reduction Act in 2022,[4] crude oil production for 2023 and 2024 is forecasted to surpass the previous record set in 2019 to rise to an average of 12.4mn and 12.8mn barrels per day respectively.[5] The UK granted 100+ new exploration licenses in the North Sea[6] while Norway drilled 17 exploration wells in 1H2022.[7] In fact, over US$1trn was invested in fossil fuel infrastructure and extraction last year – this included numerous new "carbon bomb" projects.[8] Sadly, climate change does not pause for the *"exceptional circumstances"* of war; if tense global geopolitical divides are not resolved, we could head down the IPCC's "Regional Rivalry Scenario" of >4°C – this would send us speeding down the *"highway to climate hell"*.

The time is now – Asia must step up to fill the gap. Given the G7's absence and the ever narrowing window of opportunity to rein in climate change, it's time for Asia to step up and fast track energy transition. We hope that after reading this report, policy makers, businesses and investors will understand that Asia's mighty rivers and their economies have more of a chance of surviving and thriving in a future that is powered with less coal.

Asia must rethink its energy security with water in mind. Our futures are tied by these 10 rivers; we must set aside our differences – the HKH 16 countries must work together with China and India at the helm to fast track net zero emissions to help ensure a shared future with water and energy security as well as economic prosperity for the region.

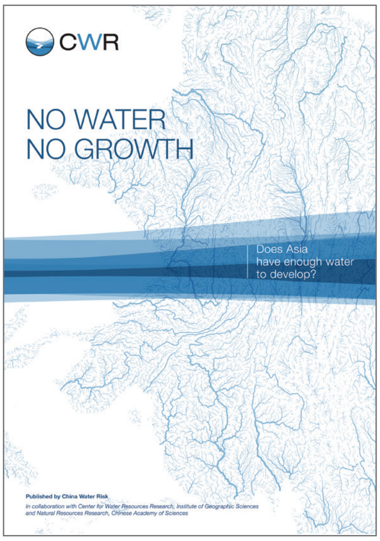
8 broad strategies for managing Asia's water

Protect Asia's rivers to ensure water resources for one in two and a half Asians

Water-nomics Roadmap Rethink our economic & development models

Revamp Agriculture Control agri water use & pollution while ensuring food security

Water-Energy-Climate Choose the right type of power for both water & climate



Resolve Transboundary issues through better water-nomic cooperation

Basin Focus Reorganise & focus on basin-level data, risk assessments & solutions

Multi-disciplinary action and collaboration beyond science to close data & research gaps

Close funding gaps in adaptation & research plus drive financial reform

Source: CWR analyses based on "No Water No Growth – Does Asia have enough water to develop?", 2018

People, power & trillions of $$$ at risk

The 10 rivers are home to 1.8-1.9 billion people which means up to one in two Asians[9] could be affected by increasing water scarcity if adding the wrong type of power accelerates climate change. Moreover, these 10 HKH River Basins grow 73% of global rice and generate over US$4trn worth of GDP per year[9] powered by 865GW of installed capacity. This means that almost half of installed capacity of the 16 countries lies in the 10 basins.

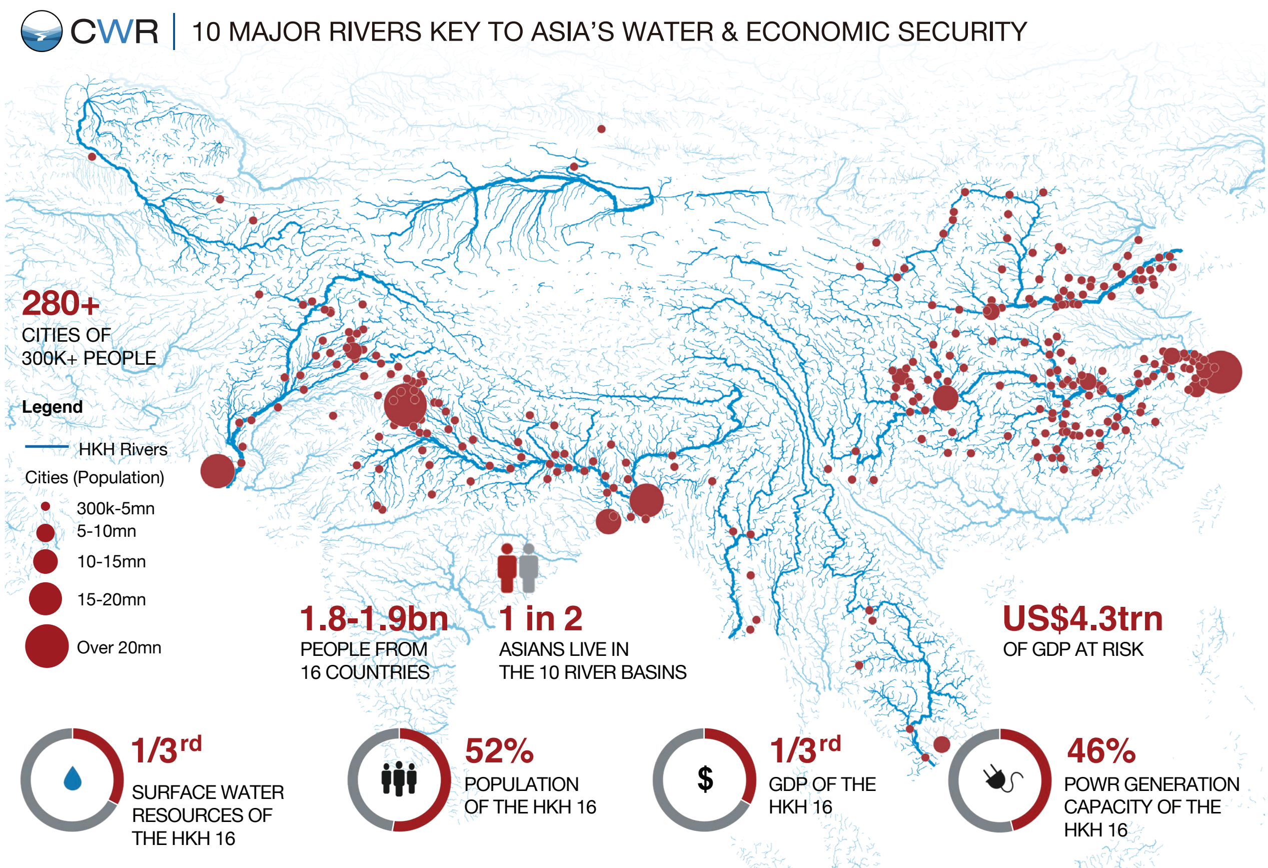
All these are at risk – exposed to rising water scarcity due to accelerated glacial melt, reduced snowfall and changing monsoon patterns as well as overexploitation of groundwater resources. As these countries develop, more people will flock to the 280+ large cities along these rivers adding pressure to already stressed systems.

Yet, Asia is still power hungry – the average per capita installed capacity in the 16 countries that rely on these 10 rivers is only at 0.46kW/pax compared to 3.67kW/pax for the USA. India's per capita installed capacity of 0.23kW/pax is almost quarter that of China's, which in turn is 59% of that of Japan's. China's per capita installed capacity of 1.01kW/pax is only 27% of that of the USA.

Asia's water-energy-climate nexus is tight. To ensure development, countries along these rivers will not just have to practice waternomics, the wedding of economic planning to water resource management, but also rethink energy security as transition policies will affect water availability. Careful management of this is vital, especially now since current policies in place with no additional action put us on a path toward 2.8ºC[2] – see clustered exposure across the 10 HKH River Basins by country in **"At-a-glance: water, people, power & the economy"**.

At 3ºC, 90% of Himalayan ice and snow will be lost and glaciers will have melted.[10] Even at 2ºC, our previous report NWNG revealed that future (2006-2055) trends are not encouraging: the five climate models show that temperatures will continue to rise with increases doubling in six of the 10 basins while snowfall will continue to decline with future losses likely more than doubling for the Indus, Tarim and Ganges. **River runoffs will experience mixed impacts with four rivers seeing shrinkages in flow**.

So while coal may be the cornerstone of Asia's energy policy for now, its expansion and "business as usual" could raise water risks that could make its rivers run dry. At these river deltas also sit mega-cities such as Dhaka, Ho Chi Minh, Karachi, Kolkata, Shanghai, Tianjin and Yangon all which will also face coastal threats as sea level rise accelerates with warming. **Given what's at stake, it's time to rethink energy security.**

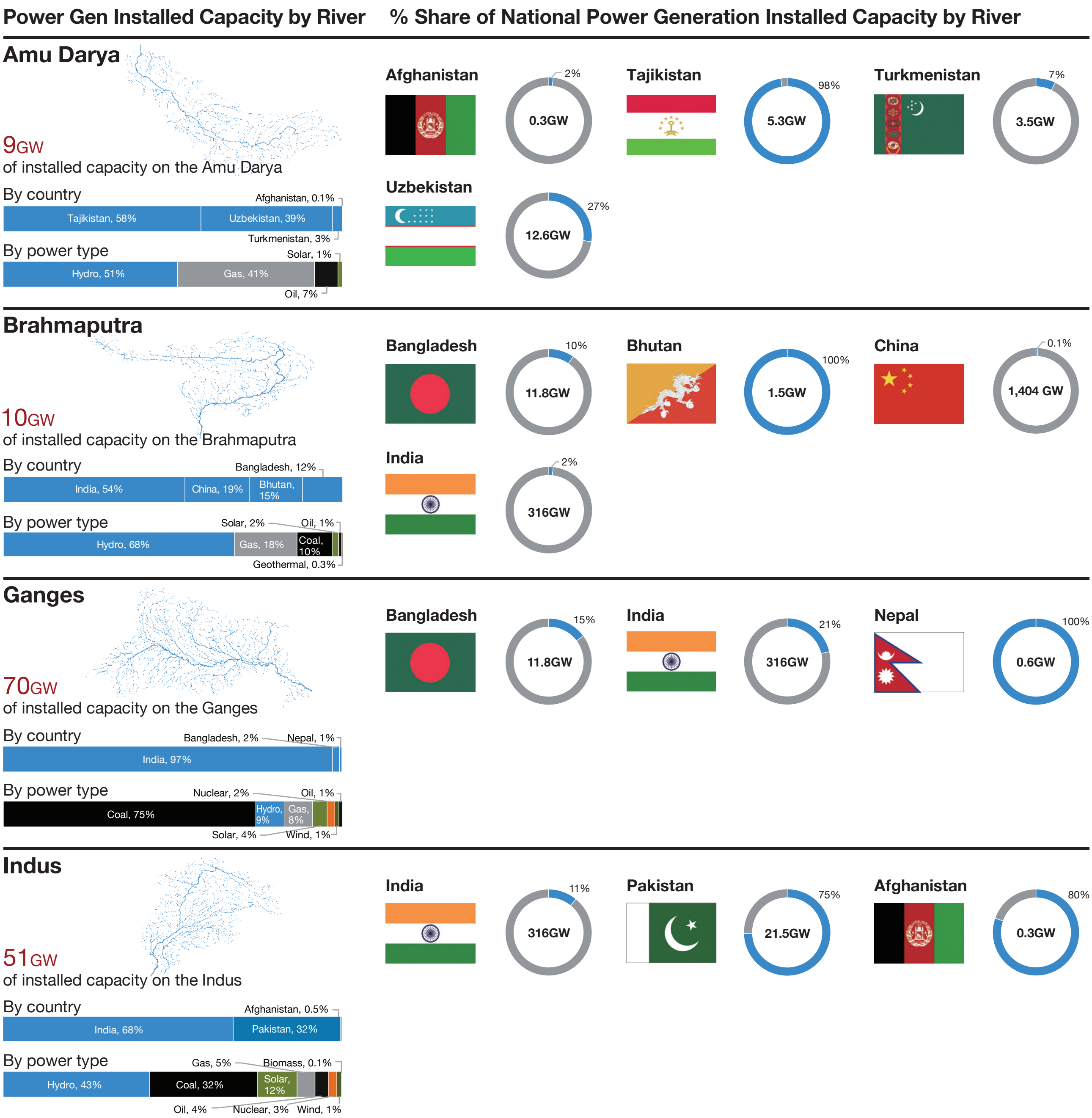


Source: CWR analyses based on "No Water No Growth – Does Asia have enough water to develop?", 2018

10 HKH Rivers power Asia

Almost half of 1.9TW of power assets analysed in this report sit in the 10 HKH River Basins. It is evident from the charts below that these rivers power Asia – some countries' power generation face single key river risk such as Bhutan with the Brahmaputra and Nepal with the Ganges. It is also clear that some rivers are more important to some countries but not to others – however, all rivers face escalating and compounding water risks due to climate change. For more on clustered risks, please see **"At-a-glance: water, people, power & the economy"**.

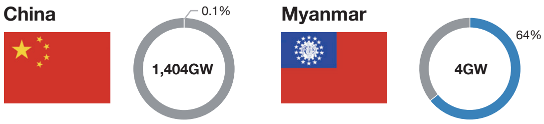
As can be seen from our analyses on **"National energy dependence on HKH Rivers"** on the following pages, the HKH River Basins also play important roles in ensuring energy security. With at least 94% of the 865GW of installed capacity located in the 10 River Basins requiring water to generate and national energy dependencies as high as 100% for some countries, the future of water and energy security across Asia are tied. This report aims to unpack the complex challenges ahead so that we can all find a way forward to ensure that these rivers which feed 1 in 2 Asians do not run dry.



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

CWR

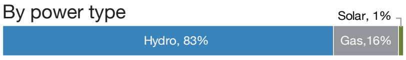
Irrawaddy



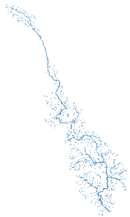
4GW
of installed capacity on the Irrawaddy

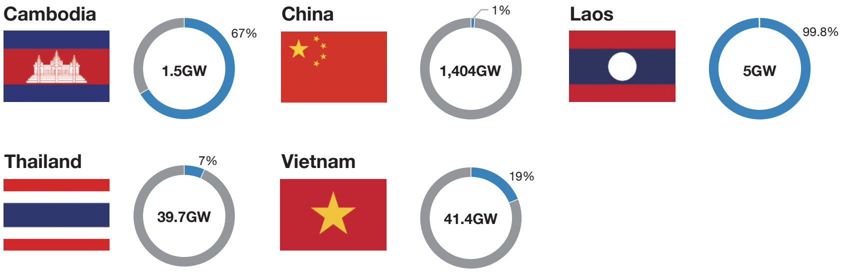
By country

By power type



Mekong

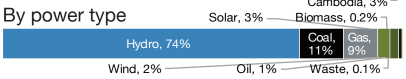




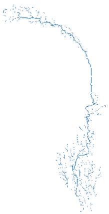
34GW
of installed capacity on the Mekong

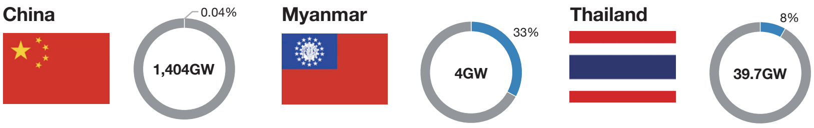
By country

By power type



Salween

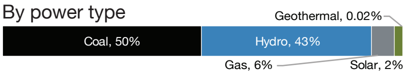




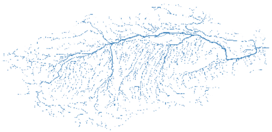
5GW
of installed capacity on the Salween

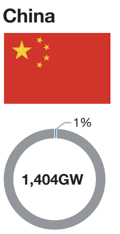
By country

By power type



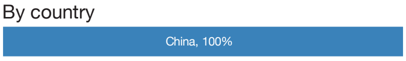
Tarim





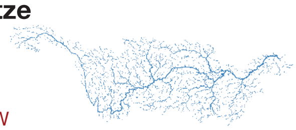
10GW
of installed capacity on the Tarim

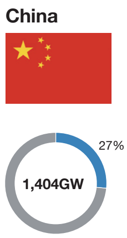
By country



By power type

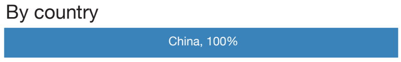
Yangtze



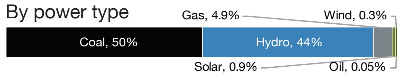


373GW
of installed capacity on the Yangtze

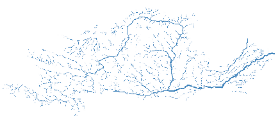
By country

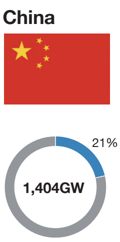


By power type



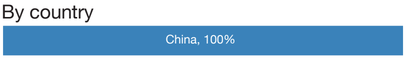
Yellow



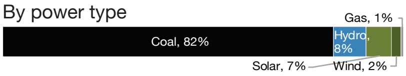


301GW
of installed capacity on the Yellow

By country



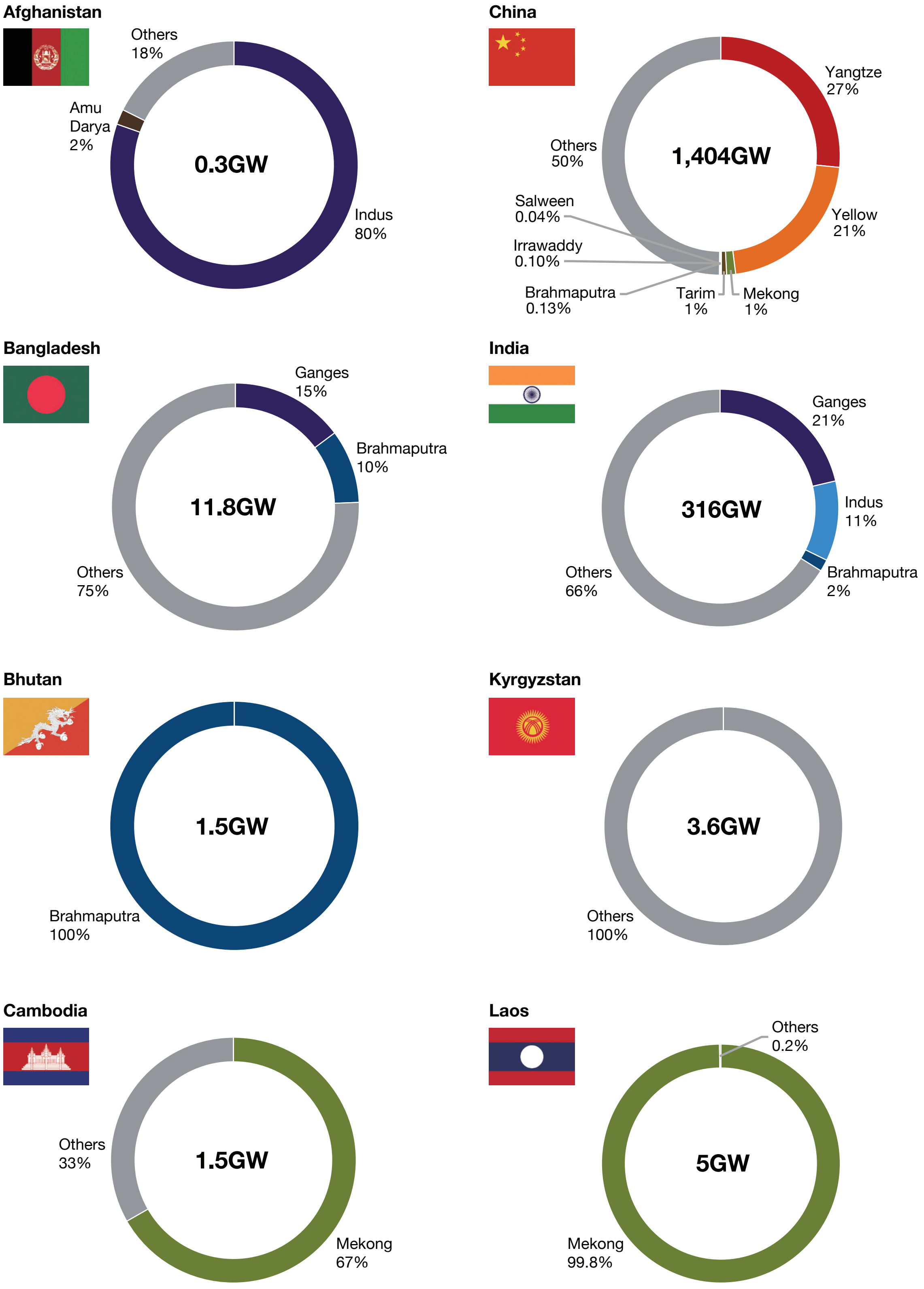
By power type



Note: For consistency and comparability purposes, all power plant installed capacity data used in the above analysis including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this report while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see **"Global Power Plant Database vs HKH 16 country statistics".**

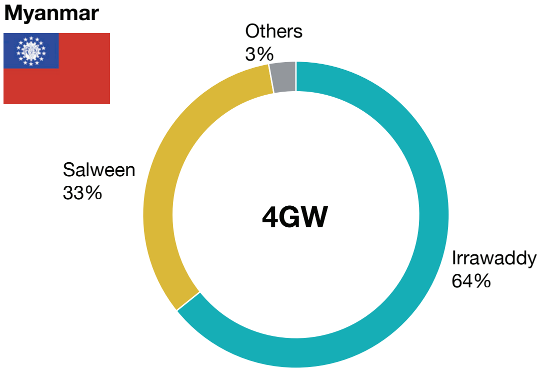
Source: CWR, Global Power Plant Database, FAO AQUAMAPS

National energy dependence on HKH Rivers

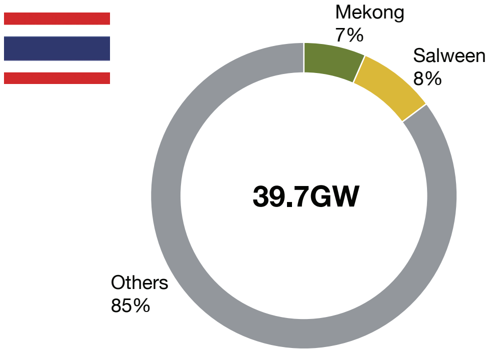


Source: CWR,Global Power Plant Database, FAO AQUAMAPS

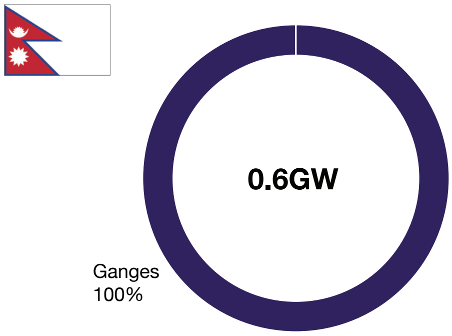
Myanmar



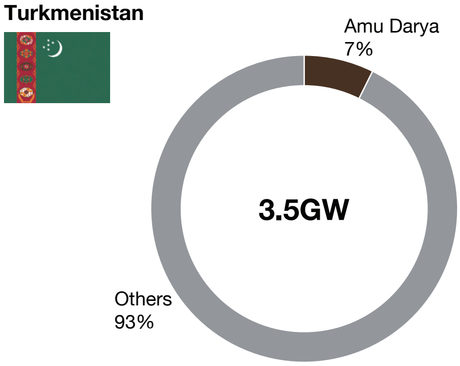
Thailand



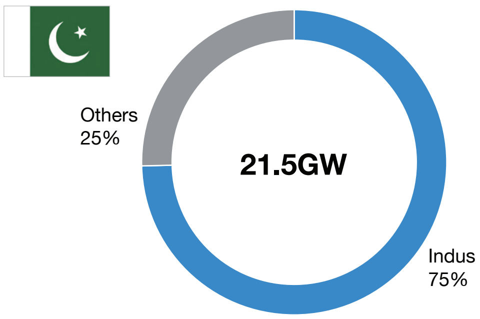
Nepal



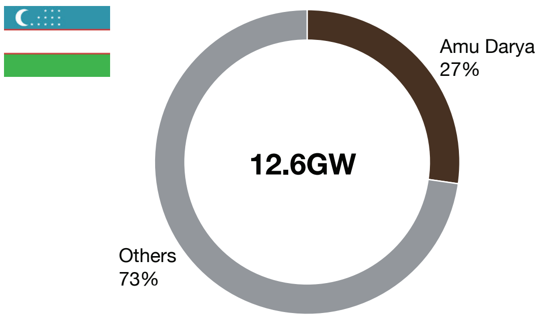
Turkmenistan



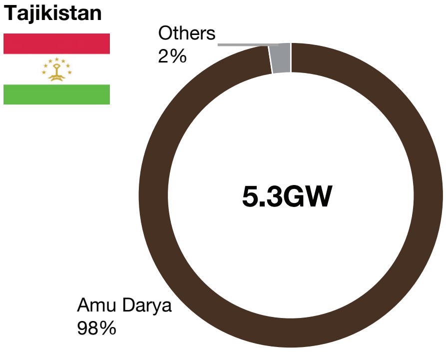
Pakistan



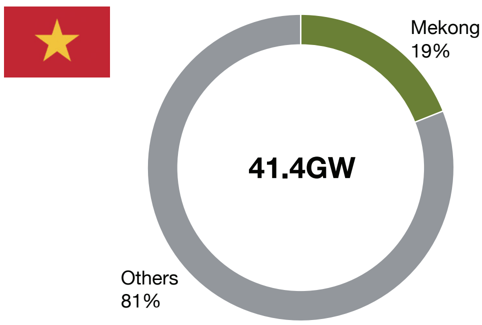
Uzbekistan



Tajikistan



Vietnam



Note: For consistency and comparability purposes, all power plant installed capacity data used in the above analysis including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this report while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see **"Global Power Plant Database vs. HKH country statistics"**.

Source: CWR, Global Power Plant Database, FAO AQUAMAPS

CWR

Executive Summary

Asia is still power hungry but power generation needs water = vicious cycle: "no water" can strand power, which in turn can exacerbate water scarcity. APAC already accounted for nearly half of global primary energy in 2020, yet it is still undergoing rapid development and urbanisation. The ADB projects that APAC energy demand will double by 2030 and since key types of power generation in the region such as thermal power and hydropower require water to generate electricity, demand for water will also rise. According to the IPCC AR6 WG2, under all 2°C scenarios, the energy sector's share of global freshwater use is projected to increase to almost a quarter by 2050; driven mainly by the rapid increase in electricity demand across developing nations. However, most thermal power assets across APAC are carbon intensive and contribute to rising water scarcity, which in turn can strand existing power assets as well as hamper power expansion. **It is thus imperative that we understand Asia's tight water-energy-climate nexus so that we can make the right energy decisions today for water & energy security tomorrow.**

We analysed 1.9TW of the HKH 16's power generation assets and found trifecta exposure to water risks across the 10 HKH River Basins. Anchored by China & India, the HKH 16 is a significant driver of APAC growth and future power needs – our analysis, based on the Global Power Plant Database, showed that the HKH 16's 1.9TW accounted for a third of global power generation capacity. As the IPCC AR6 WG2 warned of *"consistent decreases in mid-to-end of century thermal power production capacity due to insufficiency of cooling water"* with 'high confidence' in central, southern and western Asia, we mapped the HKH 16's power assets to key water sources such as the 10 HKH Rivers that flow from the Hindu Kush Himalayan Water Towers – see **"At-a-glance Power Generation in the 10 HKH River Basins"**. Our analyses indicate that **the power mix should favour less carbon & less water intensive choices due to sizeable trifecta exposure to water risks:**

1) **46% or 865GW is clustered in 10 HKH River Basins which are vulnerable to rising climate risks** – for perspective this is more than the combined capacity of Brazil, Canada, Germany, Japan & Russia;

2) **Over 94% of this installed capacity needs water to generate electricity** – of the 865GW, coal dominates with a 60% share, followed by hydropower with 30%; and

3) **Already 38% of the 865GW lies in basin areas that face 'High' to 'Extremely High' water stress or are arid** – this means 329GW of power generation (all types) are very vulnerable to rising scarcity in the basin.

National water & energy security across the HKH 16 are tied as rivers running dry can strand sizeable portions of the HKH 16's national power assets. Our analyses from each basin as well as each country perspectives revealed important regional & national energy security concerns across the HKH 16 which led us to believe that the future of water & energy security are tied for the HKH 16:

- **Significant clustering of key power types of the HKH 16 in the 10 HKH River Basins** – 73% of the total hydropower capacity of the HKH 16 are clustered in the 10 HKH River Basins, as is 44% of the HKH 16's total coal-fired capacity – see graphic **"Total Exposure of the HKH 16 to 10 HKH Rivers by Power Type"**;
- **Installed capacity ranges from 9GW on the Amu Darya to 373GW on the Yangtze** – 7 river basins house power assets that serve more than one country. The Mekong has power assets that serve 5 countries whereas the Tarim, Yangtze & Yellow's power assets only serve China – for at-a-glance summaries, please refer to **"10 HKH Rivers power Asia"** and individual **"River Power Factsheets"** in Appendix 2; and
- **National energy dependence on singular to multiple HKH rivers** – eg. Bhutan & Nepal's power generation face single key river risk with the Brahmaputra & Ganges respectively; whereas around a third of India's national power installed capacity are located across 3 rivers and ~50% of China's national capacity are spread across 7 rivers – more in **"National energy dependence on 10 HKH Rivers"**.

Uncertain future flows of the 10 HKH Rivers puts future water, energy, economic & food security at risk: 1 in 2 Asians + US$4.3trn of annual GDP are also clustered there. In addition to 865GW of power assets, the 10 HKH Rivers Basins also house up to 1.9bn people or 1 in 2 Asians and generate over US$4.3trn of GDP annually across the HKH 16. Yet, components of river flow such as glacial melt, snow/rainfall and monsoon patterns are impacted by climate change posing grave threats to the HKH 16. As our analyses show, although shares may vary by country, the stakes are high across the HKH 16 – see **"At-a-glance: water, people, power & the economy"**. Future flows of rivers under various climate scenarios must thus also be considered when planning energy expansion/security even for climate scenarios within 2°C: per our NWNG report, a RCP4.5 scenario will result in an overall fall in future river flows (2006-2055) for 4 of the 10 rivers – see **"Past 50/Next 50 years = changing water flows"**. However, all rivers will face escalating & compounding water risks (chronic & acute) if we are unable to rein in emissions. The transboundary nature of 8 out of the 10 rivers will also lend complexity to managing economic, water and energy security – see **"Transboundary issues: not just water sharing but energy policies also"**. **Curating mountains-to-oceans waternomic roadmaps that include energy policies can therefore help ensure future water, energy, economic & food security across the HKH 16.**

The HKH 16 must balance waternomic & powergen risks – especially those in the 'Overall High Risk Group'. River management is never only about managing water. Balanced power expansion must deliver energy security but not at the expense of water security and economic growth as adding more coal will accelerate climate change and increase water risks. In this regard, waternomic and energy policies will differ by river as well as by country and we have **grouped the countries into 4 risk group categories** depending on their respective national exposures to the 10 HKH Rivers across various parameters. These include the rivers' share of national surface water resources plus the shares of national population, GDP, total installed capacity, coal-fired power as well as hydropower capacity that are housed there. It's worth noting here that half of the HKH 16 fall into the **'Overall High Risk Group': Laos, Afghanistan, Nepal, Bhutan, Myanmar, Cambodia, Pakistan and Tajikistan – for these, basin risks should guide energy policy**. While we've provided an overview for each country in this report, it is but a start and deeper analysis by country is needed – for more see **"Balancing waternomic & powergen risks across the HKH 16"**.

Coal-reliant China & India fall in the 'Med-High Risk Group', but play key roles in regional energy & water security as coal-fired power is impacted by & contributes to water risk. Despite facing relatively lower risks, China and India have the most amount of GW clustered in the 10 HKH River Basins. Also, they are the two most coal-reliant of the HKH 16. As coal-fired power contributes to and is impacted by rising water scarcity, it is important that **China & India (as well as the rest of the HKH 16) choose the right type of power – one that generates more power on less water and less carbon, preferably zero**. Here, the IPCC AR6 WG2 recommends shifting to higher shares of renewables such as wind & solar PV to mitigate risks, but note that this doesn't mean that 'clean power' is without water risks (see water risk overviews for hydro, nuclear, solar PV & wind in Chapter 2). Although India & China are aggressively doubling renewables in the next 5 years, our findings show they must do more:

- **97% of the 517GW of coal-fired power** located in the 10 HKH River Basins sit in the Yellow, Yangtze, Ganges & Indus – these are key for China & India from economic, population, food & energy perspectives;
- **More than half of the coal-fired capacity** in each of these 4 rivers face at least 'Medium-High' drought risk as well as 'Medium-High' flood risk; and
- **188GW or 43% of China's coal-fired capacity in the 10 HKH River Basins** face 'High' to 'Extremely High' water stress; although India's fleet is smaller at 55GW, its exposure to severe water stress is higher at 83%.

Picking the right type of power and cooling type can help alleviate water stress but beware of trade-offs! While we need rapid decarbonisation to reduce rising chronic water scarcity risks, we recognise that it may be difficult to completely de-coal from an energy security standpoint. So, for coal-fired plants which are key to support base load and energy security, do maximise energy efficiencies, consider carbon capture and retrofit plants with cooling tech to alleviate water stress in severely water stressed areas. However, key trade-offs must be considered: 1) Carbon capture & storage can be water intensive, so limited water resources can constraint such options; 2) Using dry/air cooling can help alleviate water stress & competition for water, but lower generation efficiencies mean it will result in more carbon emissions and higher costs per unit of power generated; and 3) As extreme weather can cause disruptions in hydropower, more coal-fired capacity may be added to balance the grid and avoid disruption. Indeed, China saw a surge of "just-in-case" coal-fired power additions in 2022 after the severe droughts along the Yangtze. These trade-offs plus more are set out in **"Energy policies for a water secure future: 8 broad recommendations"**.

Tied energy & water futures = dovetailing of national energy & water security plans. If we do not rein in emissions, the IPCC AR6 warned that 3-4bn people could face chronic water scarcity. As power choices can impact water and the lack of water can strand power assets, water security should decide energy security. However, this is generally not the case at the moment – energy plans are typically prioritised over water security plans and most countries do not even have a water security plan that takes into account the latest climate science, let alone one that dovetails with energy security. **The dovetailing of water & energy policies is ever more urgent as escalating & compounding water risks as well as the rising demand for water will bring about more competition for water resources.** Indeed, extreme weather is already wreaking havoc: last year, over 30mn people lost their homes to devastating floods in Pakistan; its economy took an estimated 10% hit. At the same time, Yangtze droughts disrupted not just China's power supply but also global supply chains. While there's no one-size-fits-all policy, we've shared **"Lessons from China"** in Appendix 1 from cooling tech bans, waternomic roadmaps to managing water extremes.

High stakes = Asia has no choice but to step up & lead global decarbonisation. Although this report only analysed power assets within the 10 HKH River Basins, in reality, all carbon intensive power assets in the HKH 16 and beyond will impact the water & energy security of the HKH 16. Given that the global momentum to reduce emissions has stalled with the Russia-Ukraine war triggering an oil boom, Asia must step up to fill the leadership vacuum. The HKH 16, with heavyweights China and India, can pave the way to balance the ever-rockier geopolitical landscape and steer us away from >4°C of warming under the IPCC SSP3 "Regional Rivalry Scenario". In developing Asia, we have the luxury of real time adjustments to our development models to rein in emissions plus build infrastructure to adapt to climate impacts. **We must grasp this opportunity to fast track the transition as well as prepare and adapt for escalating water risks. We are optimistic that this is possible; for perspective, China's clean electricity output of 2,960TWh in 2022 already surpassed the EU's 2021 total electricity generation of 2,785TWh.** So while this report is far from perfect, with clear gaps, we felt compelled to make a start in unpacking the nexus. We all have a part to play and **we invite all stakeholders to build & improve on the analyses so that we all can better inform & shape our shared energy & water futures**. Now is the time for Asia to put in place sensible energy policies that will protect and not destroy our rivers. If we do not fail our rivers, our rivers will not fail us.

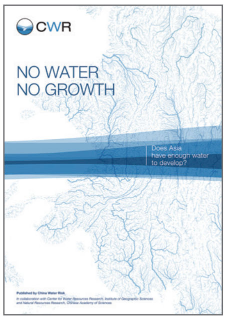
CWR

Contents

Infographics

Info Briefs

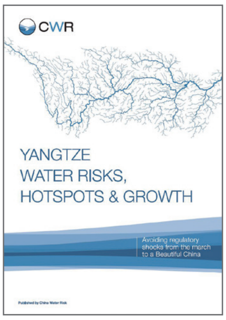
CWR: a decade of unpacking & valuing interlinked waternomic risks in the water-energy-climate nexus…



No Water No Growth – Does Asia have enough water to develop?
CWR with CAS-IGSNRR, 2018

Notably:
- Cited by IPCC AR6 WG2: "Climate Change 2022: Impacts, Adaptation & Vulnerability"
- Led to a waternomics chapter in a 2021 Nature Springer book: 'Water Security Under Climate Change" launched by Scotland's Minister of Net Zero ahead of COP26 in Glasgow

Yangtze Water Risks, Hotspots & Growth – Avoiding regulatory shocks from the march to a Beautiful China
CWR, 2019

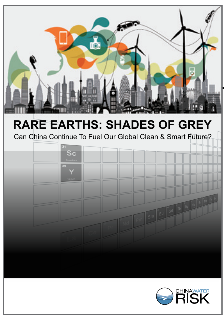


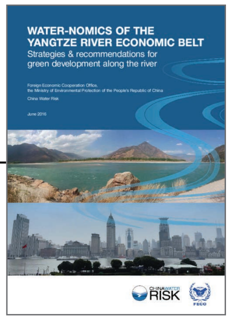
长江经济带水资源水环境指标评估及对策
Journal of Beijing Normal University (Natural Science), 2019
(Chinese only)

Rare Earths: Shades Of Grey Can China continue to fuel our clean and smart future?
CWR, 2016 (EN / 中文)

Institutional investor highlighted CWR's report in the 2016 PRI in persons meeting

The PRI tabled rare earths as an emerging risk along with cybersecurity and antibiotics





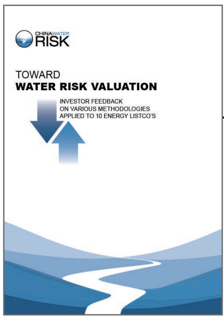
Water-nomics of the Yangtze River Economic Belt
CWR with MEP-FECO, 2016 (EN / 中文)

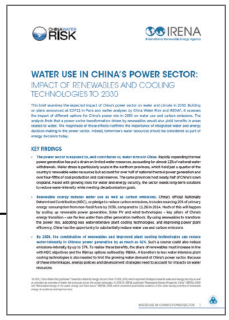
Findings were:
- Distributed internally as "red-heading" communication to central & provincial government bodies & environmental authorities of China
- Published in national academic journal "Environmental Protection" (Issue 15, 2016), one of the most influential environmental journals in China

Toward Water Risk Valuation: Investor Feedback on Various Methodologies Applied to 10 Energy ListCo's
CWR, 2016 (EN / 中文)

Methodologies included in:
- 1st ever book on "Environmental Risk Analysis by Financial Institutions" by Dr Ma Jun (Chinese only)
- Palgrave MacMillan 2021 Textbook: *"Water Risk and Its Impact on the Financial Markets and Society"*

The report is "Recommended Reading" in the 2021 CDSB (now IFRS) Framework: *"Application guidance for water-related disclosures"*





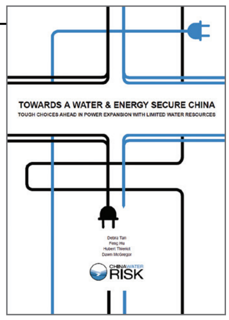
Water Use in China's Power Sector: Impact of Renewables & Cooling Technologies to 2030
CWR & IRENA, 2016 (EN / 中文)

Findings were presented by IRENA in:
- Clean Energy Ministerial (CEM) 7 Preparatory Meeting in Beijing in March 2016
- The 12th Council of the International Renewable Agency

Water for Coal – Thirsty miners will feel the pain
CWR for CLSA U, 2013

Unpacking water risks in the power sector in sell side research (institutional investors only)

No water, no power Does China have enough power to fuel expansion?
CWR for HSBC, 2012



Towards A Water & Energy Secure China – Tough choices ahead in power expansion with limited water
CWR, 2015

Unpacking water risks for different power types - coal, hydro, nuclear & renewables (open source)

Water Risk Analysis & Recommendations for Water Resource Management in Ningxia
WRI with CWR, 2015 (EN / 中文)

Provincial case study on water use permit trading between the power sector & agriculture

Power & Rivers

Asia's Water-Energy-Climate Nexus

Chapter 1

CWR

Asia is power hungry

Rapid development + urbanisation driving energy growth

Asia has witnessed fast economic growth in the last decade. It is also the world's manufacturing base; Asia's industrial value-added rose from US$2.7trn in 2000 to US$9.4trn in 2019; a remarkable 6.7% annual growth.[11] This combination of rapid economic growth and manufacturing-focused economies has greatly increased the demand for energy – already the Asia and Pacific region (APAC) consumed nearly half of global primary energy in 2020.[12]

APAC consumed nearly half of global primary energy in 2020…

Rapid urbanisation is another factor that has led to more electricity usage in transportation and utilities. Already home to 54% of the world's urban population, APAC countries, especially China and India, are still undergoing rapid urbanization. The UN projected that India, China and Nigeria will account for 35% of projected growth of the world's urban population between 2018 and 2050[13] with India and China adding 416mn and 255mn urban dwellers respectively.[14]

…yet it is still undergoing rapid urbanisation

Given rising urbanisation and continued development, energy demand is only going up. Indeed, the Asian Development Bank (ADB) estimated that APAC energy demand will double by 2030.[15] As coal-fired power is still the most stable and cheapest type of energy source available, it is tempting to use coal to close the power gap that would put Asia on par with the Global North on an installed capacity per capita basis.

ADB says APAC energy demand will double by 2030

The HKH 16 accounts for a third of global power generation capacity

To analyse the importance of the 10 HKH Rivers to each of the countries of the HKH 16, we used the Global Power Plant Database managed by the World Resource Institute (WRI). Although the database was updated in 2021, there are discrepancies between the database and the countries' own power generation statistics. For example, the total power generation capacity for the HKH 16 per the respective government statistics for 2019 (the latest year of data available for all) was 2.6TW whereas the Global Power Plant Database's total installed capacity for these 16 countries was only 1.9TW.

1.9TW of installed capacity in the HKH 16 were analysed…

… the Global Power Plant Database was used

This gap of 714GW; the majority of which is from China (606GW) is not ideal and can be attributed to emerging numbers of renewables such as solar and wind in China, which are not included in the WRI managed database as they are relatively new and smaller. However, conventional power plants, including thermal and large hydro plants, are more extensively covered in the WRI's database. Indeed, our reconciliation of the installed coal capacity revealed a much smaller gap of 92GW for China and a mere 2GW for India. Since the purpose of this report is to explore the interdependencies of coal-fired power and rivers, we have decided that the Global Power Plant Database, while not 100% accurate will suffice for the purposes of analyses contained in this report to provide insights on the Water-Energy-Climate Nexus of the HKH 16. Please refer to **"Global Power Plant Database vs. HKH 16 country statistics"** for more details.

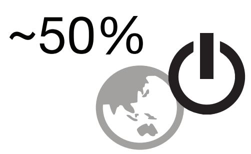
There were data discrepancies with official statistics …

… but these are narrower for the coal fleet which this report focuses on

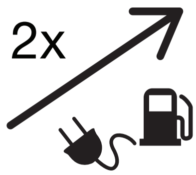
Based on the Global Power Plant Database, the HKH 16's installed capacity amounts to 1.9TW; this represents 33% of global power generation capacity as per the database, whereas other big power consumers Japan and South Korea account for 4% and 2% respectively. Given that Japan and South Korea are developed economies, their power demand is relatively stable compared to that of the HKH 16, the energy policies of the still developing HKH 16 are thus vital for successful energy transition in Asia.

The HKH 16 accounts for 33% of global powergen capacity & they are still power hungry…

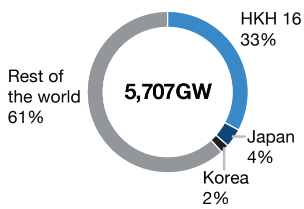
APAC consumed nearly half of global primary energy in 2020



APAC energy demand will double by 2030



Power generation capacity of HKH 16, Japan, Korea & rest of the world



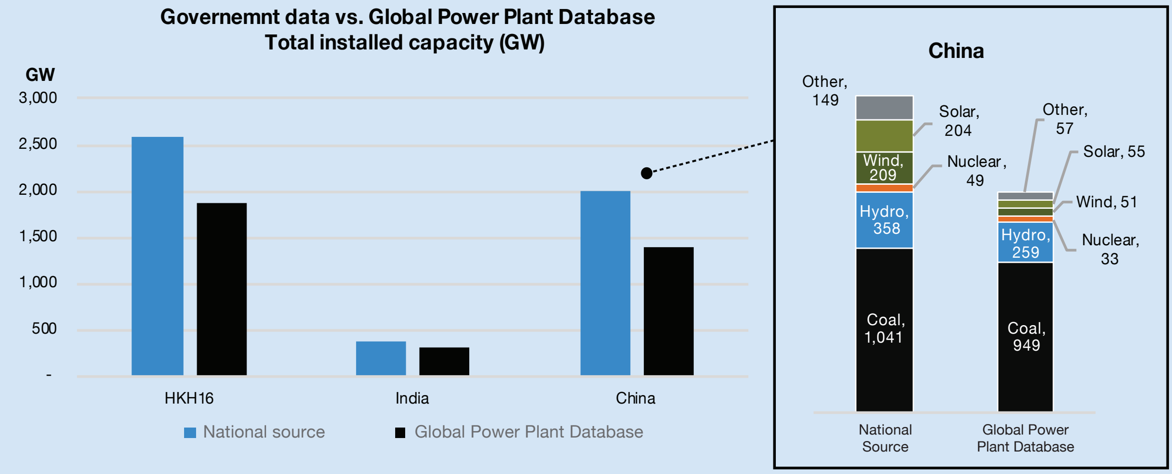
Source: CWR, Our World in Data, ADB, Global Power Plant Database

CWR

Global Power Plant Database vs. HKH 16 country statistics

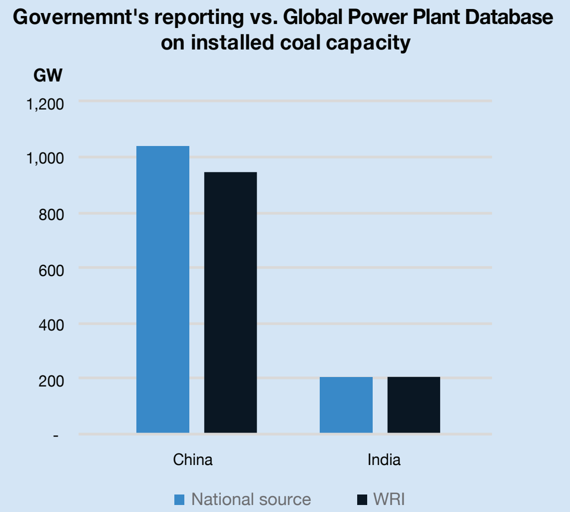
Selecting the right dataset for analyses in this report was not easy as each country reported its energy statistics with different standards and timescales. To ensure statistics across countries are comparable to generate meaningful analyses, we have used the Global Power Plant Database managed by the WRI. Although the database was updated in 2021, reconciliation to HKH 16's government statistics revealed sizeable discrepancies – the total power generation capacity for the HKH 16 per the respective government statistics for 2019 (the latest year of data available for all) was 2.6TW whereas the Global Power Plant Database's total installed capacity for these 16 countries was only 1.9TW.

As per the left chart below, it is clear that a large portion (85%) of the 714GW of discrepancy is due to China which alone accounted for 85% of the gap; while the gap for India is less at 68GW. Such discrepancies could be due to the challenges faced by the Global Power Plant Database when collecting data from 600+ sources that have varying timescales and standards, with likely reporting delays. A large part of this discrepancy can be attributed to emerging numbers of renewables such as solar and wind in China as per the right chart below. These are likely not included in the WRI managed database as they are relatively new and smaller.



Source: CWR, Global Power Plant Database & various government sources

As the purpose of this report was to explore the interdependencies of coal-fired power and the 10 HKH Rivers, we drilled down to see the data gaps on coal-fired power. We found smaller discrepancies in the coal fleet. For China and India (by far the countries with the largest power fleets in the HKH 16) the data gaps were: 92GW for China and a mere 2GW for India – see right chart.



Source: CWR, Global Power Plant Database & various government sources

These smaller gaps lend confidence to using the Global Power Plant Database as China and India already take up over 50% of installed coal capacity in the HKH 16. Indeed, the WRI database is recognised for its more extensive coverage of conventional power plants (including thermal and large hydro plants) rather than distributed renewables like wind and solar.

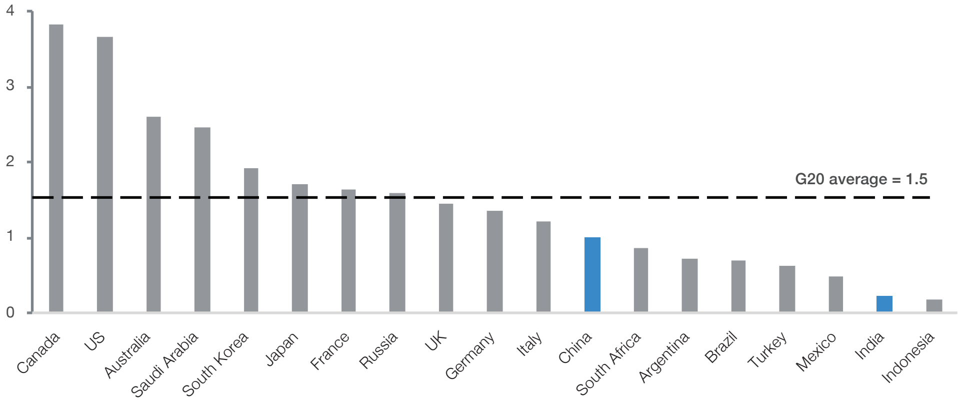
These reconciliations show that the Global Power Plant Database, while not 100% accurate will suffice as a dataset for analyses to provide a valuable "first look" at the risks that rising water scarcity poses to the coal fleet as well as the risks that coal-fired power expansion poses to river flows. All analyses in this report are thus based on the Global Power Plant Database for consistency and comparability purposes. This includes analyses of national energy dependencies on the HKH Rivers, as actual government statistics can differ from the database with discrepancies ranging from 2% in Vietnam to 59% in Afghanistan, we recommend more in-depth analyses to be carried out across the HKH 16 countries to obtain a more accurate picture of the national fleet vis-à-vis the 10 HKH Rivers. However, for the purposes of this report, this is enough to provide insights into the tight water-energy-climate nexus of the HKH 16 and catalyse such detailed mapping of power assets' exposure to water risks.

The power gap is huge! The HKH 16 countries are miles behind the G20

Developing Asia still has a long way to go with power expansion. As can be seen from the chart below, the HKH 16 countries lag the G20 in per capita installed capacity. Even China and India, the two highest energy-consuming countries in the HKH 16, had per capita installed capacity at 1.0kW and 0.23kW in 2019 respectively, way below the G20 average of 1.5kW.

The HKH 16 lag the G20 in per capita installed capacity…

G20 Installed capacity per capita (kW/pax)



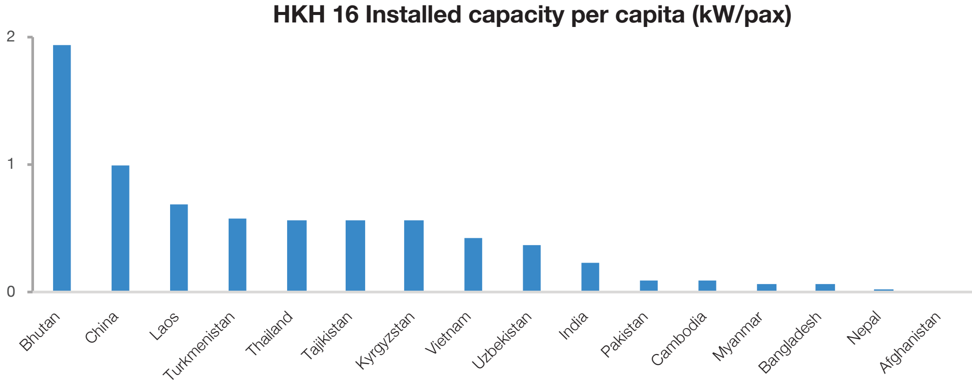
Source : CWR, Global Power Plant Database, World Bank

…even China & India are still way below the G20 average of 1.5kW/pax

As for the rest of the HKH 16, they lag even further behind 2kW/pax as per the chart below:

The rest of the HKH 16 lag even further behind…

HKH 16 Installed capacity per capita (kW/pax)



Source: CWR,Global Power Plant Database, World Bank

…Bhutan ranked the highest while Afghanistan had the lowest per capita installed capacity

Clearly, it is not "fair" but too much is at stake to play the 'Blame Game'. Historic emissions by the Global North has disadvantaged the Global South by constraining its development and fuel expansion options – for more see **"The Blame Game: Coal reliance & climate injustice"**. Nevertheless, beyond the "unfairness" of coal constraints imposed on the HKH 16, all 16 countries must revisit their energy policies with "water in mind". They must do this not because the G7 or Global North asks them to but because there are just too many assets, lives and livelihoods on the 10 HKH Rivers to get these wrong. Indeed, playing a blame game distracts from the real issue in hand – if Asia is not careful, it will shoot itself in the foot with the wrong energy policies. This is more urgent, now than ever, as there's a 50/50 chance we will breach 1.5°C by 2026.[16]

Historic emissions by the Global North has eaten into the Global South carbon budget for development

But playing a blame game distracts from real issue at hand…

Reality bites! Climate change is already disrupting water & impacting power generation. Please see "Extreme weather impacts the ability to produce power" in Chapter 3.

…wrong energy policies could sink Asia's future

The Blame Game: Coal reliance & climate injustice

No doubt, China and India as well as the rest of the HKH 16 must also do their part and resist coal expansion to deliver on or even up their climate pledges but developed nations can and must do much more to curb emissions.

- **Western hypocrisies & lack of leadership:** Closing the gap on power disparity with fossil fuels will certainly prove disastrous for climate change – this has led the "developed West" to call for Asia to "end coal". However, it is clear from these power disparities that the Global North's call for China and India to curb their coal diet by "ending coal" ring hollow. After all, the per capita installed capacity in Australia (2.6kW) and Canada (3.82kW) are 11-17x India's; whereas India's GDP is 1.6x that of Canada's and 2x that of Australia's.[17] China also appears power efficient compared to the USA – the USA per capita installed capacity of 3.7kW is 3.7x that of China's despite powering a GDP that is only 1.3x that of China.[17]

  Besides such glaring gaps, whilst calling for Asia to end coal, USA's crude oil production for 2023 and 2024 is forecast to surpass the previous record set in 2019: the UK granted 100+ new exploration licenses in the North Sea while Norway drilled 17 exploration wells in 1H2022.[5, 6, 7] In the meantime, China led on renewable energy investments with almost US$99bn invested in wind and large scale solar in 1H2022 – see infographic on next page.

- **Rich countries vs poorer countries:** Closer to home, India and China are also far behind Japan and South Korea. Despite having a GDP that is 3.6x that of Japan, China's per capita installed capacity is 41% less than that of Japan; India's GDP is 1.8x that of South Korea[17] but its per capita installed capacity is only 12% that of South Korea.[17] There are clear gaps between richer and poorer countries. Indeed, the IPCC AR6 stated with high confidence that *"Globally, the 10% of households with the highest per capita emissions contribute 34-45% of global consumption-based household GHG emissions."* The bottom 50% contributed 13-15%.

  The IPCC also notes that *"The lifestyle consumption emissions of the middle income and poorest citizens in emerging economies are between 5-50 times below their counterparts in high-income countries"*. It's no surprise then that the IPCC expects climate finance from such richer countries to drive a successful transition. But they are not, the US$100bn promised to help vulnerable countries transition and adapt is still yet to materialise. At least in COP27, due to pushback from the Global South, the loss and damages discussion is finally tabled.

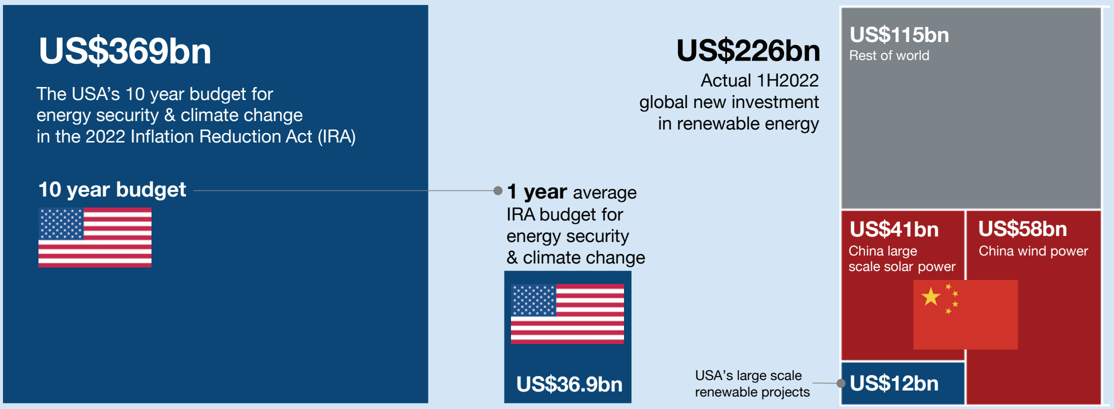
- **Asia's blamed for coal but dominance in renewable expansion is under-recognised:** While there has been more press focused on blaming China and India for not ending coal, there was less focus on China and India's aggressive renewables expansion. According to the IEA, China on its own accounts for almost half (1.07TW) of the new global renewable power capacity of 2.4TW added over 2022-2027.[18] Indeed, China is now expected to reach its 2030 target of 1.2TW of total wind and solar PV capacity five years earlier. Meanwhile, India's renewables is set to grow by 145GW, almost double its renewable capacity over 2022-2027.[18] For reference, China and India's renewables installed capacity was 1.02TW and 158GW respectively in 2021.[19,20] – see infographic on next page.

  Indeed, the latest IPCC report recognised that although China has accounted for a large chunk of rising emissions, it has also led the slowdown in global emissions. According to the IPCC, *"Average annual GHG emissions during 2010-2019 were higher than in any previous decade but the rate of growth between 2010 and 2019 was lower than that between 2000 and 2009"* – the slowing of this *"was primarily triggered by substantial reductions"* of emissions growth in China. Nevertheless, worries over the expansion of China's coal fleet persists – indeed China gave back significant gains in carbon reduction of some 380MtCO2 for the 12 months from July 2021 through to June 2022[21] as it had to resort to coal-fired power when hydropower failed along the Yangtze River due to severe droughts – see **"Water extremes: Grid flexibility & adding "just in case power""** in Appendix 1. However, there is good news – despite this and GDP growth of 3%, China's emissions still fell by 23MtCO2 in 2022.[18, 22] – see infographic on next page. More on China's efforts to decarbonise in **Appendix 1: Lessons from China** – did you know that China's clean electricity output of 2,960TWh in 2022 already surpassed the EU's 2021 total electricity generation of 2,785TWh – see infographic on next page.

- **Asia most at risk from climate impacts – from no water to sea level rise:** According to the ADB, APAC accounts for almost half of the 281 natural disasters that took place worldwide in 2019 including earthquakes, storms droughts and floods.[23] Since 2014, disasters affected 2.1 billion people and caused losses of over $500 billion in the region.[23] Worse still, 300 million in Asia and the Pacific have no access to safely managed or basic water services such as drinking water, and 1.2 billion lack adequate sanitation.[24] McKinsey estimates $1.2trn in capital stock in Asia is expected to be damaged by riverine flooding in a given year by 2050, equivalent to about 75% of the global impact.[25] The WMO also warned that a high proportion of existing critical infrastructures are in multi-hazard risk hotspots – about a third of energy power plants, fibre-optic cable networks and airports, and 42% of road infrastructure, are in multi-hazard risk hotspots in APAC.[26] Globally, APAC is the most vulnerable region to coastal threats with over 200 million people at risk from just one metre of sea level rise.[27]

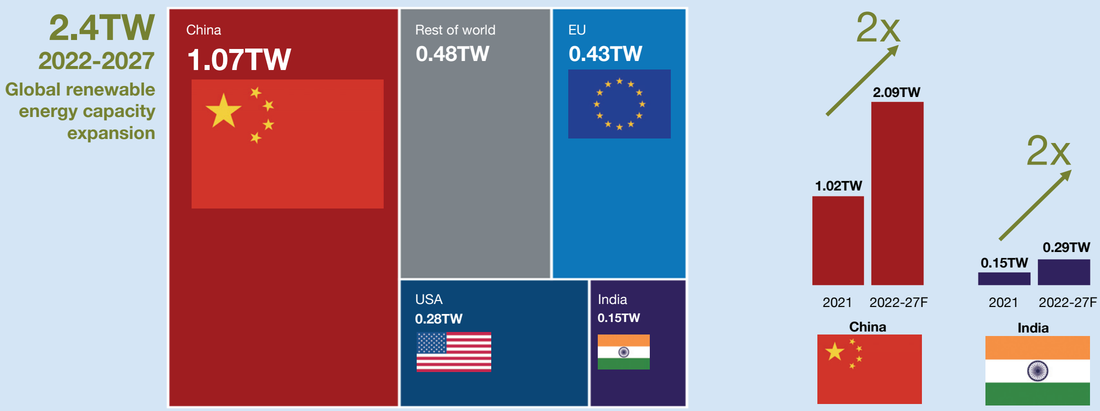
Renewables Expansion: China & India vs. rest of the world

CWR | CHINA'S WIND & SOLAR INVESTMENT FOR 1H2022 IS 2.7X THE USA'S IRA BUDGET FOR ENERGY SECURITY & CLIMATE CHANGE FOR THE YEAR …



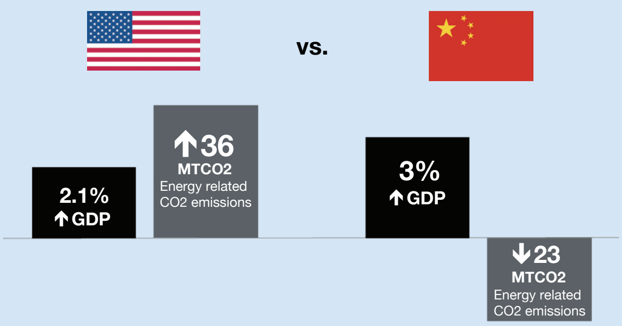
Source: CWR, IEA, www.democrats.senate.gov, BNEF

CWR | CHINA DOMINATES GLOBAL RENEWABLES EXPANSION FOR 2022-2027 CHINA & INDIA TO DOUBLE THEIR RENEWABLE ENERGY CAPACITY IN THE NEXT 5 YEARS…

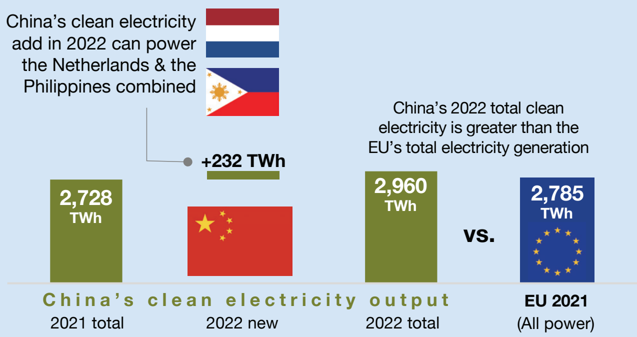


Source: CWR, IEA, www.gov.cn, Statistica

CWR | CHINA'S 2022 CO2 EMISSIONS FELL DESPITE THE GDP GROWTH…



CWR | CHINA'S CLEAN ELECTRICITY CAN POWER ALL THE COUNTRIES IN THE EU…



Source: CWR, National Bureau of Statistics of China, EIA, Eurostat "Statistics Explained", IEA, Bureau of Economic Analysis of the U.S. Department of Commerce.

10 HKH Rivers are essential to regional energy security

The HKH 10 Rivers are key to the HKH 16's economic growth, water & energy security

The HKH 10 Rivers are key to Asia's waternomic growth: they represent a third of the surface water resources of the HKH 16 countries and are home to one in two Asians who rely on their waters to grow food plus generate around US$4.3trn of GDP.[9] These rivers are also important to the energy security of the HKH 16…

Nearly 50% of installed capacity of the HKH 16 are in 10 HKH River Basins

46% of 1.9TW analysed are located in the 10 HKH River Basins…

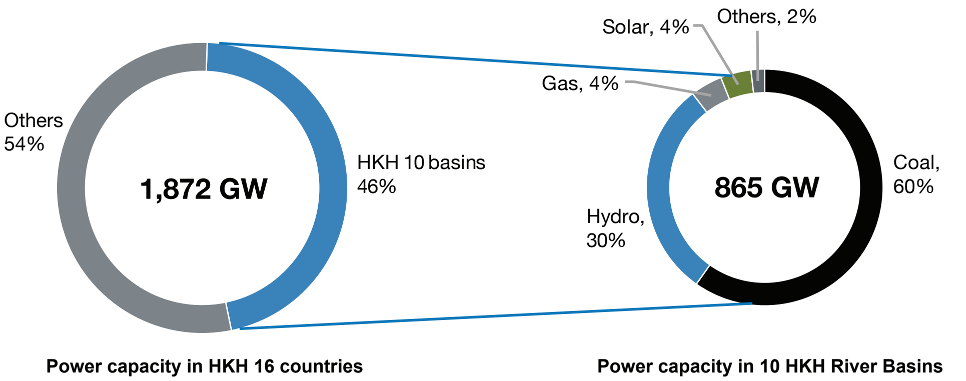
We analysed 1,872GW of installed capacity (coal, hydro, gas, solar and others) across Asia from the Global Power Plant Database to find that 46% of the total power capacity is located in the 10 HKH River Basins. Of this 865GW, coal-fired power plants dominated with a 60% share; hydropower followed with 30%, while gas-fired and solar power each accounted for a 4% share.

It is this skew towards coal-fired power that causes concern in the 10 HKH River Basin – the use/ expansion of coal accelerates climate change, which in turn impacts river flow, exacerbating water scarcity. Since coal-fired power generation requires water, the lack of water can strand existing coal assets and hamper future expansion. Whilst the importance of different types of power and their exposure to water risks are discussed in this chapter, the rest of the report is focused on coal.

Power capacity in the HKH 16 countries & 10 HKH River Basins

…of this 865GW, coal-fired power dominates with a 60% share

… hydropower follows with a 30% share



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

865GW in the 10 HKH Rivers = more than the combined capacity of Japan, Brazil, Canada, Germany & Russia

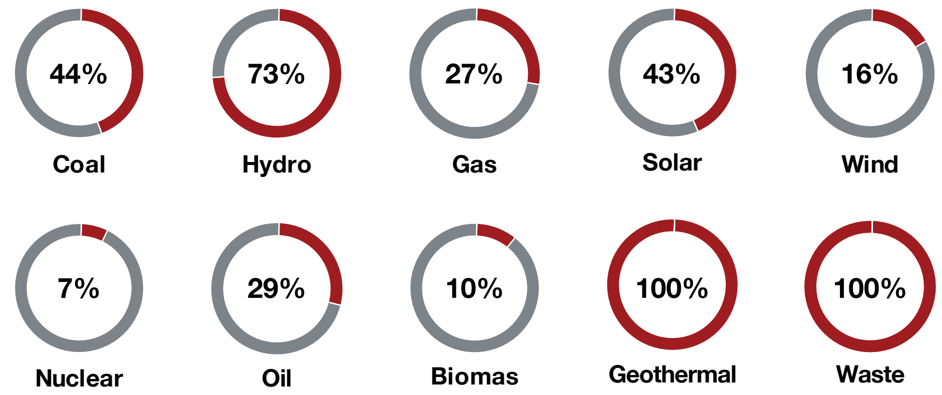
For perspective, the 865GW of installed capacity located in the 10 HKH River Basins is even greater than the combined total installed capacity of Brazil, Canada, Germany, Japan and Russia as per the Global Power Plant Database. The power capacity on the 10 HKH River Basins is nearly 60% of China's and 70% of the USA's installed capacity as per the same the same database.

10 HKH Rivers are important to different types of power

Analysis showed clustering of various types of power in the 10 HKH Basins…

Significant clustering of key power types in 10 river basins. To gauge the importance of the 10 HKH Rivers to the energy security of the HKH 16, we explored the share of each type of power located along the rivers. The results revealed a clustering of various types of power in the 10 HKH Basins. With abundant hydropower resource, 73% of the total hydro power capacity of the HKH 16 countries is not surprisingly clustered in the 10 HKH River Basins. While this was not surprising, we also found that 44% of total coal installed capacity and 43% of total solar installed capacity for the HKH 16 are also located there. Moreover, 100% of geothermal as well as 100% of waste power capacity are located in the 10 HKH River Basins – please see the following charts:

CWR | TOTAL EXPOSURE OF THE HKH 16 TO 10 HKH RIVERS BY POWER TYPE



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

73% of the total hydropower capacity of the HKH 16 is clustered in the 10 HKH Rivers…

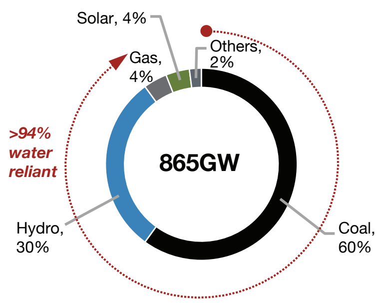
…as is 44% of the HKH 16's total coal capacity

Clustering amplifies exposure to significant river basin stress. Such clustering of people, economy as well as energy has put pressure on the water resources of the basins. Indeed, more than half of the respective basin areas for five out of the 10 HKH Rivers are already either facing 'High' to 'Extremely High' water stress or are arid. Given significant exposure, all stakeholders in the 16 countries should start assessing the exposure of power assets to basin water risk, let alone climate risks. Basin stress by river and its impact on coal-fired power generation are detailed in Chapter 3.

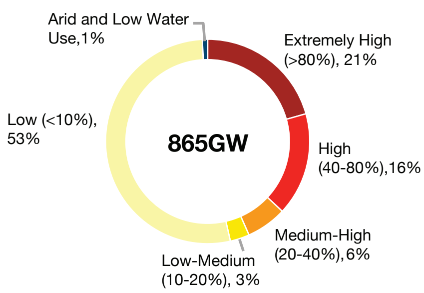
5 out of 10 HKH Rivers have >50% of their basin areas facing either 'High' to 'Extremely High' water stress or are arid…

At least 94% of installed capacity in the 10 HKH River Basins need water to generate power but >20% of the basin faces 'Extremely High' water stress. It's important to note here that almost all of the above types of power need water to generate – as per the left chart below, at least 94% of the 865GW of installed capacity in the 10 HKH River Basins is water reliant. Yet many of these plants are located in water stressed regions. Our analysis (see right chart below) revealed that 21% of the 865GW of power capacity lie in 'Extremely High' water stress areas across the basins with a further 16% in 'High' water stress areas. Another 7% lie in 'Medium-high' water stress and arid areas. Only 53% is located in 'Low' water stress regions. Such exposure makes power generation highly vulnerable to water availability.

Water reliant power in the 10 HKH River Basins



Water stress exposure of the power capacity in the 10 HKH River Basins



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

>94% of the installed capacity in the 10 basins needs water to generate power…

… but 38% of this power capacity lie in basin areas that face 'High' to 'Extremely High' water stress or are arid

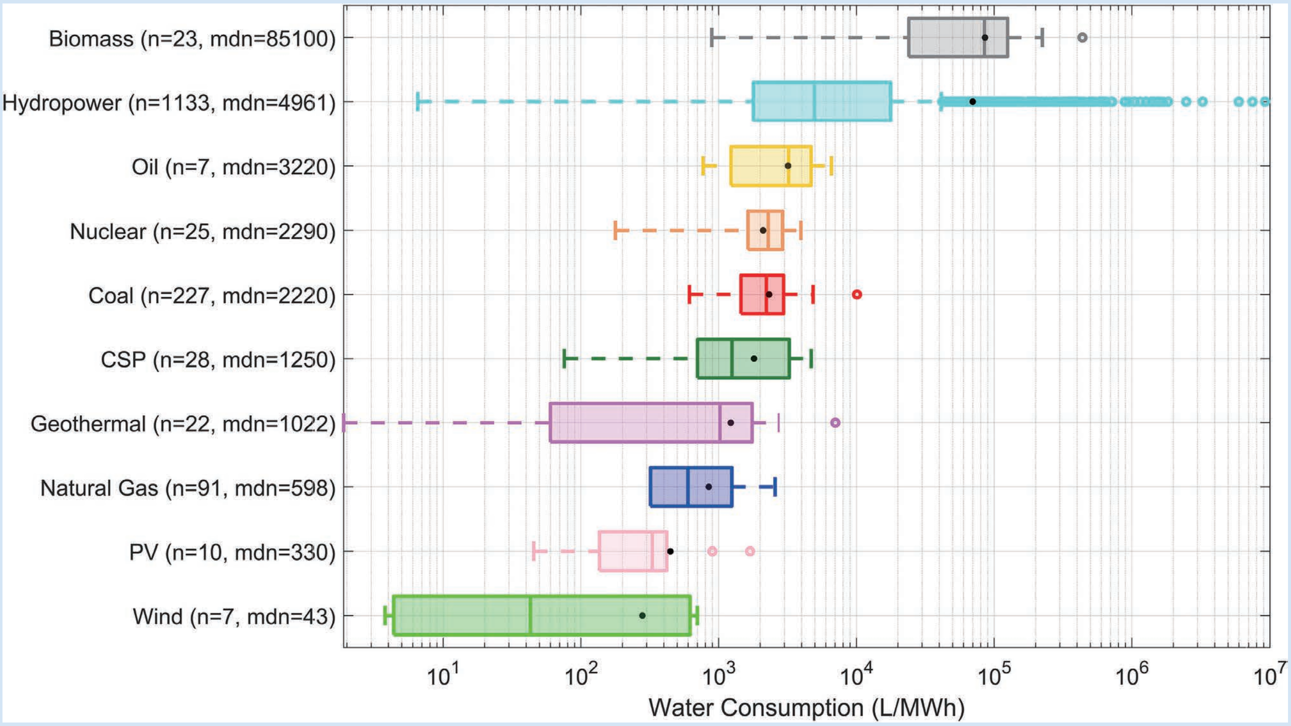
Water is one of the most vulnerable resources to climate change and rising uncertainty in water availability will make it more difficult to ensure continuity in power generation. Governments therefore need to be mindful of this vicious cycle and pick the right type of power – ideally one that will not accelerate climate change and use less water. So what's the current power mix on each river? Read on… but for an idea of water use by each type of power, please see **"Almost all power requires water to generate"**.

Beware! Water can strand power & water is vulnerable to climate change = power mix is key to avoiding vicious cycle

Almost all power requires water to generate

Water is essential to almost all types of power. There are several studies on the life cycle water consumption of different power types. As shown in the boxplot below, each power type has a range of water consumption obtained from different samples.[28] Median value is used for comparison among different power types, which is denoted by the vertical line inside the bar.

Life cycle water consumption of different power types

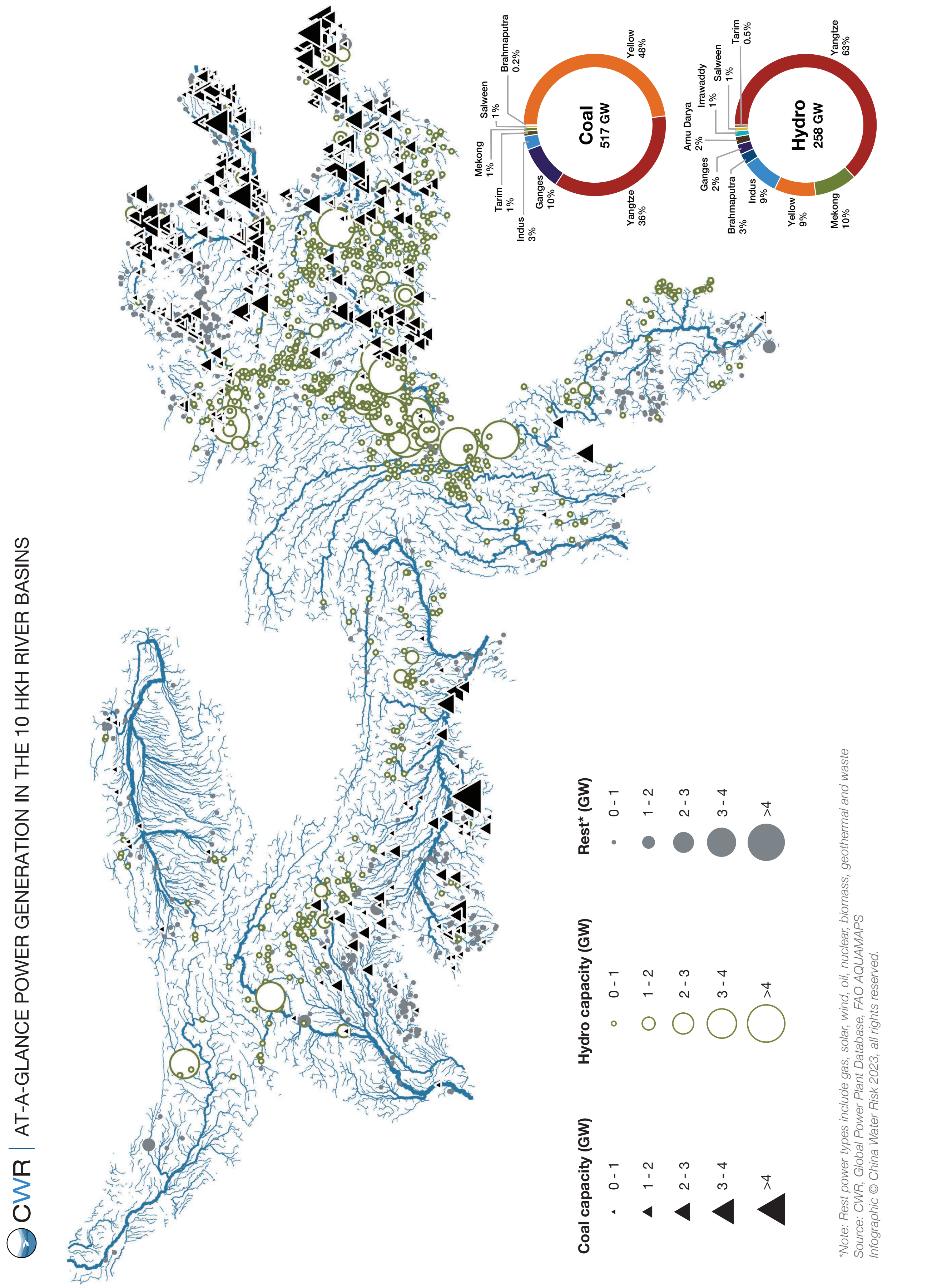


Source: Jin, Y., Behrens, P., Tukker, A., & Scherer, L. (2019). Water use of electricity technologies: A global meta-analysis. Renewable and Sustainable Energy Reviews, 115, 109391.

Key points to note are:

- **Biomass has the largest appetite for water**. The life cycle water consumption of biomass power is one to three orders of magnitude larger than other types of power, with a median value of 85,100 litres/MWh.
- **Hydropower clearly needs water to run** but technically does not consume water during operational activities.[29, 30] However, some studies have included the evaporation of connected reservoirs, which could explain the large water consumption of hydropower.
- **Coal-fired power has a relatively smaller range of water consumption**. The median life cycle water consumption of coal power is 2,220 litres/MWh, based on 227 samples. Extreme water consumption for coal power generally result from low efficiency closed-loop cooling and carbon capture equipments.[31,32,33,34] Cooling technologies used by coal-fired power plants will be discussed in detail in the next chapter.
- **Other thermal power such as nuclear, oil & gas also use large amounts of water**. Especially for oil, the median life cycle water consumption is 3,220 litres/MWh, even higher than coal. Water is the most essential for nuclear power as the lack of it could cause the reactor to overheat – more on nuclear power later in **"Overview of nuclear power's water risk exposure in the 10 HKH River Basins"**.
- **Solar PV & Wind are the most water-friendly.** Wind power uses the least amount of water followed by solar PV. But not all solar power is water-friendly – concentrated solar power (CSP) uses 1,250 litres/MWh of water in the cooling process to generate electricity.

At-a-glance Power Generation in the 10 HKH River Basins



'4 Priority Rivers': Yangtze, Yellow, Ganges & Indus dominate powergen

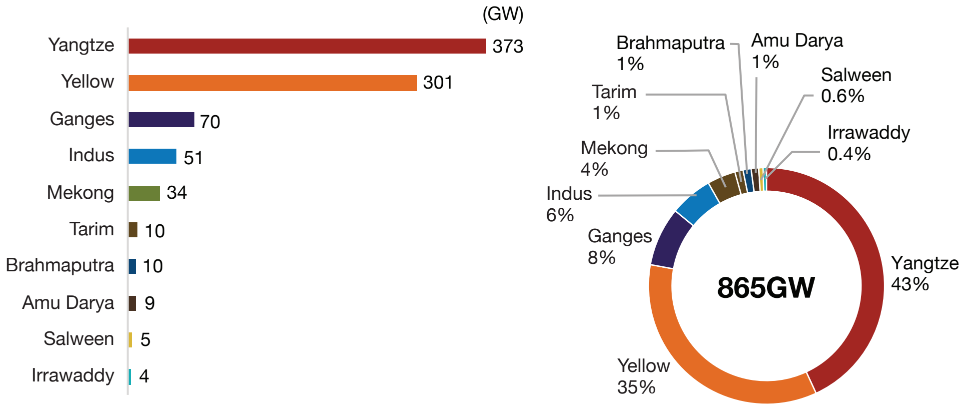
Power generation is clustered in 4 Priority Rivers…

The NWNG Report identified 4 Priority Rivers for action due to either the concentration of socio-economic risks, water stressed basin and/or both. It is clear from the at-a-glance map of power generation across the 10 HKH Rivers Basins that the power generation is also clustered in these 4 Priority Rivers. Yangtze and Yellow Rivers dominate, followed by the Ganges and Indus as shown in the chart below:

…they are the Yangtze, Yellow, Ganges & Indus

Together, they account for 92% of the total capacity in the HKH 10 River Basins

Total power capacity by 10 HKH River Basins



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

Key points to note are:

…Yangtze & Yellow have the largest share with 674GW

- At 674GW, the Yangtze and Yellow Rivers alone account for almost 80% of the total power capacity in the HKH 10 River Basins; more than 3.5x that of the other 8 basins.
- At 70GW, the Ganges while less than a fifth of the Yangtze's power generation installed capacity, still has 2x the power generation capacity of the Mekong.

Transboundary nature = important to see the extent of national power dependence on these rivers

- Given the transboundary nature of some of these rivers, while the Yangtze and Yellow Rivers only serve China, power on the Ganges is shared by Bangladesh, India and Nepal and for the Mekong by Cambodia, China, Laos, Thailand and Vietnam. Thus, it makes sense to explore the extent of national power dependence to these 10 HKH River Basins.

4 "Priority Rivers" house US$3.8trn of GDP & 1.5bn people…

… climate change impacts river flows – Ganges & Indus will likely see reduced runoff flows by 2055

4 Priority rivers from CWR's NWNG Report

Four "Priority Rivers" require urgent attention: Although every river is important to each of the HKH 16, our basin analyses reveal four "priority rivers": the Ganges, Indus, Yangtze and Yellow. Not only do they house the largest economies with an estimated total GDP of US$3.8trn, they are densely populated with 1.5bn people. All four "priority rivers" are vulnerable to climate change with glacier and snow melt contributing to over 20% to 80% of runoff in the upper reaches of these rivers. More worryingly, projections show that the entire Ganges and Indus river basins will likely see reduced runoff flows by 2055. Given clear risks ahead, India and China must act.

Source: The above is extracted from CWR's report "No Water, No Growth – Does Asia Have enough water to develop?", 2018

National energy dependence on 10 HKH Rivers

The analysis in this section should be read in conjunction with the infographics titled:

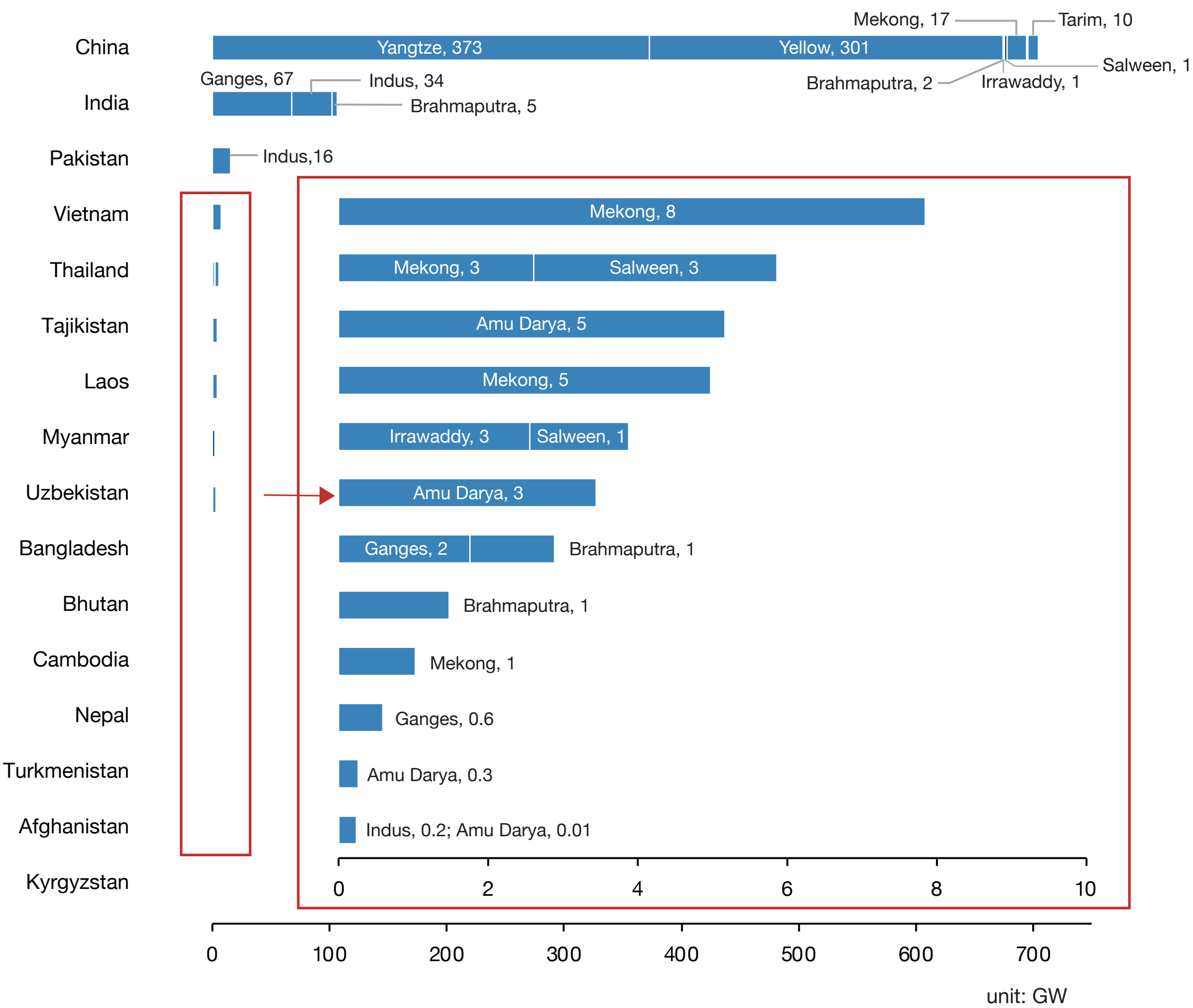
- **10 HKH Rivers power Asia (page 8-9)**
- **National energy dependence on HKH Rivers (page 10-11)**

China & India have the most power at risk

China and India have more power located in the 10 HKH River Basins than the rest of the HKH 16 by far as shown in the chart below. So, it follows that they have the most to lose if these rivers run dry. Much of these are clustered in the Yellow & Yangtze for China and the Ganges & Indus for India.

China & India have the largest exposure to rivers running dry…

Total power capacity of the HKH 16 countries by HKH River Basins



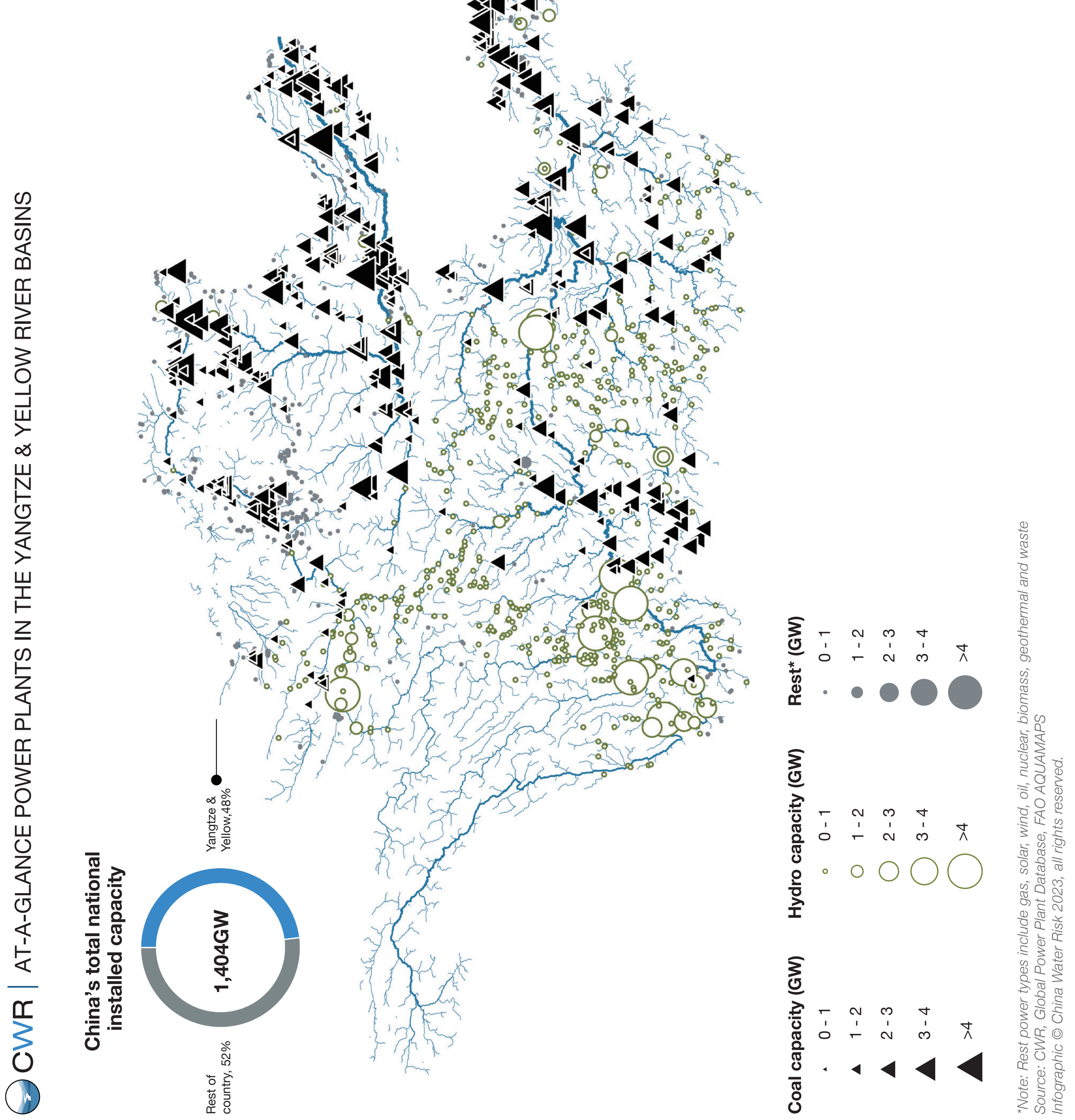
Source: CWR, Global Power Plant Database, FAO AQUAMAPS

Yangtze & Yellow dominate & are key to China's energy security

Almost half of China's national powergen capacity lie in the Yangtze & Yellow

The Yangtze has the largest share, with 373 GW of installed capacity, accounting for 27% of China's total power capacity. Yellow is the second, with 301GW of installed capacity, accounting for 21%. With a total of 48% of China's national power capacity, it is not surprising that these rivers are a top priority for the Chinese government. Indeed President Xi mentioned both these rivers in his 2022 New Year's Speech referring to them as China's Mother Rivers. Due to the heavy concentration of coal, these two basins are discussed in more detail in Chapter 3. However, this does not mean that other countries are also not vulnerable …

Coal & hydro fleets are clearly exposed to water risks…

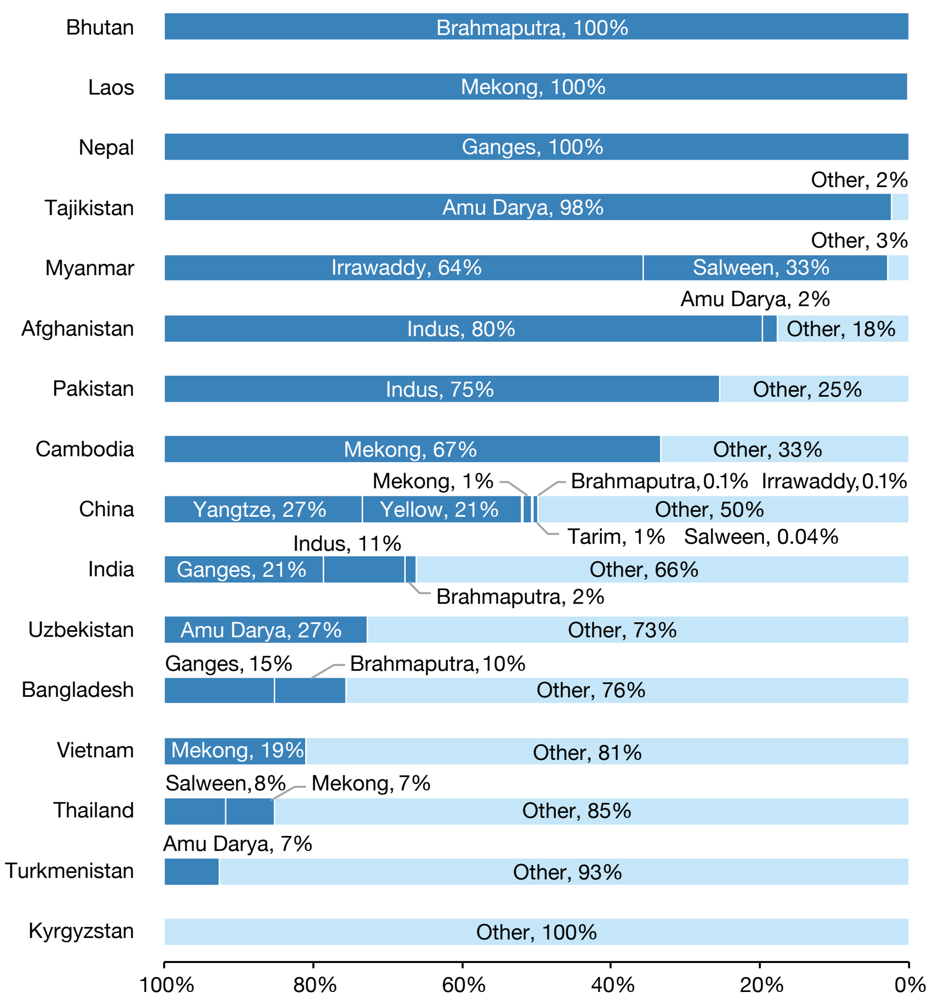


Some countries are more reliant on the rivers for power than others

Despite China's dominance in power in the 10 HKH River Basins and exposure to water availability in these basins for energy security, it is not the most vulnerable. China's power capacity is spread across 7 rivers versus some countries whose energy security is tied to a single river. The chart below shows national exposure by river basin:

HKH 16's energy security depends on the HKH Rivers…

HKH 16 Countries: Total power capacity by 10 HKH River Basins



From 100% in Bhutan, Laos & Nepal…

…to 7% in Turkmenistan

…Kyrgyzstan has zero power exposure to the 10 HKH Rivers

Source: CWR, Global Power Plant Database, FAO AQUAMAPS

Some basins are more vital to certain countries in terms of energy security than others:

- **100% reliant on power generation in the 10 HKH Rivers Basins:** Countries with all of their power capacity located in 10 HKH River Basins are: Bhutan with 100% of its national powergen capacity on the Brahmaputra; Laos, with 100% on the Mekong; and Nepal, with 100% on the Ganges. Their reliance on a single river, means that ensuring that river's continued flow is essential to sustained energy security.

Bhutan, Laos & Nepal's energy security is tied to a single river…

- **Very high reliance with almost all power capacity in the 10 HKH River Basins:** Tajikistan and Myanmar have almost all their power capacity in the 10 HKH River Basins. 98% of Tajikistan installed capacity is located in the Amu Darya whereas 97% of Myanmar's installed capacity is split between the Irrawaddy (64%) and the Salween (33%).

Tajikistan & Myanmar are also highly exposed…

Afghanistan, Pakistan and Cambodia are next: >2/3rd of powergen are in the basins…

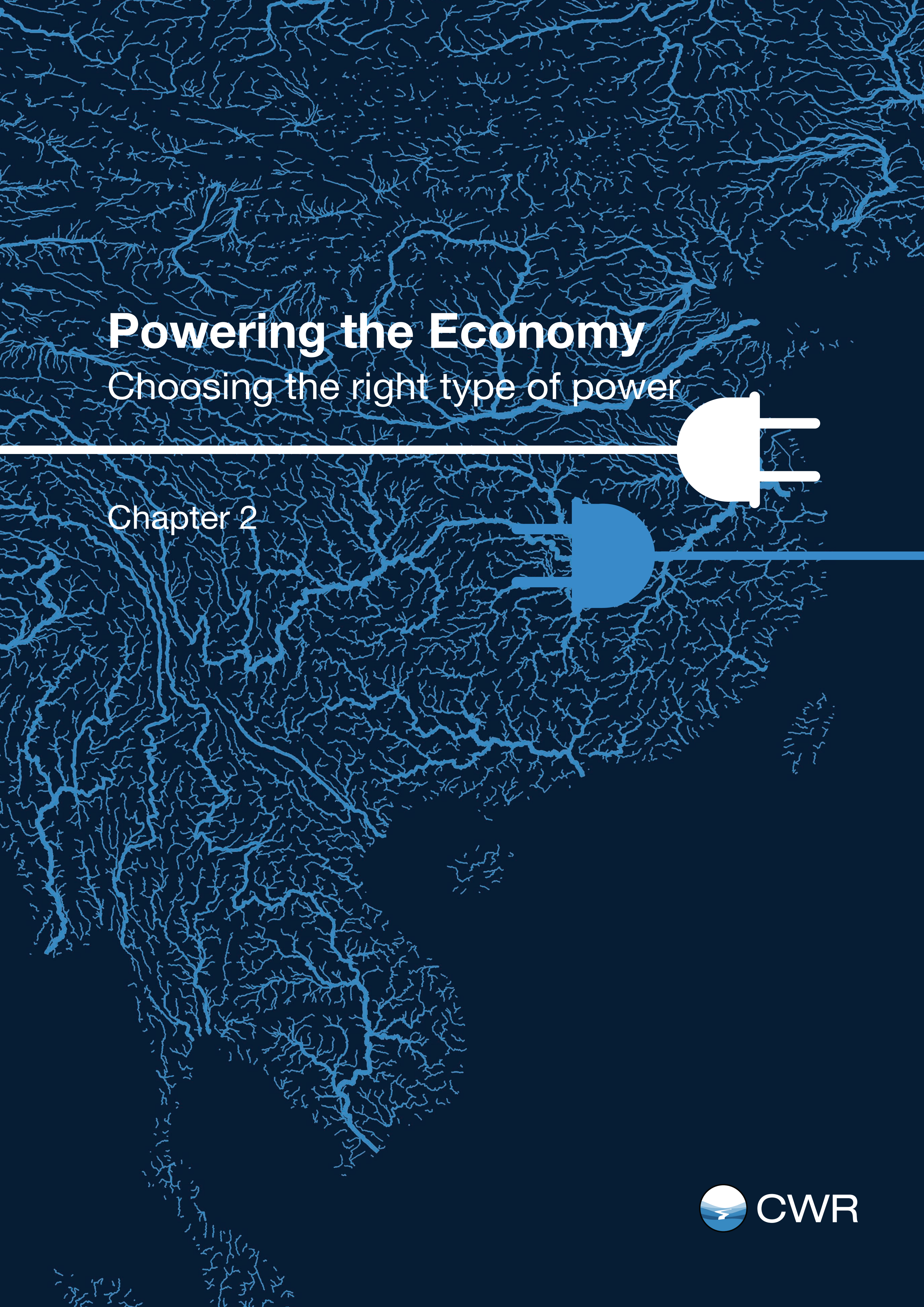
… >50% of China's capacity is spread across 7 rivers

1/3rd of India's national power is spread over the Ganges, Indus & Brahmaputra…

- **Significant reliance with >50% of national installed capacity in the 10 HKH Rivers Basins:** Afghanistan, Pakistan and Cambodia are next with over two-thirds of their respective power generation capacity located in these river basins. The Indus is key for both Afghanistan and Pakistan as it holds 80% and 75% of their national capacity respectively. Besides Laos, the Mekong is also vital for Cambodia which has just over two-thirds of its installed capacity there. China is less exposed with only half of China's installed capacity located in the 10 HKH River Basins but spread across 7 rivers.
- **Material reliance 10% to 50% of national installed capacity in the 10 HKH River Basins:** Compared to China, India is relatively less vulnerable to power capacity located in the 10 basins with only a third of national power spread over the Ganges, Indus and Brahmaputra. While Uzbekistan has 27% of its national power capacity in the Amu Darya, Bangladesh has around a quarter spread over 2 basins – the Ganges and the Brahmaputra. Vietnam also has material exposure with just under a fifth of its installed capacity clustered in the Mekong whereas Thailand has 15% spread between the Mekong and Salween.
- **Least reliant on the 10 HKH River Basins for power generation** are Turkmenistan and Kyrgyzstan. Turkmenistan only has 7% of its national power capacity located in Amu Darya, while Kyrgyzstan has zero exposure with none of its power plants located within the HKH 10 Rivers Basins.

Rivers running dry = stranding of sizeable % of the HKH 16's national power assets

Clearly many of the HKH 16 countries cannot afford to let the 10 HKH Rivers run dry lest sizeable portions of national power generation assets will be left stranded. But it is not just power assets, no water could also strand the US$4.3trn of GDP generated in these 10 River Basins per annum as well as affect the lives of up to 1.9 billion people who rely on this water.[9]



Powering the Economy

Choosing the right type of power

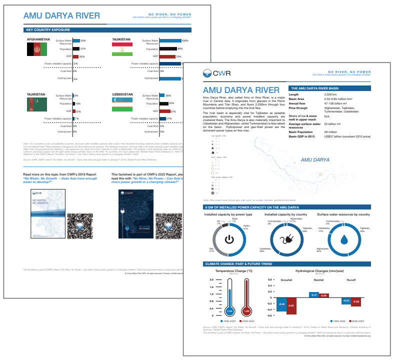
Chapter 2

CWR

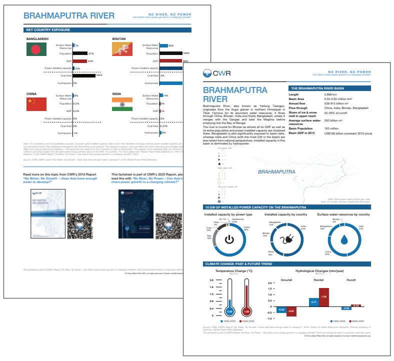
CWR

We recommend this chapter to be read in conjunction with the following **River Power Factsheets** which can be found in **Appendix 2** of this report.

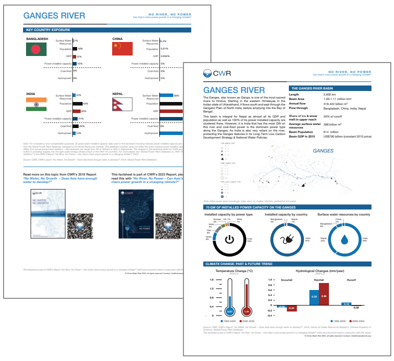
Amu Darya Power Factsheet



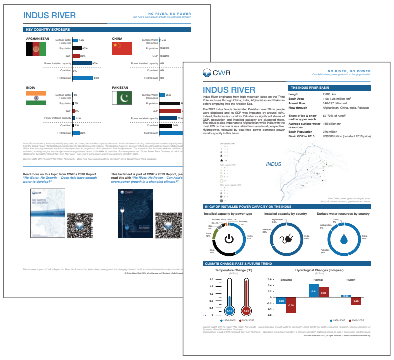
Brahmaputra Power Factsheet



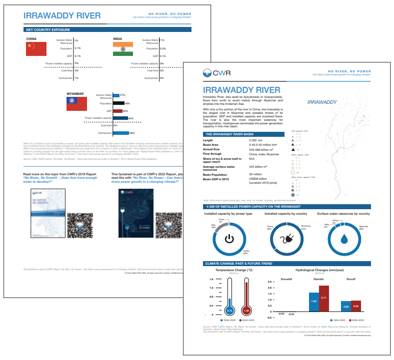
Ganges Power Factsheet



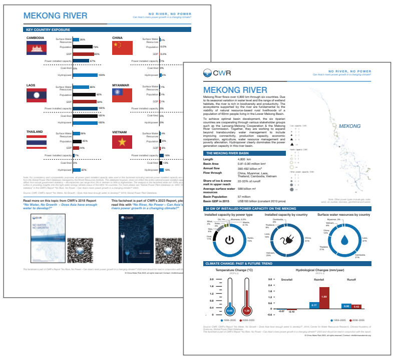
Indus Power Factsheet



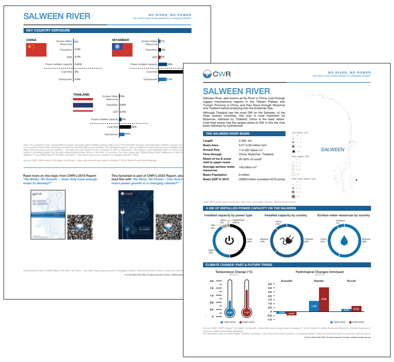
Irrawaddy Power Factsheet



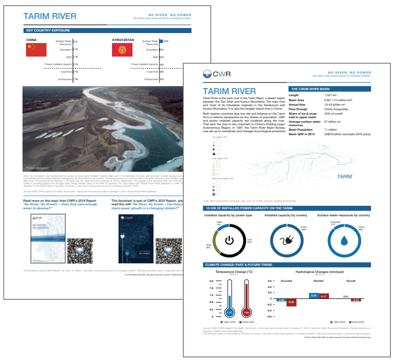
Mekong Power Factsheet



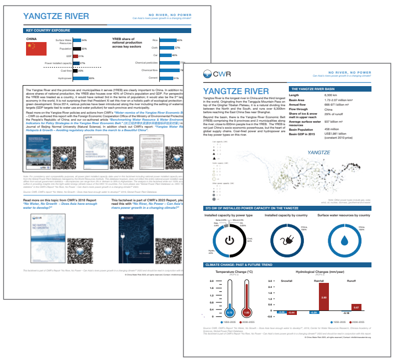
Salween Power Factsheet



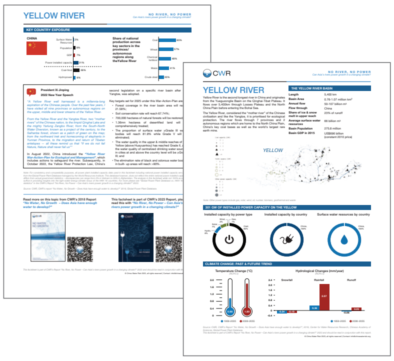
Tarim Power Factsheet



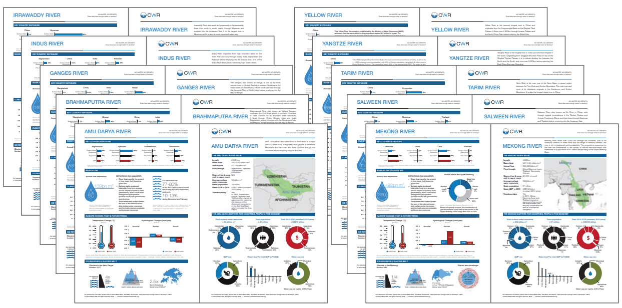
Yangtze Power Factsheet



Yellow Power Factsheet



Also check out an earlier set of River Factsheets we published alongside our report NWNG for more details:



Water, power & economies of the HKH 16 are all at risk!

Policymakers as well as business leaders in these countries will have to carefully consider the waternomic as well as power expansion capacity of these rivers as there is much at stake. A quick look at **"At-a-glance: water, people, power & the economy"** shows just how much relies on so little water for almost all HKH 16 countries.

A lot relies on a little water = Asia must consider waternomics in power planning …

Pressures of the clustering of water, population, economy and power generation will play out differently for each country – these are discussed later in **"Balancing waternomic & powergen risks across the HKH 16"**. However, since 1) at least 94% of power generation in the 10 HKH River Basins require water to generate, plus 2) the power capacity located there accounts for sizeable portions of national power generation for most of the HKH 16 countries, there is little room for error. Cautious consideration must be given towards power expansion as adding more coal to fuel development may ultimately lead the region to shoot itself in the foot.

More coal to fuel development = accelerate climate change = shoot itself in the foot

A tight water-energy-climate nexus together with the fact that Asia does not have enough water to develop mean that the HKH 16 must:

1) Prioritise a rethink of its existing power mix toward:

    a. one that generates more power on less water as well as less carbon emissions; and

    b. one that is less reliant on the 10 HKH Rivers.

2) Plan future power expansion to fast track decarbonisation with water in mind – for example, hydropower may not be a viable low-carbon option in the future in rivers which are projected to see reduced flows. As can be seen from the charts on the following pages, some of the HKH 16 have almost all their hydropower capacity located in these 10 HKH River Basins.

A tight water-energy-climate nexus = Asia must rethink power mix…

…future power expansion must keep water in mind = fast track decarbonisation

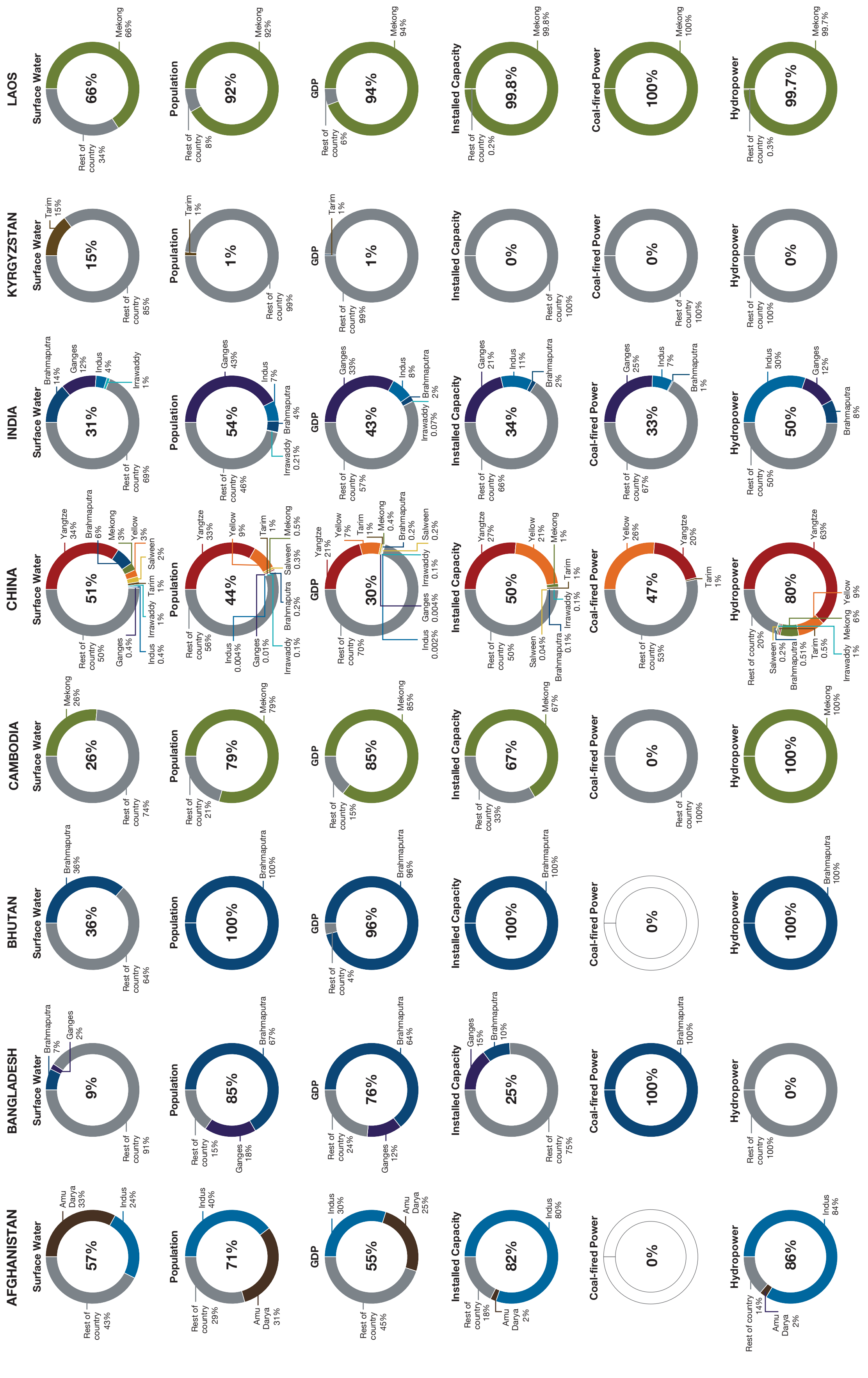
Unfortunately, this is easier said than done as each type of power has its own pitfalls – these are discussed in the next section **"Choose the right type of power for water & climate"**.

Photo by iStock

CWR

At-a-glance: water, people, power & the economy

CWR | AT-A-GLANCE: WATER, PEOPLE, POWER & THE ECONOMY



*Note: For consistency and comparability purposes, all power plant installed capacity data used in the above analysis including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this report while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see **"Global Power Plant Database vs. HKH 16 country statistics"**.*

Source: CWR, Global Power Plant Database, FAO AQUAMAPS, CWR's report "No Water, No Growth - Does Asia have enough water to develop?", 2018

CWR | AT-A-GLANCE: WATER, PEOPLE, POWER & THE ECONOMY (CONTINUED)

*Insufficient data for Tajikistan

Note: For consistency and comparability purposes, all power plant installed capacity data used in the above analysis including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this report while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see ***"Global Power Plant Database vs. HKH 16 country statistics".***

Source: CWR, Global Power Plant Database, FAO AQUAMAPS, CWR's report "No Water, No Growth - Does Asia have enough water to develop?", 2018

Balancing waternomic & powergen risks across the HKH 16

Power expansion cannot be at the expense of water security & economic growth

The analysis on the previous page shows that river management is never only about managing water. Decisions made to ensure water, economic, food as well as energy security will result in trade-offs. A holistic approach that integrates water management with socio-economic needs and economic development is required as is balanced energy expansion. This balanced power expansion must deliver energy security but not at the expense of water security and economic growth as adding more coal will accelerate climate change and increase water risks.

Exposure to the HKH River across various parameters differ by country…

In this regard, waternomic and energy policies will differ by river as well as by country. Here, we have grouped the countries into four categories depending on their respective national exposure to the HKH Rivers across various parameters as shown in the table below:

Laos is the most exposed…

…. while Vietnam is the least exposed

		National Exposure to HKH River Basins					
	Country	Surface water share	Population	National GDP	Total Installed Capacity	Coal-fired power capacity	Hydropower capacity
Overall High Risk	Laos	High	Very High	Very High	Very High	Very High	Very High
	Afghanistan	High	Very High	High	Very High	Low	Very High
	Nepal	High	Very High	Very High	Very High	Low	Very High
	Bhutan	Med-High	Very High	Very High	Very High	Low	Very High
	Myanmar	Med-High	High	Med-High	Very High	Very High	Very High
	Cambodia	Low-Med	Very High	Very High	High	Low	Very High
	Pakistan	Low-Med	Very High	Very High	Very High	High	Very High
	Tajikstan	n.a.	Very High	Very High	Very High	Low	Very High
Overall Med-High Risk	China	High	Med-High	Med-High	High	Med-High	Very High
	India	Med-High	High	Med-High	Med-High	Med-High	High
	Bangladesh	Low	Very High	Very High	Low-Med	Very High	Low
Overall Low-Med Risk	Thailand	Med-High	Med-High	Low-Med	Low-Med	Med-High	High
	Uzbekistan	Low-Med	Med-High	Med-High	Low-Med	Low	Low
Overall Low Risk	Kyrgyzstan	Low-Med	Low	Low	Low	Low	Low
	Turkmenistan	Low	Low	Low-Med	Low	Low	Low
	Vietnam	Low	Low	Low	Low-Med	Low-Med	Low-Med

Key

<10% low	Low
10-29% low-med	Low-Med
30-49% med-high	Med-High
50-69% high	High
>70% very high	Very High

Source: No River, No Power – Can Asia's rivers power growth in a changing climate?

Important points to note are:

Power mix + future flows should be considered for those in 'Overall Med-High Risk' to 'Overall High Risk' groups…

- Countries with 'High' to 'Very High' exposure of national total installed capacity on the 10 HKH River Basins should consider basin risks when deciding energy policy. This is especially pertinent when both coal-fired power and hydropower exposure are also 'High' and/or 'Very High'. Choosing the right type of power for expansion is therefore important – please see the next section on **"Choose the right type of power for water & climate"**;
- Future flows of rivers under various climate scenarios should also be considered. This is covered later in the next chapter in **"Past 50/Next 50 years = changing water flows"**;

Beware! Coal plants beyond the 10 HKH Rivers can also impact future flows

- Low exposure of coal-fired power plants here does not indicate that the country cannot do anything to help fast track decarbonisation. It just means that a low proportion of the national coal-fired power capacity is located there. It does however indicate that there is low risk that the lack of water for cooling will strand the national coal fleet. The coal fleets of the 16 countries located in the HKH River Basins are analysed in greater detail in the next chapter **"Rivers & Coal: A Tied Future"**; and

Overview by country is provided, but more analysis by country is encouraged…

- While the above shows the overall exposure to the HKH River Basins, it is important to analyse the exposure by country by river. Key points of note for each country are summarised in the following pages; countries are listed in alphabetical order across the four risk groups. These should be read together with **"Energy policies for a water secure future: 8 broad recommendations"** in Chapter 4.

Overview of countries in the 4 Risk Groups

Overall High Risk Group: Each country in this group faces significant exposure to a single river…

Afghanistan

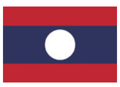
- The Amu Darya and Indus River Basins are key to Afghanistan: together they provide 57% of Afghanistan's surface water but house 71% of its population and 55% of its GDP.
- Clustering in the Indus is more pronounced than the Amu Darya; the Indus accounts for almost a quarter of Afghanistan's surface water but houses 40% of its population and just under a third of national GDP.
- Almost 80% of Afghanistan's national installed capacity is hydropower and therefore vulnerable to water risks – 84% of this is located in the Indus River Basin which faces 'High' to 'Extremely High' water stress as well as high flood and drought risk.
- Afghanistan should develop Indus River Basin waternomic strategies to ensure food, water and energy security; especially since the Indus will likely see overall lower runoff flows in the future in a 2°C scenario.[9]

Bhutan

- The Brahmaputra River Basin is essential to Bhutan – although it provides 36% of Bhutan's surface water, 100% of its population and 96% of its GDP are located in this river basin.
- Bhutan is powered by hydropower and 100% of its national installed capacity is located in the Brahmaputra River Basin.
- This level of reliance on a single river means that ensuring the river's continuous flow is essential to continue its energy security.
- The good news is that Bhutan is the upper riparian; the bad news is that Bhutan will have to put in place plans to manage fast melting glaciers, potential glacial lake outburst floods (GLOFs) as well as consider diversifying away from hydropower to other renewables to counter rising water risks.

Cambodia

- The Mekong River Basin is strategically important to Cambodia as it provides 26% of Cambodia's surface water but is home to 79% of its population and 85% of its GDP.
- Moreover, around two-thirds of Cambodia's national installed capacity sits in the Mekong River Basin; all of this is hydropower and highly vulnerable to water risks.
- While the basin also has some oil, solar and wind capacity, Cambodia's coal fleet is not located in the basin. Nevertheless their emissions will impact the river's future flow and Cambodia should balance their expansion with basin needs.
- Collaboration with upstream (China, Laos, Thailand) as well as downstream (Vietnam) countries is important via the Mekong River Commission as well as the Lancang-Mekong Cooperation – more on this in **Chapter 4: Energy policies for a water secure future: 8 broad recommendations**.

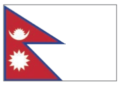


Laos

- Like Cambodia, the Mekong River Basin is essential to Laos. However, Laos' exposure is higher as the river accounts for two-thirds of Laos' surface water and houses over 90% of its population and GDP.
- Almost 100% of Laos's national installed capacity on the Mekong: 100% of the country's coal fleet is in the Mekong River Basin whereas 99.7% of its hydropower is located there.
- Such levels of reliance on a single river means that ensuring that river's continued flow is essential to sustain energy security; similarly its energy decisions will also impact river flows.
- It is therefore essential for Laos to develop waternomic strategies for the Mekong River Basin – collaboration via the Mekong River Commission as well as the Lancang-Mekong Cooperation should help the nation ensure water security. More on this in **Chapter 4: Energy policies for a water secure future: 8 broad recommendations**.

Myanmar

- The Irrawaddy, Salween and Mekong provide 35% of Myanmar's surface water and house its 58% of population and 46% of its GDP.
- Power generation capacity is more clustered: 97% of Myanmar's installed capacity is split between the Irrawaddy (64%) and the Salween (33%).
- Although assets are spread across three rivers, Myanmar is most exposed to the Irrawaddy River Basin which is home to over 48% of its population, 39% GDP and 64% installed capacity. While all its coal fleet is in the Salween, 68% of hydropower sit in the Irrawaddy River Basin.
- Myanmar should prioritise waternomic development along the Irrawaddy to ensure that it is waterproofed from rising climate risks.



Nepal

- The Ganges is key for Nepal's prosperity: it accounts for 59% of Nepal's surface water and houses nearly all its population as well as GDP.
- Moreover, 100% of Nepal's national installed capacity sits in the Ganges River Basin – as a lion share of this capacity is hydropower, Nepal's power output is very vulnerable to water risks.
- This level of reliance on a single river is of concern especially as 55% of the Ganges River Basin areas face 'High' to 'Extremely High' water stress.
- While Nepal is an upper riparian, it will face high mountain water challenges similar to those in Bhutan. Plans to manage fast melting glaciers, potential GLOFs as well as consider diversifying away from hydropower to other renewables to counter rising water risks should be implemented.

Pakistan

- Pakistan faces significant clustering in the Indus River Basin: the basin accounts for 25% of Pakistan's surface water yet it houses 88% of its population and 92% of its GDP.
- In addition, 75% of Pakistan's national installed capacity is located on the Indus – while the Indus drives all of Pakistan's hydropower, over half of its coal fleet is also located there.
- The management of the Indus from source to sea is therefore important for Pakistan. As Pakistan is the lower riparian, it will have to collaborate with upper riparian countries of the Indus tributaries flowing from Afghanistan, India and China to monitor and manage flows from the source regions.
- The Indus River Basin is also water stressed with 62% of the area facing 'High' to 'Extremely High' water stress. Moreover, swathes of the basin are exposed to floods and droughts. This 2022 floods showed the urgency to develop source-to-sea waternomic policies take energy mix and security into account so as to futureproof the river in a changing climate.

Tajikistan

- Amu Darya provides a significant amount of Tajikistan's surface water resources and houses 81% of its population and 73% of its GDP.
- 98% of Tajikistan's installed capacity sits on the Amu Darya. However, unlike the Indus and the Ganges, only 28% of the Amu Darya basin areas face 'High' to 'Extremely High' water stress.
- That said, the proportion of hydropower as national installed capacity (>80%) makes Tajikistan highly vulnerable to water risks and the flows of the Amu Darya.
- As the Amu Darya will likely see overall lower runoff flows in the future in a 2°C scenario,[9] it is important to plan development in the basin with waternomics in mind. Power expansion should also shy away from adding more oil-fired power as this will accelerate water risks.

Overall Med-High Risk Group: Assets are spread across multiple river basins. Although the single river risk is not as high as the previous group, each of the key river basin for each country still carries significant clustered risk…

Bangladesh

- Bangladesh faces significant clustered exposure to the Brahmaputra & Ganges River Basins: together, they only account for 9% of the nation's surface water – Brahmaputra (7%) & Ganges (2%) – yet they support 85% of its population and 76% of its GDP.
- A large part of this exposure is on the Brahmaputra – home to 67% of its population and 64% of GDP is generated there.
- However, power generation is less exposed to these rivers with only a quarter of Bangladesh's national installed capacity is split between the Ganges (15%) and the Brahmaputra (10%). Although 100% of Bangladesh's coal fleet is in the Brahmaputra Basin, coal is only a small part of the national power mix.
- Gas-fired power is the key power source and most of this (81%) is located outside of the Brahmaputra River Basin.

China

- 9 out of the 10 HKH River Basins provides half of China's surface water; only the Amu Darya does not flow through China. These 9 rivers support 44% of China's population and 30% of its GDP; significant shares of these are in the Yangtze River Basin.
- Correspondingly, half of China's national installed capacity are also located in the 10 River Basins but across 7 rivers – a lion's share of this in the Yangtze & Yellow River Basins; there are no power plants in the Indus or Ganges River Basin.
- Indeed, the Yangtze & Yellow house almost half of China's power capacity – the Yangtze has 27% of national installed capacity, the Yellow has 21%. The Yangtze carries a significant share of hydro with just under two-thirds of national hydropower capacity as well as a fifth of the nation's coal fleet; the Yellow has just over a quarter of China's coal capacity.
- As both these rivers are key to powering China's economy as well as providing water for food security, industrial growth and municipal use, China has focused economic development to take into account source-to-sea management of the Yangtze & Yellow Rivers – see **Appendix 1: Lessons from China – "Mountains-to-oceans waternomic management for the Yangtze & Yellow Rivers".**
- As China has the largest coal fleet, it can make a significant difference in setting energy policies today for a water secure tomorrow – more on this in **Chapter 4: Energy policies for a water secure future: 8 broad recommendations.**

India

- 4 HKH River Basins – Brahmaputra, Ganges, Indus and Irrawaddy – supply 31% of India's surface water yet they house 54% of its population and 43% of its GDP.
- 34% of India's national installed capacity is split between the Ganges (21%), the Indus (11%) and the Brahmaputra (2%). These rivers are key drivers of hydropower and half of the national hydropower capacity lie across these four rivers. However, only a third of the national coal fleet is located on these rivers.
- Both the Ganges and Indus are of concern: not only do both rivers have significant basin areas facing 'High' and 'Extremely High' water stress, they both are projected to see overall lower runoff flows in the future in a 2°C scenario.[9]
- The Ganges is however, more important to India: 43% of its population is clustered there as well as a third of its GDP. The basin is also home to slightly over a fifth of the national coal fleet as well as 12% of hydropower capacity.
- As India has the second largest coal fleet, it can also make a significant difference in setting energy policies today for a water secure tomorrow – for more, please refer to **Chapter 4: Energy policies for a water secure future: 8 broad recommendations**. Also included in Chapter 4 are overviews of India's energy and water policies – please see **"India's Long-Term Low-Carbon Development Strategy" and "India's National Water Policies"**.

Overall Low-Med Risk Group

Thailand

- Nearly a third of Thailand's surface water is from the Mekong River Basin which supports 35% of its population and 24% of its GDP. Only 2% of its surface water is from the Salween, which supports less than 1% of Thailand's population and GDP.
- However, the Salween is equally important as the Mekong in power generation – 15% of Thailand's national installed capacity sits on these two rivers – Salween (8%) and Mekong (7%).
- While the coal fleet is exposed to water risks in the Salween, coal only represents a small share of Thailand's national power mix. A large share of Thailand's national power generation (85%) is located around Bangkok which sits outside of the HKH River Basins.
- Albeit exposed to lower risk than the other countries, Thailand should develop waternomic strategies for the Mekong River Basin via the Mekong River Commission & the Lancang-Mekong Cooperation – more on this in **Chapter 4: Energy policies for a water secure future: 8 broad recommendations**.

Uzbekistan

- The Amu Darya provides one fifth of Uzbekistan's surface water and houses 32% of its population and 37% of its GDP.
- 27% of Uzbekistan's national installed capacity is in the Amu Darya but none of the nation's coal-fired or hydropower plants are located in this basin.
- Uzbekistan is primarily powered by gas – the majority of the gas fleet is located outside of the Amu Darya River Basin.

Overall Low Risk Group

Kyrgyzstan

- Kyrgyzstan faces low clustered risks: only 1% of its population and GDP is located in the Tarim River Basin; the basin provides 15% of Kyrgyzstan's surface water resources.
- None of Kyrgyzstan's national power capacity is located in the 10 HKH River Basins.

Turkmenistan

- Only 5% of Turkmenistan's surface water is sourced from the Amu Darya River Basin, which supports only 10% of its population and 12% of GDP.
- Correspondingly, only 7% of Turkmenistan's national installed capacity sit in the Amu Darya River Basin. Turkmenistan doesn't have coal-fired or hydropower plants; its power sources are oil & gas which are beyond the scope of this report.

Vietnam

- Vietnam faces low clustered risks: the Mekong River Basin only provides 4% of Vietnam's surface water and houses 8% of its population as well as 6% of its GDP.
- However, 19% of Vietnam's national installed capacity is located in the Mekong River Basin; 13% of the national coal fleet and 18% of the hydro fleet lie in the basin.

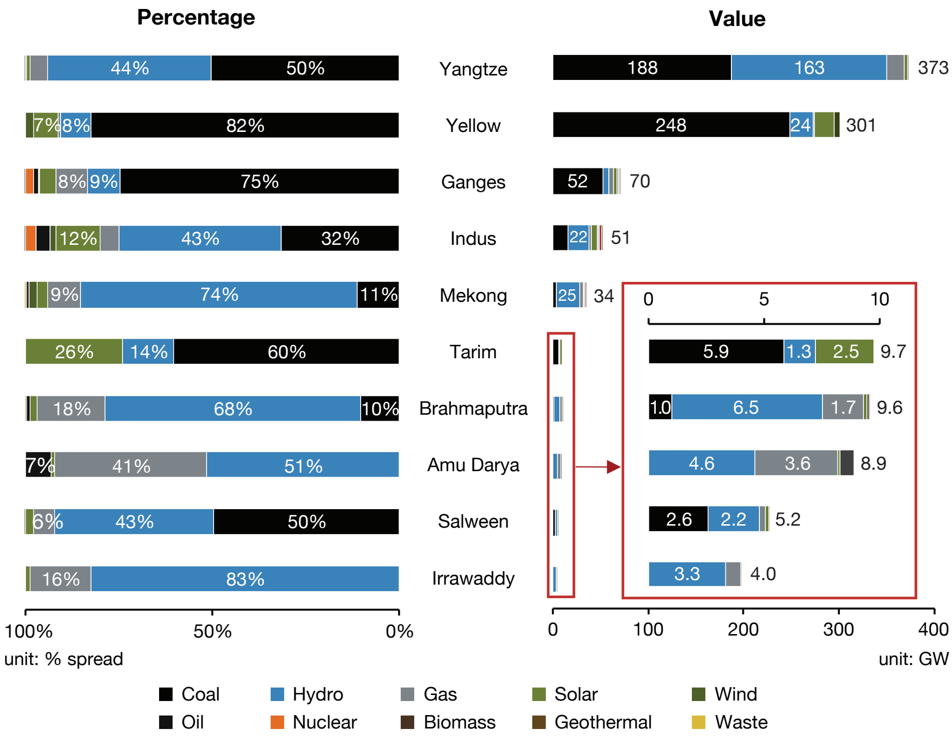
Choose the right type of power for water & climate

Choosing the wrong type of power could sink the HKH 16's economy. It is clear from the material exposures on the previous pages that a wrong move in planning energy security could sink an entire country's economy. So it is imperative to choose the right type of power – one that generates more power on less water and less carbon; preferably zero to rein in carbon emissions. The current spread of power types across the 10 HKH River Basins are as follows:

Wrong moves in power expansion could sink an entire country's economy…

…so, pick the right power type that generates more power on less water & carbon

Total capacity breakdown by basin



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

But coal dominates in 6 out of 10 HKH River Basins:
- **Yangtze**
- **Yellow**
- **Ganges**
- **Indus**
- **Tarim**
- **Salween**

The Yellow River has the most coal-fired power

Power generation in 6 out of 10 HKH River Basins are dominated by coal. The chart above shows the percentage spread as well as total installed capacity across the HKH 10 basins. Coal dominates in 5 basins, namely Yangtze, Yellow, Ganges, Tarim and Salween where it accounts for at least half of the respective river basins' installed capacity. Whilst not accounting for more than half of the basin's installed capacity, coal-fired power on the Indus is also sizeable – at 16GW, it is still over 2x that of the coal-fired capacity in the Tarim.

…Yellow & Yangtze's coal-fired power is >5x the rest

Yellow & Yangtze together have 436GW of coal-fired power, over 5x the rest. While coal dominates the Yellow, it only accounts for half the power capacity located in the Yangtze. The power mix on the Ganges is also heavily skewed (75%) towards coal.

…Ganges also has a heavy coal skew

Sadly, many of these river basins already face varying degrees of water stress, which will only become worse if the region continues with such coal-dominated power mix as emissions will accelerate climate impacts. Indeed, rising scarcity could mean that coal fleets could be stranded earlier than expected, forcing countries to revisit their energy policies. We deep dive into such risks in **"Coal-fired power & water stress in 10 HKH River Basins"** in Chapter 3. However, other types of power are also not without risks.

More coal = speeds up climate impacts = assets stranded earlier than expected

Other thermal power e.g. oil & gas also water-reliant

Don't forget that the lack of water could also strand oil & gas-fired power. Focusing merely on coal can lead to the omission of other water risks related to other thermal power types such as oil and gas, which also need large amounts of water to cool. For example, although Amu Darya has no coal capacity, it has 4GW of water-reliant gas power capacity accounting for 41% of its total power capacity.

Hydro is also vulnerable …

At 163GW, the Yangtze has the most hydro assets at risk …

…2022 Yangtze drought led to power disruptions & global supply chain shocks

Hydropower is also important in the power mix in the 10 HKH River Basins. Hydropower dominates the power mix in the Irrawaddy (83%), Mekong (74%), Brahmaputra (68%) and the Indus (43%). However, it is hydropower in the Yangtze that dwarfs the rest – at 163GW, it is 1.7x the rest of the hydropower capacity combined. This is why severe drought can disrupt hydropower generation. Sichuan province is especially sensitive as 80% of its electricity is derived from hydropower – last year, the drought cut power production by 50% and a large number of industrial enterprises and factories were told to suspend production for 6 days to ensure that public basic needs of power and water were met.[35] Given that the world's factories are located along the Yangtze, these led to supply chain shocks and the world woke up to how exposed it was to a drought in China. So while hydropower expansion can help lower emissions, future climate impacts may dampen power generation capabilities. As this report does not focus on hydropower, we have produced a brief summary of risks in this report – please see **"Overview of hydropower's water risk exposure in the 10 HKH River Basins"**.

Nuclear add should be cautious due to rising water scarcity

Water scarcity could hamper nuclear expansion. While nuclear could be a good baseload replacement for coal in terms of cutting GHG emissions, expansion in these river basins should be cautious given rising water scarcity. Get an overview with **"Overview of nuclear power's water risk exposure in the 10 HKH River Basins"**

Solar PV & wind doesn't require much water for generation…

… but need rare earths that can pollute water & soil

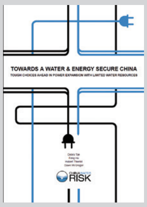
Solar PV & wind are the least water intensive, but necessary rare earths are highly polluting. CWR's policy paper with IRENA clearly showed that renewables have the potential to reduce both water use and carbon emissions, in particular through the development of solar PV and wind turbines. Cooling technologies of thermal power plants also matter.[36] However, the extraction and processing of rare earth minerals essential for the manufacture of solar PV and wind turbines are highly polluting and could damage water as well as soil resources.[37] For quick insights into the potential water & carbon savings from aggressive renewable expansion as well as rare earth pollution please see – **"Overview of solar & wind power's water risk exposure in the 10 HKH River Basins".**

Recommend reading: CWR's publications in the Water-Energy-Climate Nexus

The Water-Energy-Climate Nexus is an integral part of CWR's work in promoting a comprehensive view on water risks. Since 2012, CWR has collaborated with financial institutions to illuminate water risks in the power sector as well as IGOs like WRI and IRENA to write policy papers. Some of these led to coal stock sell downs in 2013-15; others were discussed at Clean Energy Ministerial meetings or used as internal communiques within the Ministry of Environmental Protection of the People's Republic of China. CWR's previous work has focused on China: as the largest emitter of GHG, it plays a central role in this global nexus for it needs to add significant power with limited water resources.

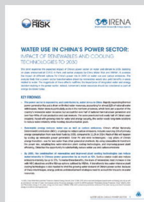
No water, no power – Does China have enough power to fuel expansion? (HSBC 2012)

Water for Coal – Thirsty miners will feel the pain (CLSA U 2013)

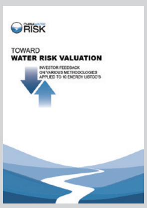


Towards A Water & Energy Secure China – Tough choices ahead in power expansion with limited water (CWR 2015)

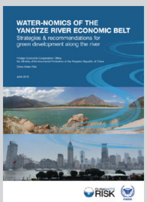
Water Risk Analysis & Recommendations for Water Resource Management in Ningxia (WRI-CWR 2015)



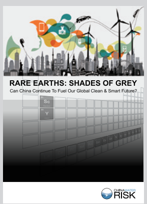
Water Use in China's Power Sector: Impact of Renewables & Cooling Technologies to 2030 (CWR-IRENA 2016)



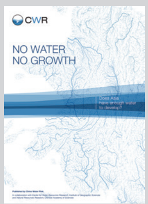
Toward Water Risk Valuation: Investor Feedback on Various Methodologies Applied to 10 Energy ListCo's (CWR 2016)



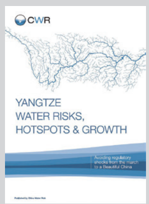
Water-nomics of the Yangtze River Economic Belt (CWR 2016)



Rare Earths: Shades Of Grey – Can China continue to fuel our clean and smart future? (CWR 2016)



No Water, No Growth – Does Asia have enough water to develop? (CWR 2018)

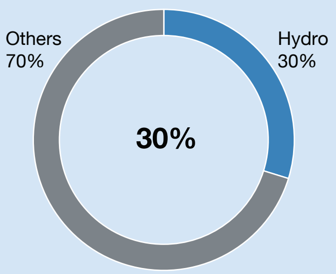


Yangtze Water Risks, Hotspots & Growth (CWR 2019)

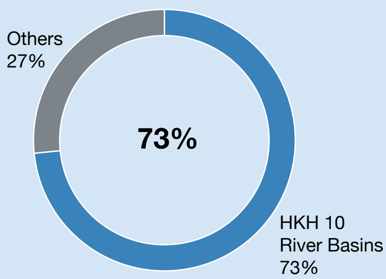
Overview of hydropower's water risk exposure in the 10 HKH River Basins

Although hydropower located the HKH 10 River Basins only accounts for 30% of the total power capacity of the HKH 16 countries – see left chart below, almost three-quarters (73%) of the HKH 16's total national hydropower capacity sit in these basins see centre chart below. Of the 258GW of hydropower in the HKH Rivers, the lion's share is on the Yangtze (63%) with the remainder spread across Mekong (10%), Yellow (9%), Indus (9%), Brahmaputra (3%), Ganges (2%), Amu Darya (2%), Irrawaddy (1%), Salween (0.85%) and Tarim (0.5%) – see right chart below.

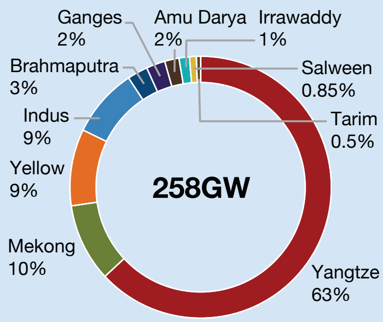
Hydropower capacity in the 10 HKH River Basins



National hydropower capacity of the HKH 16 in the 10 HKH River Basins



Hydropower across the HKH 10 River Basins



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

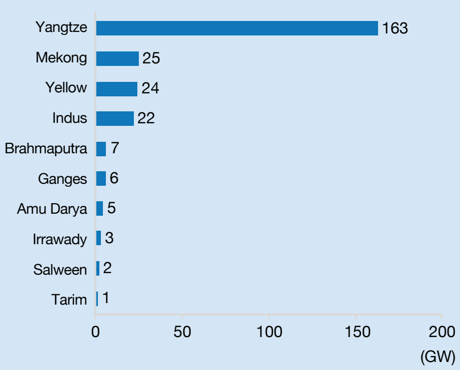
For 6 countries – Bhutan, Myanmar, Nepal, Pakistan, Cambodia and Laos – the HKH Rivers are crucial as 100% of their hydropower capacity is situated in these 10 HKH River Basins.

Hydropower has a dual purpose – power generation as well as water management. In times of excessive rain, dams can help hold back water and prevent flooding whereas in times of droughts they can help provide relief. However, in such circumstances, power supply will be disrupted. With climate change impacts accelerating, we are already seeing this all around the world: from rationing of power in Sichuan province which draws more than 80% of its power from hydropower; output losses along Europe's mighty Po, Rhone & Rhine rivers to the USA's Lake Powell and Mead only operating at a third of their power generation capacity. [38, 39, 40, 41]

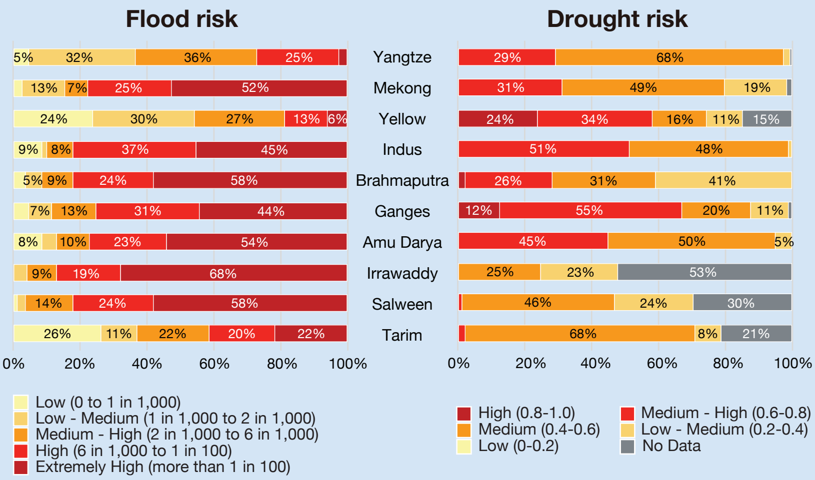
As extreme weather intensifies with climate change, drought as well as flood extremes will be pushed out. The unpredictability of extreme weather and widening of extremes will make water management along rivers more and more difficult. These fluctuations can be extreme – for example, in 2021, China was worried about flooding along the Yangtze as multiple dams were breached; in 2022, concerns have turned towards record-breaking low levels of water.[42] Such fluctuations not only make water management but also power management more difficult with many provinces/countries resorting to coal-fired power as a back-up. This of course is not a solution as turning to coal only exacerbates the problem.

Given the amount of hydropower in each of the 10 HKH River Basins (left chart below) and the underlying overall flood and drought risk on these river basins (middle and right charts below), we recommend a holistic review of all hydropower generation capacities under various climate scenarios to be undertaken given climate impacts on river flows.

Hydropower capacity in the HKH 10 River Basins



Overall basin flood & drought risk

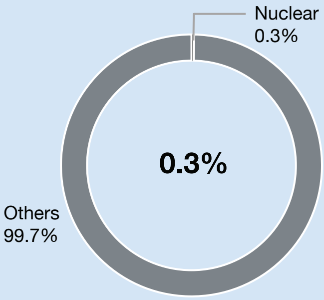


Source: CWR based on Global Power Plant Database; FAO AUQAMAPS, Aqueduct Global Map 3.0

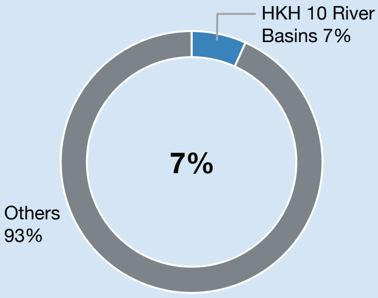
Overview of nuclear power's water risk exposure in the 10 HKH River Basins

Nuclear power located in the HKH 10 River Basins only accounts for less than 0.3% of the total power capacity of the HKH 16 countries. In terms of nuclear, only 7% of the HKH 16's total national nuclear power installed capacity sit in these basins. Of this 2.95GW of nuclear power in the HKH Rivers, 55% is in the Ganges (India) and 45% is in the Indus (Pakistan).

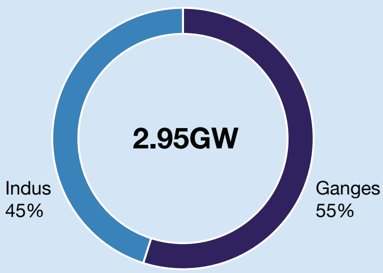
Nuclear power capacity in the 10 HKH River Basins



National nuclear power capacity of the HKH 16 countries



Nuclear power capacity across the 10 HKH River Basins



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

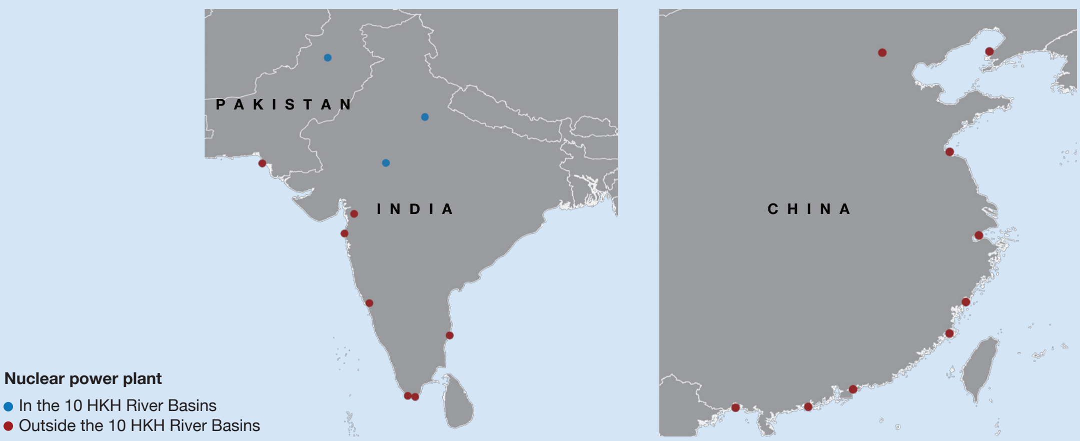
It is important for nuclear power plants to be located next to a constant water resource for cooling. When the water flow is too little or too warm, nuclear power plants are required to reduce power or temporarily stop operating. Already, we see nuclear power plants cut output in France as rivers warmed due to heatwaves.[43] Given that both the Indus as well as the Ganges could see overall falls in river flow in the mid-term under RCP4.5,[9] it may be time to rethink existing and future nuclear power plant expansion in both these basins.

One option is to locate them along the coast and use seawater for cooling. However, coastal nuclear power expansion must also take into account increasing coastal threats such as storm surges and sea level rise. Given that storm surges in the APAC region have already reached 5m with Typhoon Goni in 2020,[44] serious adaptation measures need to be in place to protect existing coastal nuclear plants to avoid another Fukushima disaster.

Beyond the HKH River Basins, most of the nuclear power plants are located in coastal areas – as shown in the maps below for China, India and Pakistan. China has the largest nuclear fleet at >50GW at the end of 2021 – most of these are coastal and none are located in the 10 HKH River Basins. That said, there are two nuclear power plants in Zhejiang Province, albeit close, this falls outside of the Yangtze River Basin boundary. For consistency, these were excluded in the above analyses.

Going forward, China is planning to expand its nuclear energy power plants as part of its decarbonisation push. According to China's 14FYP, nuclear power generation is expected to grow to reach 70GW by 2025; this is a modest increase compared to other types of power additions such as wind and solar.[45] This indicates that China is well aware of the water risks associated with nuclear power. Indeed, seas around China has risen faster than the global average, reaching 3.4mm/year.[46] Given that the IPCC warned that 2-5m of sea level rise *"cannot be ruled out"* by 2100 and 2150 respectively on the current climate path,[47] policymakers must contend with both freshwater and coastal threats when considering nuclear power expansion. So, although nuclear can substitute coal as the baseload power, water-related risks could hamper its expansion in a changing climate.

CWR | NUCLEAR POWER PLANTS IN THE HKH 16 COUNTRIES (PAKISTAN, INDIA AND CHINA)

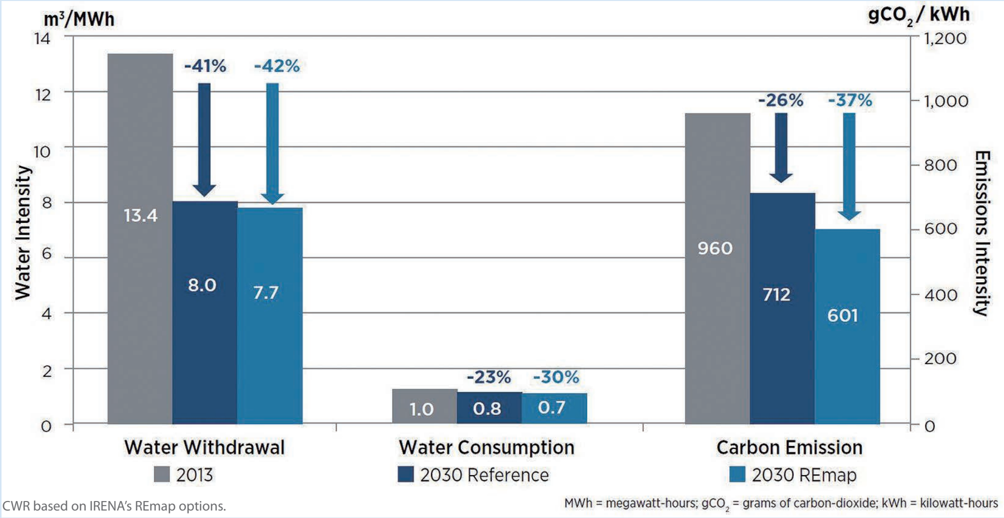


Source: CWR, Global Power Plant Database, FAO AQUAMAPS

Overview of solar & wind power's water risk exposure in the 10 HKH River Basins

Less water intensive: Given that over 90% of power generation located in the 10 HKH River Basins are water-reliant, it makes sense to add less water-intensive power generation like solar PV and wind power. As CWR's joint policy brief with IRENA showed, accelerated renewables deployment in China will help alleviate pressures on scarce water resources as well as deliver reduction in carbon emissions. Under an aggressive renewables scenario, dual savings in water and carbon can be achieved: by 2030, water use intensity of power generation can be decreased by as much as 42% while carbon emissions intensity could fall by 37% under the 2030 Remap aggressive renewable expansion scenario (2030 Remap).[36]

Water and carbon intensity of power generation (2013-2030)

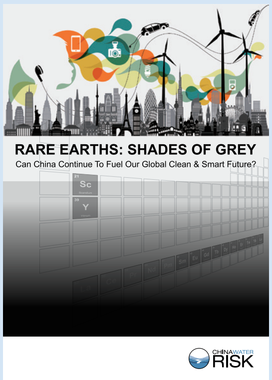


Source: CWR, IRENA (2016) Water Use in China's Power Sector: Impact of Renewables and Cooling Technologies to 2030.

The magnitude of these effects clearly reaffirms the value of integrated water and energy decision-making in the power sector. According to the paper, a transition to less water-intensive plant cooling technologies is also needed to limit the growing water demand of China's power sector as the power sector is both exposed to and contributing to water stress. Overall, around 45% of China's power generation faces a double whammy, being both water-reliant and located in highly water stressed regions.[36] Cooling technologies for coal-fired power and their impacts on water resources across the 10 HKH River Basin are discussed in more detail in the next chapter.

But can be highly polluting due to underlying rare earth minerals: Energy policies and development strategies need to account for impacts on water resources, but not just from an availability perspective but also on the pollution front. While solar PV and wind turbines use less water, they can be highly polluting due to rare earth minerals that are crucial in their production. Current non-fossil fuel, highly smart and climate-friendly technologies do not work without rare earths.

Rare earth mining and processing is a polluting and toxic process, and given China's dominance in their global production, China's water resources and arable land have borne the brunt of the pollution. As China clamps down on pollution and promotes a clean as well as high tech future, transitional risks related to rare earths are a plenty. For more on such risks, please read the following…



Rare Earths: Shades Of Grey – Can China continue to fuel our clean and smart future?

(CWR 2016)

Toxic Phones: China controls the core

CLSA U 2017 (CWR guest authored the report)

Transboundary issues: not just water sharing but energy policies also

8 out of 10 HKH Rivers are transboundary…

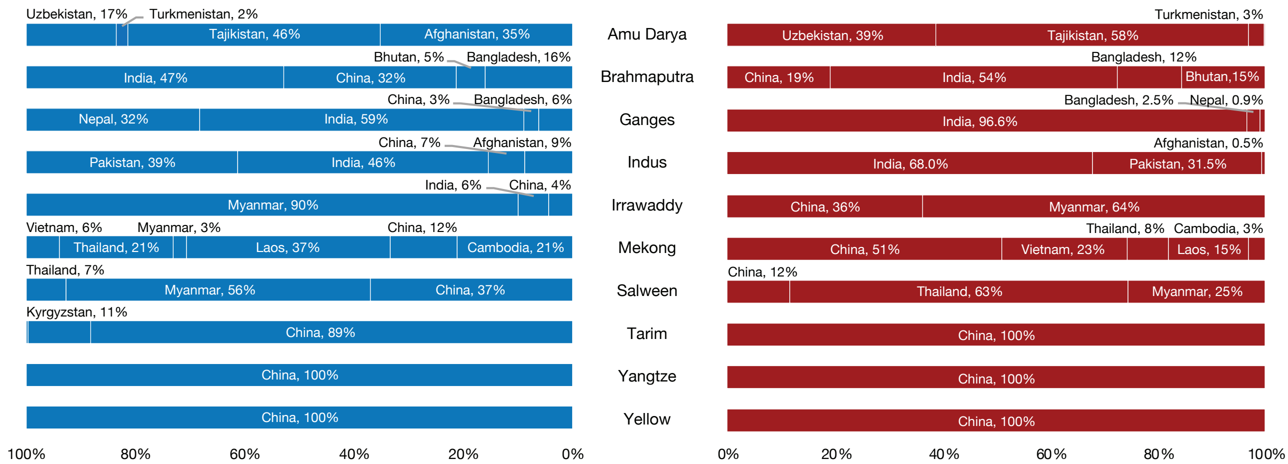
Eight of the 10 HKH Rivers are transboundary. Decisions made by one country will affect others be they about agriculture, energy mix, economic/infrastructure development or water resource management. A fossil fuel heavy mix will accelerate climate change and exacerbate already complex transboundary issues.

…so cooperation on water sharing as well as energy policies + economic planning is key

As each country's power sector mix will impact the water resources in the basin. The HKH 16 countries should therefore not just cooperate on water sharing but also on energy policies as well as economic planning as industrial mix will also take a toll on water resources. As the charts below show, the HKH 16 countries have no choice but to cooperate with each other if they want to have a water and energy secure future.

The HKH 16's share of surface water resources in the 10 HKH River Basins

The HKH 16's share of power installed capacity in the 10 HKH River Basins



Source: CWR, FAO AQUAMAPS, Global Power Plant Database

Key points to note are:

China has full control of the Yangtze & Yellow but cannot delay action…

- China has full ownership over the Yangtze and Yellow which holds almost 80% of the power capacity in the HKH 10 River Basins. Although China has "control" over both water and therefore more flexibility with transitioning its power mix in these basins, delaying transition will only exacerbate uncertainties in river flows which could be dire. The Yellow and Yangtze rivers support a significant share (28%) of China's GDP,[9] besides China has half of its power in the 10 HKH River Basins.

India shares its rivers with other countries … but only 1/3rd of its power assets lie there

- Although India shares its key rivers: Ganges, Brahmaputra & Indus with other countries, it only has a third of its national power generation capacity clustered on these rivers. This gives it more flexibility than China, in transitioning to a greener mix.

Laos has the largest share (37%) of the Mekong's water

- Bhutan, Nepal and Laos have 100% of their power in the HKH River Basins. However, while Bhutan and Nepal are upper riparians, the same cannot be said about Laos which shares the Mekong with 4 other countries (Cambodia, China, Thailand and Vietnam). However, as per the chart in the **"Mekong River Power Factsheet"**, Laos has the largest share (37%) of the Mekong's water resources; China often cast as the bad actor in transboundary water only has a 12% share.

Pakistan is heavily reliant on the Indus but is downstream

- Pakistan is at a disadvantage – it is heavily reliant on the Indus, yet it is the downstream of Afghanistan, India and China. Pakistan's water resource share of the Indus is 39% yet it has 75% of its national power on the river.

Rivers & Coal: A Tied Future

10 HKH River Basin Risks

Chapter 3

CWR

Rivers & coal share a tied future

Coal-fired power is exposed to & contributes to water stress…

Coal-fired power is exposed to and contributes to water stress. Coal-fired power could directly and indirectly add to water stress – directly as coal-fired power generation is itself water intensive and indirectly as carbon emissions will accelerate climate change which in turn exacerbates water stress. On the other hand, less water in the future could strand coal-fired power assets. This relationship is clearly recognised by the IPCC – see box below.

…usable capacity factor of thermal powergen can fall by up to 12% by 2050

Globally, studies have estimated that the usable capacity factor of thermal power generation could fall by 1.6-16% in the USA, 6.3-19% in Europe and 7-12% on average globally by mid-21st century under various climate scenarios.[48,49,50,51] This is because of the constraints in both the availability and temperatures of water resources for cooling.

Studies show downside impacts can be up to 40% for India; 74% for China; 65% for SEA

For developing Asia, coal-fired power expansion may be vulnerable as the coal fleet in the HKH rivers mainly use river water for cooling. Studies showed that there will be decreases in the annual usable capacity factor of coal-fired power generation in Mongolia (20-74%), South East Asia (up to 65%) and parts of India (11-40%) and China (20-74%), unless water adaptation measures are taken.[52]

Water stress profiles, cooling tech, trade-offs – all matter…

The direct interdependencies of water and coal in the 10 HKH River Basins are explored in this chapter as we analyse the water stress exposure profile of the 517GW of coal-fired power located therein. As coal is the base power for many of the HKH 16 countries, we also examine the possibility of the adoption of various cooling technologies that could relieve water stress – can tech help? What about carbon capture technologies that could reduce carbon emissions, can they work in water scarce regions? Read on …

The IPCC notes:

IPCC Climate Change 2022: Impacts, Adaptation and Vulnerability

Water is needed for 94.7% of the world's current electricity generation

The latest IPCC report recognises a tied future for water & power generation and warns that mitigation measures such as carbon capture and storage can be water intensive. However, the report noted that shifting to renewables sources that are less dependent on water, such as solar and wind, can help ensure energy security in the future.

"Water is a crucial input for hydroelectric and thermoelectric energy production, which together account for 94.7% of the world's current electricity generation."

Energy sector's freshwater needs will rise & take up almost 1/4th of global water demand by 2050…

"Global freshwater demand for the energy sector is projected to increase under all 2°C scenarios due to the rapid increase in electricity demand in developing countries. Despite the water shortage and climate change impacts, industry and energy sectors' share in global water demand has been projected to rise to 24% by 2050, which will increase the competition among various water-use sectors."

…yet less water in the future = *"consistent decreases"* in thermal capacity

"A systematic review showed consistent decreases in mid to end of the century in thermal power production capacity due to insufficiency of cooling water in southern, western and eastern Europe (high confidence); North America and Oceania (high confidence), central, southern and western Asia (high confidence) and western and southern Africa (medium confidence)."

Shifting to solar PV & wind = less reliant on water = ensures energy security

"Shifting to a higher share of renewable sources less dependent on water resources for energy production could substantially reduce the vulnerability of this sector Diversifying energy portfolios to reduce water-related impacts on the energy sector is another effective adaptation strategy with high mitigation co-benefits."

Beware! Carbon mitigation tech is water intensive

"Many mitigation measures, such as carbon capture and storage, bioenergy and afforestation and reforestation, can have a high-water footprint."

Source: IPCC Sixth Assessment Report Working Group 2 – Climate Change 2022: Impacts, Adaptation and Vulnerability (Chapter 4: Water)

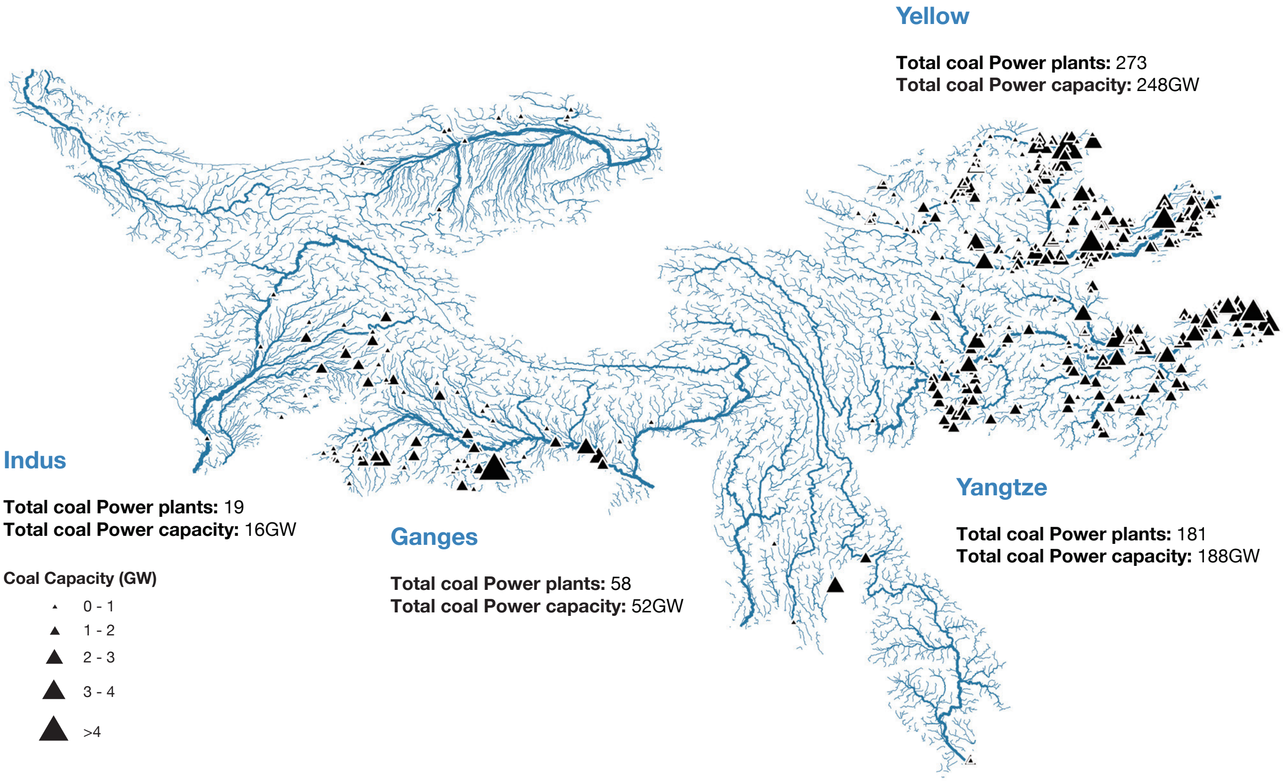
At-a-glance coal-fired power plants in the 10 HKH River Basins

For easy access to water, many coal-fired power plants are located along rivers, resulting in a clustering of the coal fleet in the 10 HKH River Basins. These plants serve the cities and population as well as industries and economies that are also clustered there.

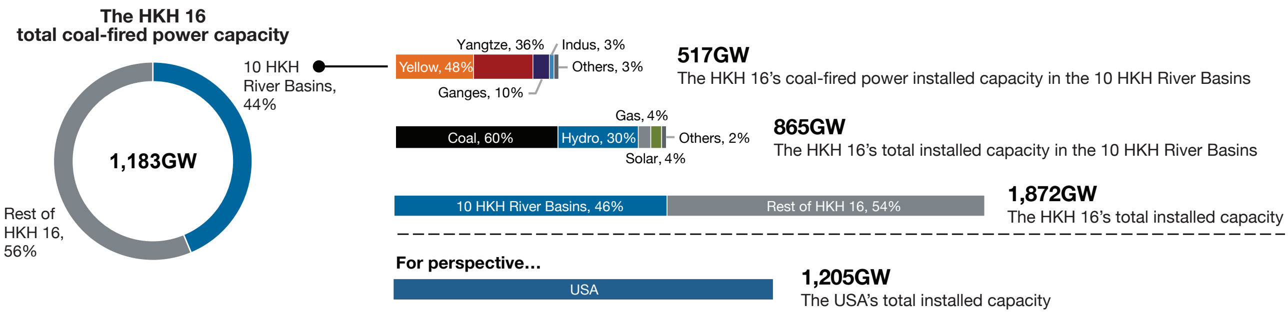
Coal-fired power capacity dominates the power mix in the 10 HKH River Basins accounting for 60% of the total basin installed capacity of 865GW. The spread of the 517GW of coal-fired power is shown in the graphic below. At a glance, you can see that the Yellow and Yangtze Rivers dominate with the most plants; followed by the Ganges and the Indus.

The Yellow, Yangtze, Ganges & Indus have the largest coal footprint…

CWR | AT-A-GLANCE COAL-FIRED POWER PLANTS IN THE 10 HKH RIVER BASINS



HKH 16 Coal-fired power perspectives…



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

Together the 4 Priority Rivers have 97% of coal-fired capacity…

The Yellow has the most in terms of numbers & capacity…

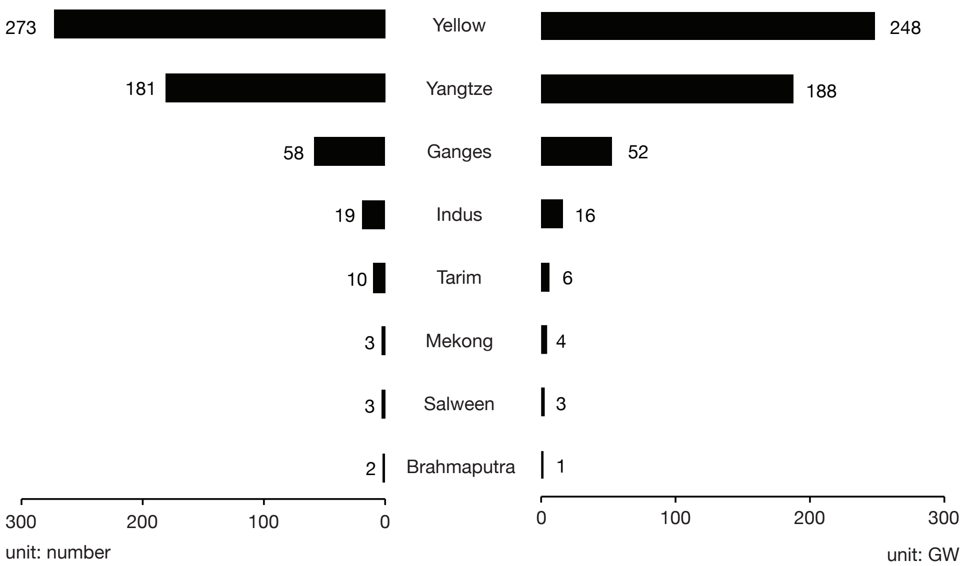
…followed by the Yangtze, Ganges & Indus

Only 8 river basins have coal-fired power assets; the Irrawaddy & Amu Darya have none

4 Priority Rivers dominate with 504GW

The charts below illustrate the number and the capacity of coal-fired power across the 10 HKH River Basins:

Total coal-fired power plants numbers vs. installed capacity by river



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

Key points to note are:

- **Only 8 rivers are shown out of 10 – the Irrawaddy and Amu Darya are missing** as there are no coal-fired power plants found in these two basins as per the Global Power Plant Database.

Yellow & Yangtze account for 84% of the coal capacity in the 10 HKH Rivers Basins

- **Yellow & Yangtze dominate with 84% of coal capacity across the 10 HKH Rivers**. It is obvious that the majority of the power plants are located in two basins in China along the Yellow and Yangtze Rivers. There are 454 coal-fired power plants located on these rivers. At 48%, the Yellow River Basin holds for the largest share of coal-fired capacity located in the 10 basins; the Yangtze River Basin holds another 36%.
- **Ganges is next with a 10% share followed by the Indus with a 3% share**. Together the Ganges and Indus have 77 coal-fired powers plants located in their basins – still, this is less than fifth of that along the Yellow and Yangtze.
- **The 4 Priority Rivers have 97% of the coal-fired capacity** in the 10 HKH River Basins. The fact that the 4 Priority Rivers identified for action in our NWNG Report has the lion's share of coal-fired capacity is a cause for concern and points to joint efforts to reduce reliance on coal to preserve river flows in the future.

….which could bring about energy security issues as some rivers are running dry

Clustering of coal-fired power in these 4 Priority Rivers, could bring about energy security issues should rivers face droughts like parts of the Yangtze currently or worse still run dry due to climate change. We examine the exposure of water-reliant coal-fired power to water stress next.

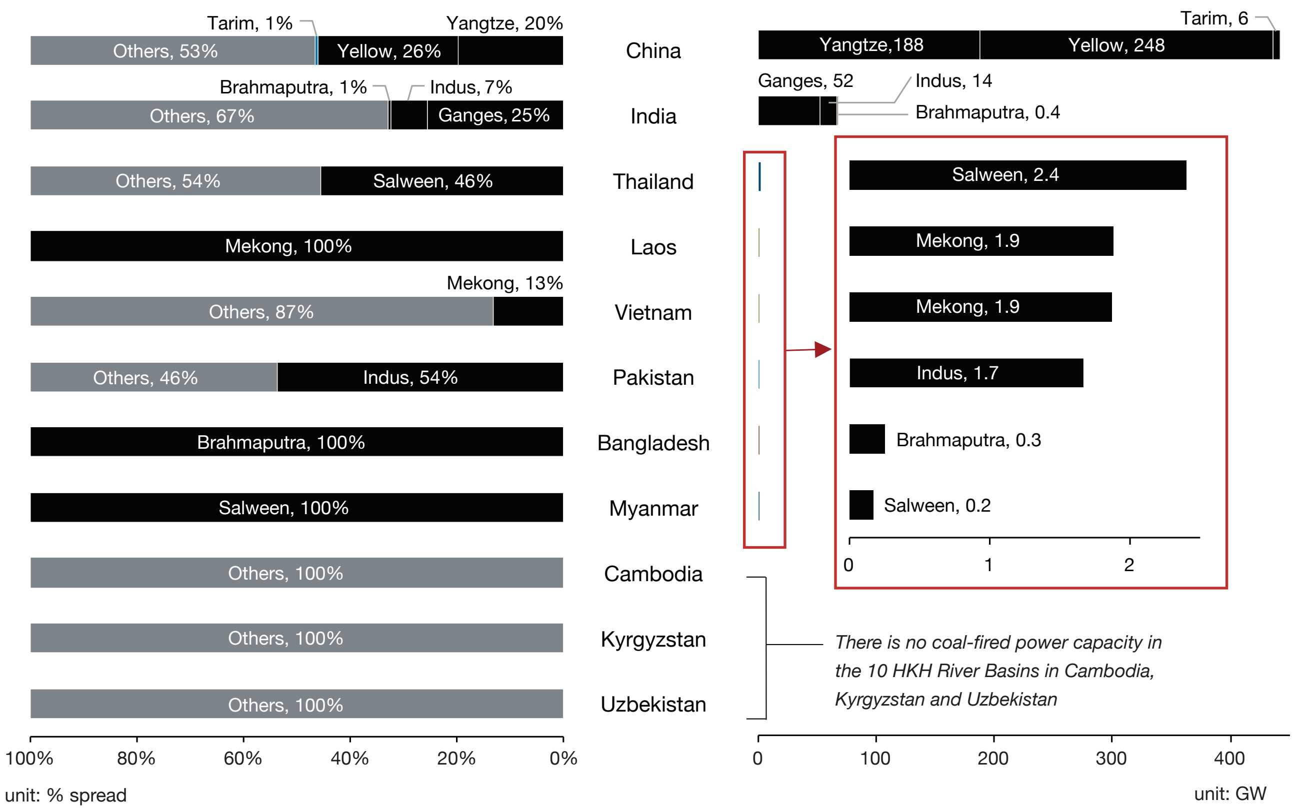
However, before moving on, it is worth noting that while 517GW is a sizeable amount of coal-fired power on these 10 rivers – for perspective, this is at least 43% of the total installed capacity of the USA as per the Global Power Plant Database. Besides, the coal capacity in these 10 HKH River Basins are only 44% of the total coal capacity of the 16 HKH countries which stands at 1,183GW.

Basins matter on a national level for coal-fired power

The chart below left shows the share of national coal-fired power capacity in the 10 HKH River Basin by country whereas the chart below right shows the absolute value of coal-fired power in each river basin by country:

Some countries' coal-fired power capacity are more exposed to river risk than others…

Total coal-fired power capacity of the HKH 16 across the 10 HKH River Basins



Source: CWR, Global Power Plant Database, FAO AQUAMAPS

Key points to note are:

- **China has the largest coal fleet among the HKH 16 countries, 47% of this capacity sits in the 10 HKH River Basins**. As significant shares of coal-fired power lie along the Yellow and Yangtze, it is not surprising that China dominates coal fleet in the 10 HKH River Basins. Across the Yellow, Yangtze and Tarim, China has a total of 442GW coal-fired power capacity. These three basins account for 47% of China's total coal capacity of 949GW as per the Global Power Plant Database. They provide power to support 43% of China's population and contribute to 29% of China's GDP. Basin management of the Yellow, Yangtze and Tarim to ensure water thus of clear importance to China's energy security – see what China is doing in **Appendix 1: Lessons from China – "Mountains-to-oceans waternomic management for the Yangtze & Yellow Rivers"**.

  Rising water stress could also strand coal-fired power in the Yellow and Tarim as our previous research showed 63% and 37% of the respective basin areas face 'High' to 'Extremely High' water stress.[9] We explore the overlay of plant location and water stress regions in the next section **"Coal-fired power & water stress in 10 HKH River Basins"**.

China has 47% of its national coal-fired power capacity spread across 3 Rivers…

…442GW sit on the Yellow, Yangtze & Tarim

…63% of the Yellow & 37% of the Tarim basins face 'High' to 'Extremely High' water stress

India has the 2nd largest coal fleet with 67GW located in Ganges (25%) & Indus (7%)…

…both river basins are highly water stressed

- **India has the next largest coal fleet with a capacity of 205GW but only a third of this lies in the 10 HKH River Basins**. India's coal fleet is less concentrated in the 10 HKH River Basins with only 25% located in the Ganges and 7% in the Indus. Together, these plants provide power to support 41% of India's GDP and 54% of the population clustered in the HKH River Basins. These are much higher power capacity to population/GDP ratios than China adding pressure on the plants to deliver. Since our previous research showed that over 34% of the basin areas of the Ganges and 47% of the basin areas the Indus faced 'Extremely High' water stress,[9] it's also worth exploring India's coal-fired power fleet's exposure to water stress to gauge risks.

- **Thailand, although significantly less than India & China, has the 3rd largest coal-fired power capacity in the 10 HKH River Basins**. Thailand only has 2.4GW in the Salween but this accounts for almost half of its entire national coal-fired power capacity, leaving the country with significant exposure to HKH River Basin risks.

Although small in GW, Laos, Bangladesh & Myanmar have 100% of their coal plants in the 10 HKH River Basins

- **All coal-fired power in Laos, Bangladesh & Myanmar are located in the 10 HKH River Basins**. These countries have a 100% of their coal power plants located respectively in the Mekong, Brahmaputra and Salween. So although the absolute amount of GW is insignificant compared to China and India, they are heavily exposed to the basin risks.

- **Cambodia, Kyrgyzstan & Uzbekistan have no coal-fired power in the basins**.

5 countries have no coal-fired power recorded in the database

- **Not all HKH 16 countries have coal-fired power capacity in the dataset**. The Global Power Plant Database has no coal-fired power installed capacity for Afghanistan, Bhutan, Nepal, Tajikistan and Turkmenistan. These countries are thus not shown in the chart above.

Coal-fired power & water stress in 10 HKH River Basins

>1/3rd of total power installed capacity lie in 'Extremely High' to 'High' water stress areas…

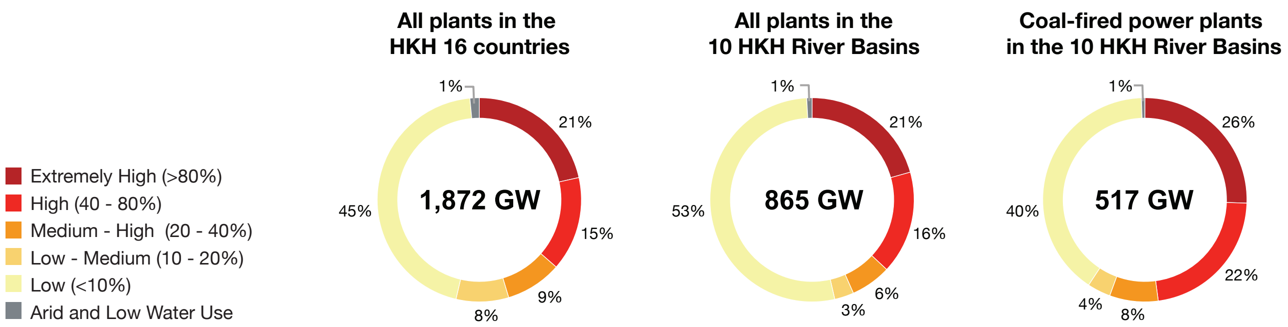
We overlaid all the power plants over WRI's Aqueduct Global Maps 3.0 and found that 36% of the 1.9TW of total installed capacity of all power generation types lie in 'Extremely High' to 'High' water stress regions. Another 9% faced 'Medium-High' water stress while 45% faced 'Low' water stress – as shown in the below left chart. As expected, the water risk exposure profile improved as we honed in on the 10 HKH River Basins with a higher share (53%) of power generation capacity facing low water stress as per the below centre chart.

It's worst for coal…

…48% of coal-fired capacity face 'High' to 'Extremely High' water stress

However, as we focused in on the coal-fired power plants in the 10 HKH River Basins, we found that the water risk exposure intensified. As per the below right chart, 48% of coal-fired power plants were located in 'High' to 'Extremely High' water stress areas in the basins with a further 8% in 'Medium-to-High' water stress areas. Only 40% of coal-fired power plants were located in 'Low' water stress areas.

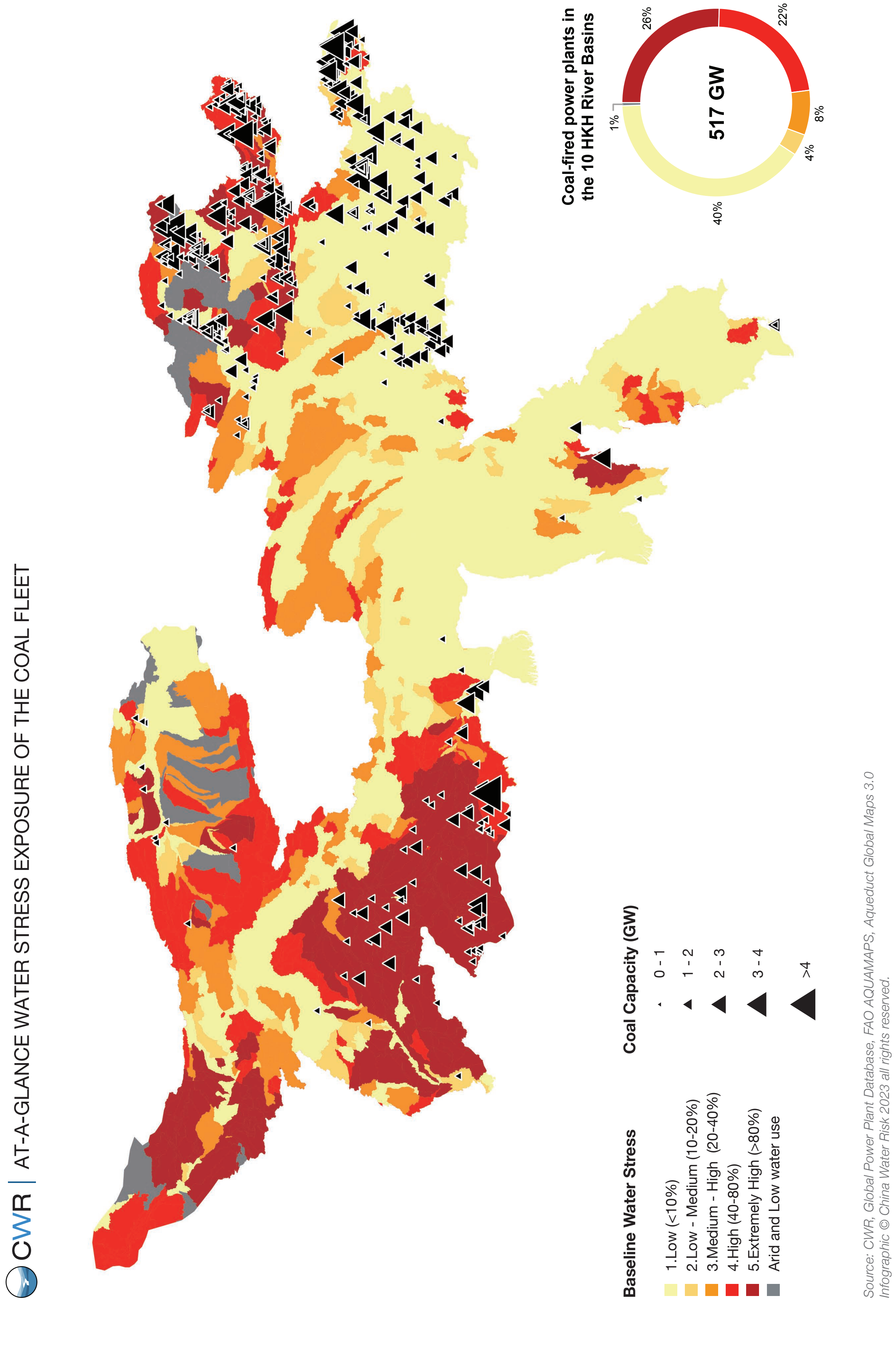
Coal-fired power exposure to baseline water stress



Source: CWR, Global Power Plant Database, FAO AQUAMAPS, Aqueduct Global Maps 3.0

Such high levels of water stress exposure can be clearly seen in the following graphic. Given this, as the ability of water stress to strand coal-fired power plants is high, we delved into the exposure by basin.

At-a-glance water stress exposure of the coal fleet



A lion's share, 93% of coal-fired power facing severe water stress sit in 3 basins…
- Yellow
- Ganges
- Indus

The Ganges is the most populated followed by the Yangtze & Indus…

In terms of GDP, the Yangtze leads, followed by the Ganges & Yellow…

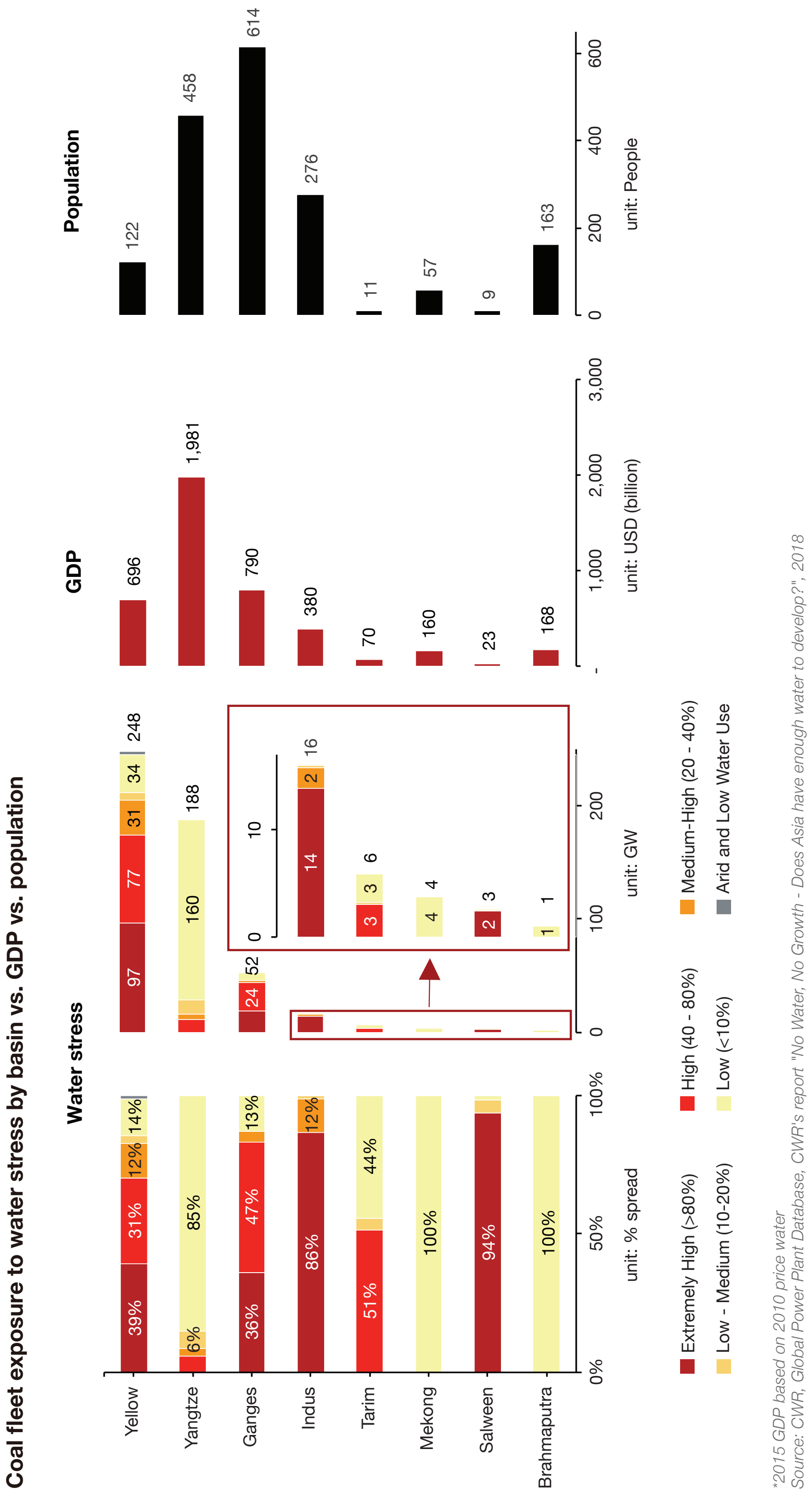
The Yellow has by far the largest coal GW exposure to severe water stress…

…but the Ganges, Indus & Salween have higher % shares exposed to severe water stress

The coal fleet in the Brahmaputra & Yangtze face the lowest water stress

Basin breakdown: water stress vs. GDP vs. population

The charts below left show the percentage spread and absolute exposure to water stress for the 517GW of coal-fired power capacity across the HKH 10 River Basins while the charts below right show GDP as well as population by basin. Within the 8 basins with coal-fired power capacity, water stress exposure varies but a lion's share (93%) of capacity facing 'High' to 'Extremely High' water stress sits in 3 basins – Yellow, Ganges and Indus.



Key points to note from the previous charts are:

- **Of the 4 Priority Rivers, coal-fired power capacity in the Yangtze faces the least water stress:** The Yangtze River Basin has the 2nd largest coal fleet but it faces significantly lower water risks than the other 4 Prioirty Rivers. Only 6% of the Yangtze coal-fired power capacity is located in 'High' water stressed regions.

  Yangtze also has less coal-fired power despite supporting a GDP and population that is 2.8x and 3.8x that of the Yellow respectively. Although this signals that the Yangtze is better positioned from a chronic basin risk perspective, the basin is still subject to extreme weather events such as the 2022 drought that wreaked havoc across global supply chains – see **"Extreme weather ahead disrupts power output"** covered later in this chapter for more. As this river has the largest hydropower capacity, both hydropower and coal-fired power must be considered together when assessing water-related energy security risks in this basin.

- **The Yellow River Basin coal fleet face largest water stress exposure with 174GW in 'High' to 'Extremely High' water stress areas**. This amount represents 70% of the entire coal fleet in the Yellow River Basin. Such clustering of coal-fired power plants in the Yellow makes sense as it is also where most coal production bases lie.[53] However, the basin's highly stressed water resources means there is a high risk that the lack of water could strand these assets.

  It is worth noting here that this basin despite being home to 26% of China's entire coal-fired power capacity supports a relatively smaller GDP and population compared to the Yangtze. Although this could signal potential to de-coal, the close proximity to coal reserves and the need for energy security could make this difficult. To avoid being stranded by water stress, plants in the Yellow River therefore must manage water stress and emissions by using the right type of cooling and if possilble carbon capture – we cover this in more detail later in this chapter in **"The right cooling tech can help alleviate water stress"**.

- **The Ganges & Indus River Basins have over 80% of respective coal fleets exposed to 'High' and 'Extremely High' water stress**. The coal power plants in these two South Asia basins face severe water stress – the Indus has 86% while the Ganges has 83% of their coal-fired power capacity located in 'High' to 'Extrememly High' water stress areas. These levels are higher than that for the coal fleet in the Yellow River Basin.

  Moreover, the pressure on this coal capacity is high from a GDP and population perspective. For the Ganges, its coal-fired power capacity is 28% that of the Yangtze's yet supports a population of over 600 million, 1.3x that of the Yangtze. The fact that Ganges' GDP is less than halve that of the Yangtze signals potential for future growth which will only put further pressure on power and water resources.

  The trend is similar for the Indus, but the risks of systemic faliure due to a mismanagement of the river are magnified as 88% of Pakistan's population and 92% of the GDP is clustered in the Indus River Basin.[9]

- **The Salween coal fleet faces the highest exposure to water stress at 94%.** Although the Salween only has 2.6GW of coal-fired power, almost all of it, 94% is located in 'Extremely High' water stress areas. Almost all of this (2.4GW) is located in Thailand and could have implications for Thailand's energy security – more on this below.

- **Mekong & Brahmaputra coal fleet face low water stress**. Both these rivers hold small amounts of coal-fired power capacity compared to the 4 Priority Rivers and they are located in 'Low' water stress areas. However, as can be seen in **"10 HKH Rivers power Asia"**, they are heavily reliant on hydropower which has its own set of water risks – please see **"Overview of hydropower's water risk exposure in the 10 HKH River Basins"**

It is clear from the above exposure to water stress, that there are implications for the energy security as well as economic security of the countries which these rivers flow through, so next ... we look at this through a national lens.

Only 6% of the Yangtze's coal-fired capacity is exposed to 'High' water stress…

…but it is vulnerable to extreme weather events (see later)

>1/4th of China's national coal-fired capacity sits in the Yellow River Basin due to proximity to coal reserves…

…174GW face 'High' to 'Extremely High' water stress

>80% of the Ganges & Indus' coal GW face severe water stress…

But the Indus faces higher systemic risks from river failure…

…88% of Pakistan's population & 92% of its GDP are clustered there

Salween's high exposure may impact Thailand's energy security (see later)

As coal is key to energy security, national perspectives are important

CWR

National perspectives on coal-fired power capacity & water stress

For most of the HKH 16, coal is a key resource for energy security…

8 out of the HKH 16's coal fleet are exposed to various degrees of water stress…

…China has the biggest exposure of coal GW to severe water stress

…but India, Thailand & Pakistan have higher % shares of their coal GW in severely water stress areas

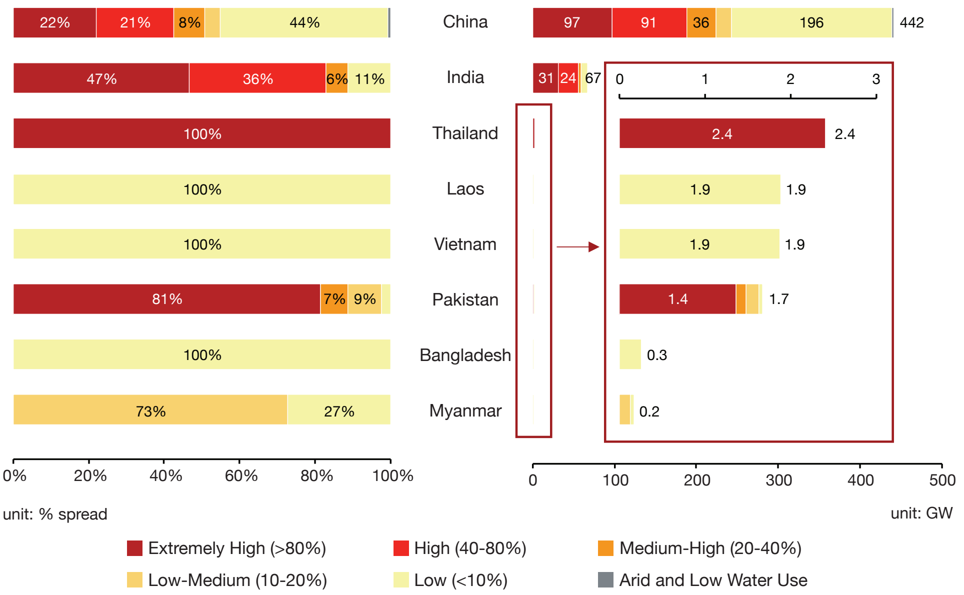
Coal plants in Laos, Vietnam, Bangladesh & Myanmar face low water stress…

…but 100% of Laos, Bangladesh & Myanmar's coal-fired power are located in the 10 HKH River Basins

Through a national lens, China & India are the most reliant on coal + have material shares of coal-fired power on the 10 HKH River Basins…

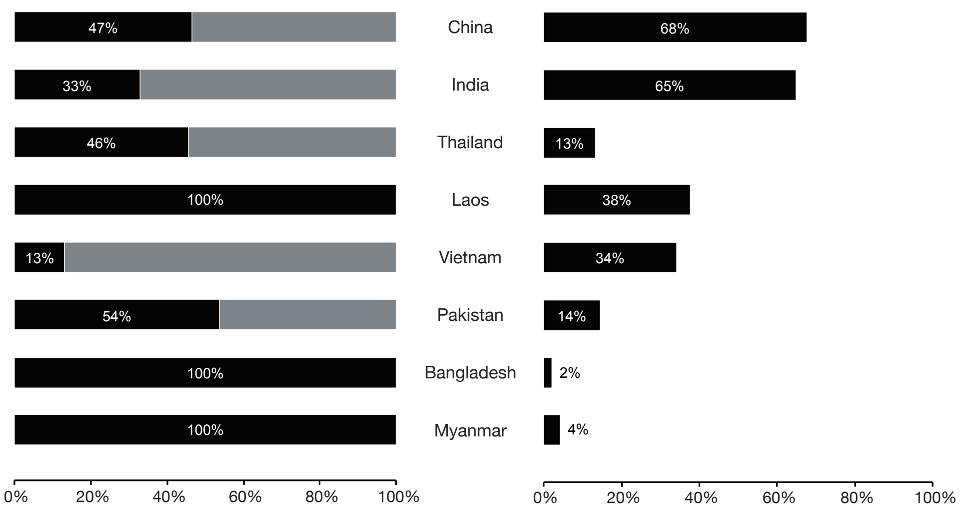
The first set of two charts below the water stress exposure profiles (% spread & absolute terms) of the 517GW of coal-fired power capacity in HKH 10 River Basin basins by country. From a country perspective, China and India have the largest GW amount exposed to 'High' to 'Extremely High' water stress areas. It makes sense to de-coal in these areas but for many of the HKH 16, coal is a key resource for energy security and so we also provide perspectives on the percentage share of national coal-fired power capacity located in the 10 HKH River Basins as well as coal-fired power's share of the total national installed capacity in the second set of two charts below. These 4 charts were considered together and our takeaways are set out on the following page.

10 HKH Rivers' coal-fired power capacity exposure to water stress by country



Share of national coal-fired power capacity located in the 10 HKH River Basins

Coal-fired power share of total national installed capacity



Source: CWR, Global Power Plant Database, FAO AQUAMAPS, Aqueduct Global Maps 3.0

Key points to note from the previous charts are:

- **Coal is China's primary power fuel source; China faces the highest exposure to water stress in terms of the absolute value of coal-fired capacity in the 10 HKH River Basins**. China has 188GW of coal-fired capacity located in 'High' to 'Extremely High' water stress areas with a further 36GW in 'Medium-High' water stress areas. This means that just over 50% of its coal-fired power capacity across the 10 river basins face 'Medium-High' to 'Extremeley High' water stress. However, despite having a sizeable 442GW of coal-fired power in the 10 HKH River Basins, this only account for 47% of the entire coal-fired capacity of China. This signals China has more room to maneuver to ensure energy security beyond the 10 basins. Note that the 10 HKH River Basins account for less than 50% of its population and GDP.

>50% of China's coal-fired capacity across the 10 HKH Rivers lie in 'Medium-High' to 'Extremely High' water stress regions…

- **Coal is India's primary power fuel source; India's coal fleet in the 10 HKH River Basins are more exposed to water stress than China**. At 67GW, India has significantly less coal-fired capacity located in the 10 HKH River Basins than China. However, a larger share of this (89%), faces 'Medium-High' to 'Extremely High' water stress. The pressure will be high on this capacity as a total of 54% of India's population is located and 43% of India's GDP is generated in the 10 HKH River Basins. That said, only 33% of India's coal-fired power capacity sits in the 10 HKH River Basins adding significant room to maneuver to ensure energy security.

…whereas India's exposure to the same water stress profiles is 89%

- **Pakistan has significant share of coal-fired power exposed to water stress in the 10 HKH River Basins but coal only fuels 14% of its national installed capacity**. That said, over 80% of Pakistan's coal-fired power capacity sits in 'Extremely High' water stressed regions across the 10 HKH River Basins. The clustering of Pakistan's population (88%) as well as GDP (92%) on the Indus compounds the risk exposure to water stress. On top of this, 54% of Pakistan's national coal-fired power capacity lies in the 10 HKH River Basins. Moreover, beyond coal, a sizeable share (nearly 40%) is derived from hydropower. All this means that Pakistan's energy security is very vulnerable to basin water stress or indeed floods as recent events have shown.

Pakistan's energy security is very vulnerable to basin water stress, floods & drought

- **Thailand has significant exposure to the Salween but coal only accounts for 13% of national installed capacity**. Thailand only has one 2.4GW coal-fired power plant located in an 'Extremely High' water stress area of the Salween River Basin. As this water stressed power plant accounts for 46% of Thailand's overall coal-fired power capacity, water risks could pose serious threats to the national energy security. However, this amount only represents 6% of Thailand's total installed capacity as its key fuel is natural gas. Also, unlike China, India and Pakistan, the 10 HKH River Basins only account for 24% of Thailand's GDP and 36% of population. That said, although much less exposed than the other three countries, Thailand should take note of such clustered risks.

Although Thailand's plant on the Salween faces 'Extremely High' water stress…

…coal only accounts for 13% of Thailand's national installed capacity

- **Four countries have no exposure to 'Medium-High' water stress. These are Laos, Vietnam, Bangladesh and Myanmar**. This is good as Bangladesh, Myanmar and Laos all have 100% of their coal-fired power capacity in the 10 HKH River Basins. Vietnam is the least exposed with only 13% of its coal-fired power capacity located in the 10 HKH River Basins; coal accounts for around a third of Vietnam's national installed capacity.

Vietnam's coal plants are the least exposed out of the 8 countries

China clearly has a role to play – it has the largest coal-fired power fleet across the 10 HKH Basins accounting for 85% in terms of number and capacity across the Yellow, Yangtze and Tarim. Not surprisingly all eyes are focused on the country's coal movements which at times could appear to be moving away from transitioning to a low-carbon future as China balances transition with energy security. More on this is in **Appendix 1: Lessons from China**.

China has a clear role to play in balancing transition with energy & water security…

Clear implications for energy security = must look at projected future flows. Rising urbanisation as well as development across the HKH 16 will put more pressure on the river basins. Already, a RCP4.5 scenario show that future overall trend of river flow of the Ganges and Indus will fall adding to water woes. Meanwhile, the overall flow of the Yangtze and the Yellow will rise. Both will cause problems for India, Pakistan and China. For more on this, please see the **"Past 50/Next 50 years = changing water flows"** extracted from our NWNG Report in the following pages. Given this, it is important to use the right cooling tech as it can help alleviate water stress today … Read on.

Besides water demand pressure from development, future river flows must also be considered…

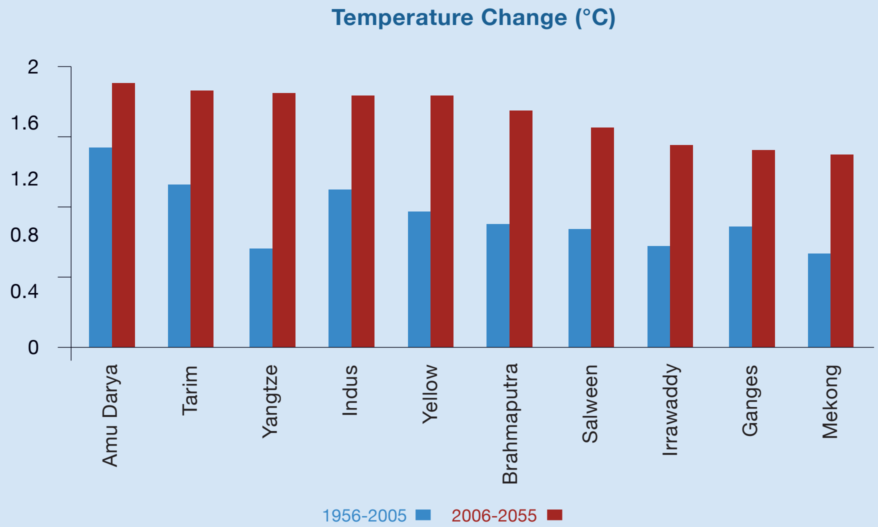
Past 50/Next 50 years = changing water flows

Below are excerpts from our NWNG Report; please refer to the NWNG Report for full references for this section.

Climate change is evident in the HKH Region. As warned by UNEP, its impacts on water resources are becoming more pronounced in the HKH River Basins. Based on IPCC Representative Concentration Pathway (RCP) 4.5 scenario (see box below), our research partner at CAS-IGSNRR examined the historical changes from 1956 to 2005 for four common climate and hydrological indicators: 1) temperature, 2) snowfall, 3) rainfall and 4) runoff.

Using five climate ensemble models, future projection of these indictors by 2055 were also calculated. Due to historical data availability, in some of these models, 2005 is used as the dividing year for the past 50 and next 50 years. The results are as follows:

1. **Hotter & hotter: temperatures continue to rise across all 10 basins**
   Average temperature has seen a clear rise of 0.68-1.48°C across the HKH River Basins. Future warming is projected to be even greater in the next few decades by 2055. The projected increase across the 10 HKH River Basins ranges from 1.39°C in the Mekong to 1.90°C in the Amu Darya (see chart below).



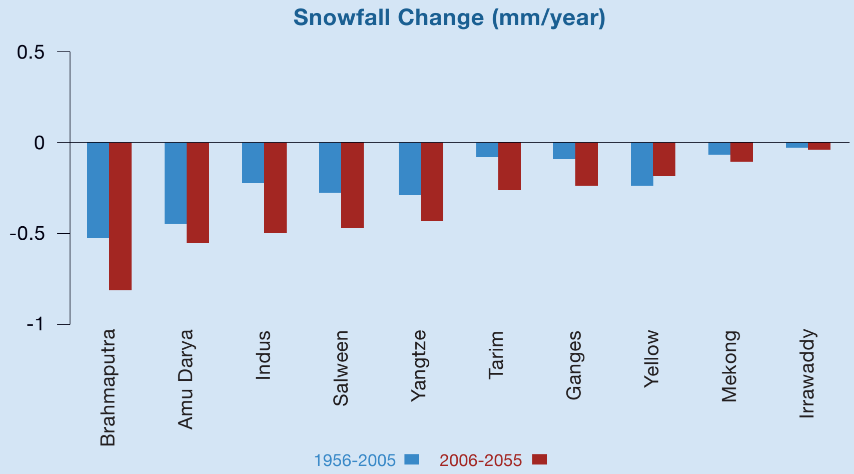
Source: China Water Risk based on data from Center for Water Resources Research, Chinese Academy of Sciences. Rainfall, snowfall and runoff change are expressed in equivalent water height. All data are calculated from five ensemble model (BCC-CSM1.1, CanESM2, CCSM4, MIROC5, MPI-ESM-LR) in IPCC AR5.

The Yangtze, Yellow, Amu Darya, Tarim and Indus are likely to see the biggest increase in temperature of 1.80-1.90°C. It is also worth noting that for 6 of the river basins (Yellow, Yangtze, Mekong, Salween, Irrawaddy and Brahmaputra), the projected temperature rise in the next 50 years is nearly or more than double that of the previous 50 years. Rising temperature will have direct impacts on the water cycle and the availability of water resources, especially in snow-dominant or glacier-fed river basins. Moreover, rise in water temperature could reduce raw water quality and threaten drinking water sources.

2. **Less snow in the past and for the future**
   Already, snowfall has been overall falling in the past few decades. This trend is projected to continue at a faster pace in the near future, with the exception of the Yellow River Basin. As can be seen from the chart below, the Brahmaputra, Amu Darya, Indus, Salween and Yangtze are projected to experience the greatest losses in snowfall.

   It is important to note that snowfall losses are likely to more than double for the Indus, Tarim and Ganges in the next 50 years. This may pose problems for these basins putting the Indus, Ganges and Tarim at risk. Continued greater snowfall losses in the Mekong could also impact the Upper Mekong which has significant runoff contribution (33%) from snowmelt. The Upper Salween could also be affected with up to 28% of its runoff from snowmelt.

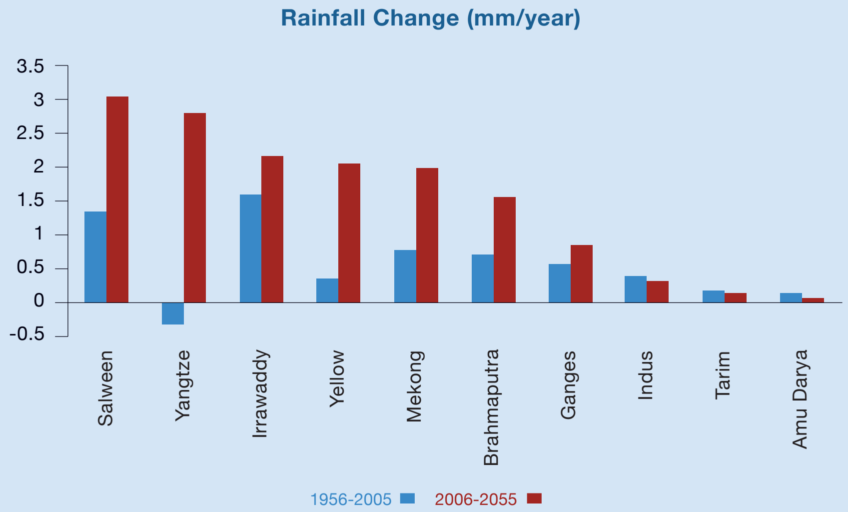
   Moreover, it is worth noting that these physical impacts of snow cover go beyond the HKH region. Wu et al. (2015) found that the changing snow cover in the Tibetan Plateau contributed to over 30% of the total variances of heat wave variability in southern Europe as well as north-eastern Asia.



Source: China Water Risk based on data from Center for Water Resources Research, Chinese Academy of Sciences. Rainfall, snowfall and runoff change are expressed in equivalent water height. All data are calculated from five ensemble model (BCC-CSM1.1, CanESM2, CCSM4, MIROC5, MPI-ESM-LR) in IPCC AR5.

3. **Rainy days ahead**

In comparison, average rainfalls have been increasing during 1956-2005, with the exception of Yangtze. Projections for the period of 2006-2055 show continued increase in rainfalls, but with a slower rate of change in the Indus, Amu Darya and the Tarim.



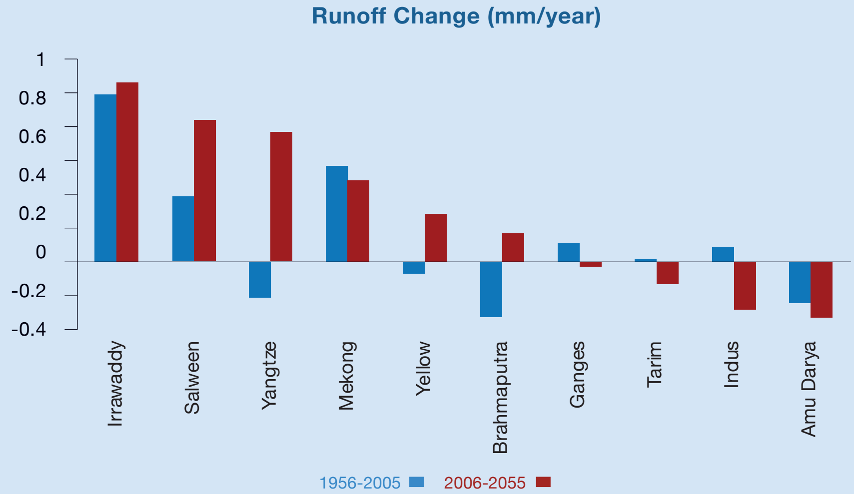
Source: China Water Risk based on data from Center for Water Resources Research, Chinese Academy of Sciences. Rainfall, snowfall and runoff change are expressed in equivalent water height. All data are calculated from five ensemble model (BCC-CSM1.1, CanESM2, CCSM4, MIROC5, MPI-ESM-LR) in IPCC AR5.

From the chart above, it is evident that the Yangtze and the Yellow face the largest swings in trend from the past 50 to the next 50 years. Both rivers are demonstrating dramatic increases in rainfall. Indeed, China experienced the wettest year in 2016 with the most number of heavy rainy days since 1961. That year, the national average precipitation reached 730mm, 13% more than 2015 and 16% more than an average year; and the national total rainfall nearly reached 6.9 trillion m^3, which is 771 billion m^3 more than the 2015 level. At 1.25x the total national water use of 615 billion m^3 in 2016, rainfall is an important component of water resources.

However, the increase in rainfall doesn't necessary mean increase in availability of water resources throughout the year. Currently, about 70-80% of the rainfall in the central Himalayan region and about 50% of that in the western part happen during the monsoon season. For instance, nearly 75% of India's annual rainfall concentrates in the summer monsoon season from June to September, and the other 10% and 11% happen during the pre-monsoon and post-monsoon seasons respectively.

Despite differences in projected results due to different climate models and study areas, an overall upward trend is observed for future summer monsoon precipitation in several river basins including the Indus, the Ganges and the Brahmaputra.

4. **Mixed results for runoffs across 10 basins: 4 down & 6 up**
The results for future runoffs are mixed. As expected from the previous projections of climate indicators the most vulnerable river basins are the Amu Darya, Indus and Tarim. All these together with the Ganges will see reduced runoffs in the next few decades. Meanwhile, trends in the annual runoffs for both the Yellow and Yangtze will likely reverse over the next 50 years in favour of an increased flow. The Mekong, Salween and Irrawaddy will continue to see increased runoffs. Please refer to the chart below:



Source: China Water Risk based on data from Center for Water Resources Research, Chinese Academy of Sciences. Rainfall, snowfall and runoff change are expressed in equivalent water height. All data are calculated from five ensemble model (BCC-CSM1.1, CanESM2, CCSM4, MIROC5, MPI-ESM-LR) in IPCC AR5.

It is important to note here that for those rivers with projected increase in runoff, it does not necessary mean there would be more water for use. The mountainous topography in many parts of the HKH Region makes rivers quickly run through deep valleys and makes rainfalls flow down steep hill slopes. Thus, without proper water storage and supply infrastructure, water supply would not necessary increase with increased runoffs and water access may still remain a challenge, especially for people living in the mountain communities. Basins need to adapt to a near to mid-term future with more rain and river flow by building better drainage facilities and storage reservoirs.

Moreover, increases in runoff are often seasonal and happen within a short time period which could lead to floods. For instance, more than 80% of annual precipitation in much of the HKH region falls during the monsoon season. This uneven temporal distribution of precipitation has led to some serious floods during the rainy seasons, especially in mountain.

A word of caution here: we should bear in mind that climate projections (at least currently) are full of uncertainties. Results may vary depending on the climate model used, assumptions made and areas studied. For instance, in terms of future runoff change, Su et al. (2016) suggested a 10.7-21.4% increase in the Upper Yangtze during 2041-2070 in comparison to the baseline period 1971-2000.[54] While, this is relatively comparable to the CAS-IGSNRR projection for the Yangtze, the same study also suggests a 6.3- 22.4% increase in the Upper Indus river flow for the same period, which is evidently opposite to CASIGSNRR's results above showing a decline in river flow. This difference may be explained by the different areas studied the Upper Indus vs. the entire Indus River Basin.

Nevertheless, it is clear from the above results that projected changes in temperature, snowfall, rainfall and runoff during the next 50 years (2006-2055) will likely be greater than changes in the past 50 years (1956-2005). This trend holds true for all 10 HKH River Basins and is worrying.

Finally, it is important to note that the projections below are made based on RCP4.5. So they are likely to change across the HKH River Basins if we fail to keep the global surface temperature change within the 2°C threshold. Since projections under RCP 4.5 already show that water stressed Ganges, Indus, Tarim and Amu Darya will likely see significant negative impact on runoffs in the next 50 years, it is imperative that we adopt aggressive measures to mitigate climate change to stay within the 2°C threshold.

As can be seen, the impacts within the 2°C thresholds already do not bode well for future flows in some rivers, let alone the consequences of our current policy path of 2.8°C – this path will be dire for future flows.

The right cooling tech can help alleviate water stress

Uncertainty in future flows means that it is important to have the right cooling tech today that can help alleviate water stress and lower emissions. Ideally, the HKH 16 should stop relying on coal for energy security but if it cannot, it must ensure that carbon emissions are captured and that power generation is water efficient – using less water to generate each MW.

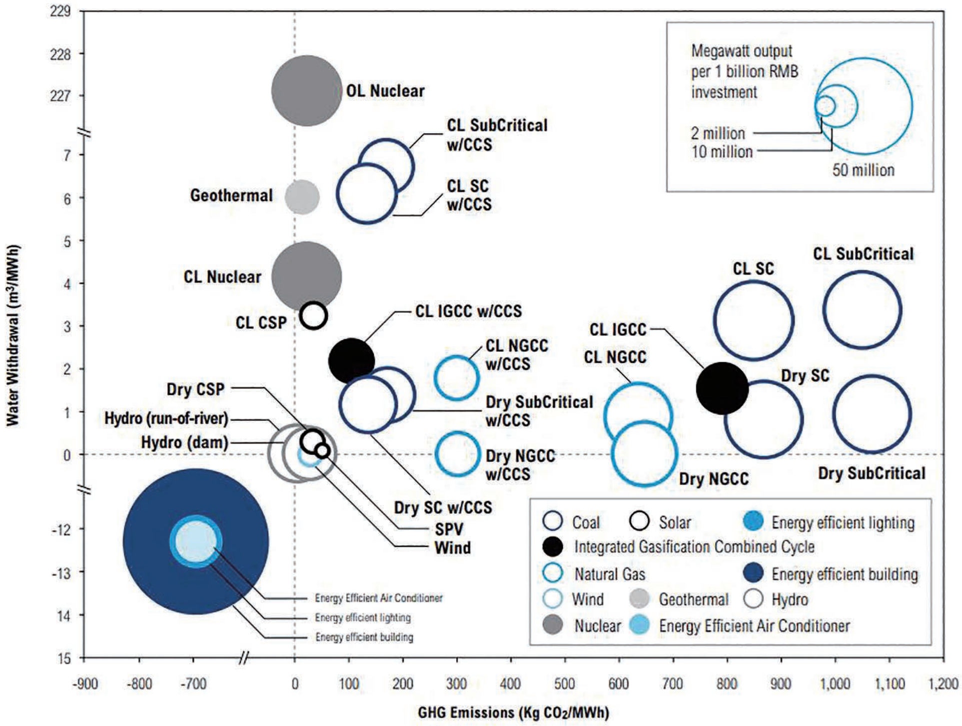
The right cooling tech can alleviate water stress…

Choose carefully! different tech = different emissions & water use

Thermal power types such as coal, oil and gas are among the top emitters off CO2 causing climate change. Water is also required for cooling to generate power – the water consumption/withdrawal varies by fuel and cooling types. The chart below by WRI, although dated, provides an idea of the trade-offs between water use and carbon emissions between different cooling types per MWh of electricity generated:

WRI evaluated trade-offs between water use & GHG emissions of different powergen tech & cooling systems…

Water Withdraw and Greenhouse Gas Emissions of Power Fi Generation Technologies and Energy Efficiency Measures



Source: Extracted from Seligsohnetal. (2015). Opportunities to Reduce Water Use and Greenhouse Gas Emissions in the Chinese Power Sector.

Aim for energy efficiency with water in mind…

But beware!

…air/dry cooling tech emits more GHG unless there is CCS…

…but tech with CCS increases water use materially

Run-of-river hydro, wind & solar PV are choices with least water + least GHG emissions

Clearly, policymakers should choose the right type of power generation technology that is the least water intensive and has the least carbon emissions. Indeed, in our policy brief with IRENA, showed that improved cooling technologies can reduce water use and when deployed together with aggressive renewable expansion can reduce water-intensity in Chinese power generation by as much as 42%.[36]

Policymakers should choose power mix + cooling tech that optimises carbon & water savings…

The brief notes that the *"sharp decrease in water withdrawal intensity results from the choice of cooling technologies (in particular the absence of once-through cooling in new coal-fired plants) and the change in power mix towards renewables and natural gas"*. The different cooling types are explained in more detail below.

… IRENA says aggressive renewables can reduce water-intensity in China powergen up to 42%

Cooling is most of coal power plants' water use, so cooling type matters

~90% of water use in thermal power plants is for cooling…

Different cooling technologies = different amounts of water withdrawn & consumed. Cooling represents most of the water use in thermal power plants, typically 90%. The remaining 10% is used for flue gas desulfurization, boiler make-up and ash handling. As a result, levels of water use are mainly dependent on the type of cooling technology adopted. Set out below are three main types of technologies with wide-ranging levels of water withdrawal and water consumption.

Once-through needs the most water withdrawal per MWh…

- **Once-through cooling:** entails significant water withdrawal (up to 100x more than other technologies) but low water consumption. It is more sensitive to droughts and can only be used in regions where water is plentiful (e.g. along the coast). Adverse impact on biodiversity has led many governments to ban this technology.

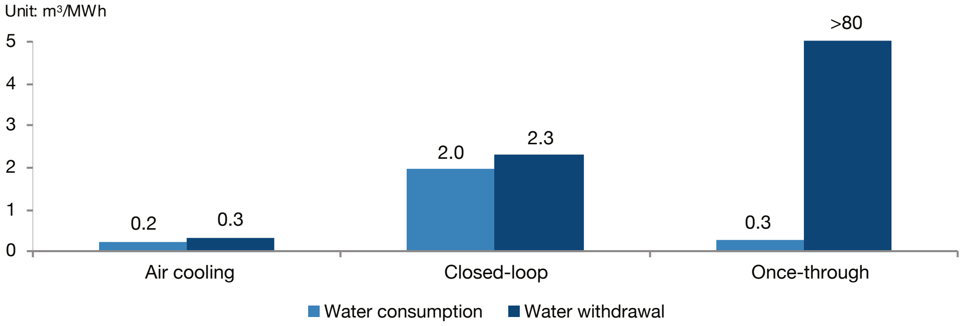
…while closed-loop withdraws less

- **Closed-loop cooling:** withdraws much less water than once-through cooling but consumes most of it. This is nowadays the default technology for most new power plants, except in water-stressed areas in China where air cooling is becoming a prominent option. In general, closed-loop systems are less efficient and more costly than once-through systems.

Air/dry-cooling uses the least water but reduces the plant efficiency… so it generates more CO2 per MWh

- **Air cooling or dry-cooling:** relies on air to evacuate the heat of power plants, thereby drastically reducing the amount of water required but also the plant efficiency, leading to higher coal consumption and pollutants emission. Air cooling is also more expensive to build.

Water use of coal-fired power plants for different cooling technologies



Source: CWR based on Qin, Y., Curmi, E., Kopec, G. M., Allwood, J. M., & Richards, K. S. (2015). China's energy-water nexus-assessment of the energy sector's compliance with the "3 Red Lines" industrial water policy. Energy Policy, 82, 131-143.4 Average supercritical units in China

Note! Water risk lies with the withdrawal amount and not the amount consumed…

Water withdrawal		Water consumption
Water withdrawal refers to the amount of water removed from a surface or groundwater source, whether it is ultimately returned to its original catchment or not.	vs.	Water consumption refers to the amount of water withdrawn which is not returned to its original catchment. In power generation, most of the water is consumed through evaporation.

The use of various cooling types can therefore alleviate or increase risks – air cooling will clearly reduce water risks and once-through cooling will increase risks in already water stressed areas. It is important to note here that the water risk lies with the withdrawal amount and not the amount consumed – if you cannot withdraw the total amount, you will not be able to generate power.

Closed-loop should ideally be used instead of once-through in water stress zones…

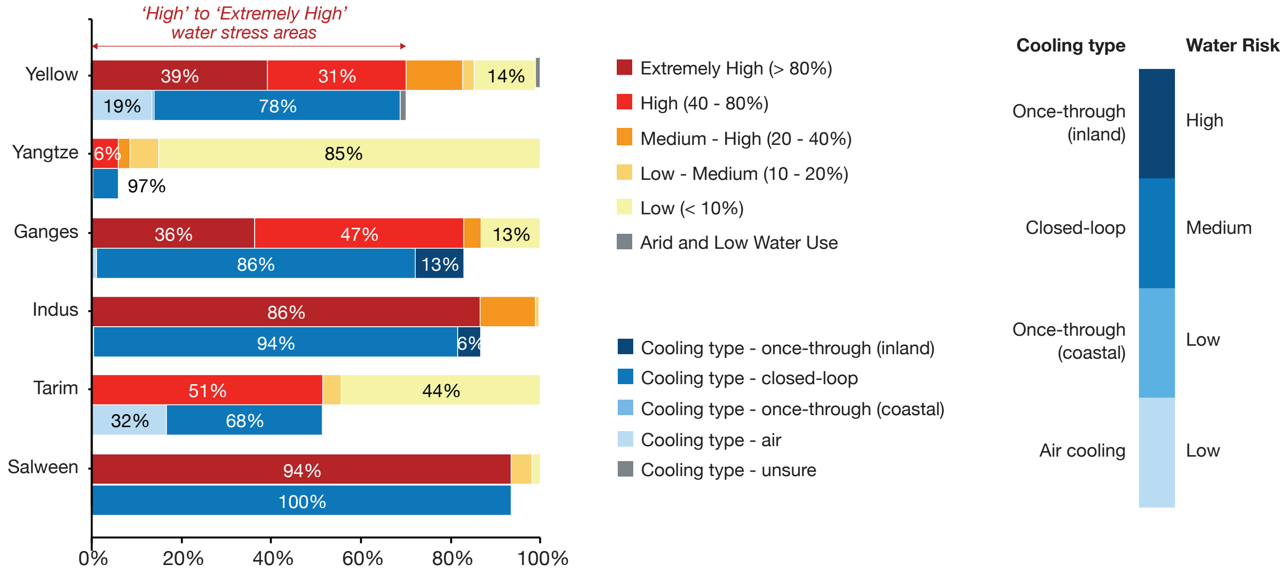
In severely stressed areas, air cooling should be considered

It follows that 'High' to 'Extremely High' water stress areas should use air cooling whereas once through is only viably deployed in low water stress areas. As previously discussed, a significant portion of the coal fleet in the 10 HKH Rivers Basins are exposed to water risk as they sit in 'High' and 'Extremely High' water stress regions. Therefore, to determine a better picture of water stress exposure, we had to **further analyse power generation located in 'High' to 'Extremely High' water stress areas for cooling types**. However, there is no public disclosure/database available for cooling types, so we had to examine satellite images of each coal-fired power plant located in the basins to determine cooling type.

The results of our analysis is illustrated in the chart below which shows both the water stress profile of the coal-fired power plants in each basin and corresponding cooling technologies for plant areas that are located in 'High' to Extremely High' water stress. While the red to yellow colours denote water stress, the blues denote cooling type – the blue vertical bar below right indicates the level of water risk per cooling type.

Cooling types in severely water stressed areas were analysed…

Power generation by cooling type in highly water stressed areas by basin



Source: CWR, Global Power Plant Database, Aqueduct Global Maps 3.0

Key points to note are:

- **Only 6 basins have at-risk coal-fired power plants** that are located in 'High' and 'Extremely High' water stress regions.
- **Air-cooled power plants in the 10 HKH River Basins are located in 'High' to 'Extremely High' water stressed regions** – the Yellow and Tarim have the highest share at 33GW and 0.97GW respectively, followed by the Ganges with 0.57GW.
- **Closed-loop cooling is the main type of cooling across the coal fleet** in the HKH basins. While this is better than once-through, there is still a medium risk that water could strand these assets.
- **Once-through cooling represents the highest risk** as it needs the highest water withdrawals, but note that we only consider once-through with freshwater to be of high risk but once-through cooling with seawater to be of low water risk. Coal-fired power plants in 'High' and 'Extremely High' water stress areas with once-through cooling are found mainly on the Ganges and Indus, with smaller amounts on the Yangtze and Yellow. This not only adds to the water stress of the basins but in turn the lack of water could easily strand these assets.
- **Seawater cooling**: Although representing low water risk on the availability front, coastal power plants face other risks such as sea level rise and storm surge – please see box below:

Closed-loop is the main type of cooling

The Yellow & Tarim have the highest share of air-cooled power plants that are in 'High' to 'Extremely High' water stress areas…

Once-through cooling with the highest type of water risk is mainly present in the Ganges and Indus

Coastal plants may have enough water but they are vulnerable to coastal threats

River delta power plants face coastal threats

Most of the power plants located in the 10 HKH River Basins are inland but some are located in the river deltas. While the latter may utilise seawater for cooling thus ensuring continuous availability, they face other risks such as rising seas and typhoons.

Our analysis shows that 5GW of coal plants in the Yangtze River Delta face 'Extremely High' coastal flood risk. However, it is the Mekong that faces the most risk with half of its coal-fired plants in the basin facing 'Extremely High' coastal flood risk. While this report does not explore impacts of coastal threats in detail, such risks must not be ignored when drawing up energy security plans in a changing climate.

We recommend coastal threat analyses – plants beyond the 10 HKH Rivers must also be considered to see the full extent of the impacts of coastal threats to energy security. This is especially important in Asia, which is particularly prone to sea level rise risk as well as typhoons; both of these threats are accelerating and intensifying as warming continues. For an idea of coastal threats ahead, please see our 5-report series ***"CWR Coastal Capital Threat Series"*** which benchmarks risks for 20 coastal capitals and economic hubs in APAC from Tokyo to Sydney.

China has banned once-through cooling in water stress areas…

… air-cooled thermal power plants reached 112GW by 2012

There's at least 52GW of air-cooled plants in severe water stress areas in the Yellow, Yangtze & Tarim

- **China has little once-through cooling in its basins in 'High' to 'Extremely High' water stress areas:** China has had policies in place that ban once-through cooling in water stressed areas across provinces with mandatory retrofitting/closure of such plants. Moreover, since May 2004, the NDRC required new power plants in the water-scarce Northern regions to adopt air-cooling.[55] As a result, China's air-cooled coal power capacity expanded rapidly. At the end of 2012, the installed capacity of air-cooled power plants reached 112GW, accounting for 14% of China's thermal power capacity.[56] Our analysis of the coal fleet located in 'High' to 'Extremely High' water stress areas as per the Global Power Plant Database showed that there is 51GW of air-cooled power plants on the Yellow, 0.4GW on the Yangtze and a further 1GW on the Tarim. See what China has been doing in **Appendix 1: Lessons from China – "Water use & pollution caps for coal extraction & coal-fired power".**

Ganges' coal fleet faces material water risk…

… in severe water stress areas, none are air cooled; 13% are once-through freshwater cooling;

- **The Ganges is the most at-risk; plants can be retrofitted with cooling tech to help alleviate stress**. The Ganges has 83% of its coal power capacity located in 'High' to 'Extremely High' water stressed regions. Out of this, 13% adopts once-through freshwater cooling, which has the highest water risk; another 86% adopts closed-loop cooling, which also relies greatly on water availability. The overall falling trend of river flow discussed previously for this basin also **do not bode well for future energy security in this basin which could disrupt up to a third of India's GDP and over 600 million livelihoods**.

- **The Indus is similarly exposed** with no air-cooling for plants in 'High' to 'Extremely High' water stressed zones. 6% of plants located there adopts once-through freshwater cooling while 94% adopts closed-loop cooling. The overall falling trend of river flow in the Indus for the next 50 years, plus **Pakistan's high concentrations of GDP and population in this river basin do not bode well for future energy, water or economic security for the country.**

None of Pakistan's coal plants in severe water stress areas are air-cooled either

- **India and Pakistan can consider taking a page out of China's energy policies** at the water-energy nexus – for more on China's actions to de-coal and its dual carbon targets, please see **Appendix 1: Lessons from China**.

- **Trade-offs between water & carbon emissions from different types of cooling tech must also be considered**. See box below.

Pakistan & India can follow China on air-cooling but beware of trade-offs…

In addition to water stress, there is extreme weather to consider. Recent news of severe drought in the Yangtze to devastating floods in the Indus will have implications for coal-fired power generation in the basins also – we examine exposure of these plants flood and droughts next in **"Extreme weather ahead disrupts power output"**.

Tough Trade-offs: Water & Carbon emissions

Both the technologies below will have to improve in order to deliver real savings for both water & carbon emissions in an ever tighter water-energy-climate nexus:

Dry/Air cooling to save water emits more carbon per unit of power generated: It is important to note that while good for water, air-cooling will result in lower power generation efficiency and therefore more carbon emissions, as well as higher costs. As our brief with IRENA also warned *"reducing withdrawals through changes in cooling technologies, however, translates into a trade-off between water and climate. Dry cooling reduces water withdrawals drastically, but comes at a cost for plant efficiency. This translates into higher costs as well as greater fuel use and emissions to generate the same electricity."* The carbon intensity savings calculated in that report therefore factors in this trade-off.

Carbon capture to save carbon requires more water: Ultimately, these plants will have to turn to carbon capture but this too may be difficult as current carbon capture and storage technologies also require water! According to various studies on CCS, water use for power plants with CCS is significantly higher than those without. Indeed, dry/air-cooling power plants with CCS uses almost the same amount of water as wet cooling power plants without CCS. Furthermore, CCS units uses energy as well, lowering the efficiency of power plants.

Source: IEA's report "Technology Roadmap – Concentrating Solar Power, May 2010; Eldardiry, H., & Habib, E. (2018). Carbon capture and sequestration in power generation: review of impacts and opportunities for water sustainability. Energy, Sustainability and Society, 8(1), 1-15; Zhai, H., Rubin, E. S., & Versteeg, P. L. (2011). Water use at pulverized coal power plants with post combustion carbon capture and storage. Environmental science & technology, 45(6), 2479-2485.

Extreme weather ahead disrupts power output

Extreme weather impacts the ability to produce power

Rising temperatures doesn't simply mean a hotter environment, but also more extreme climate events such as heat/cold waves and tropical cyclones. According to the latest IPCC report, both the frequency and intensity of extreme weather will increase with rising global temperatures.[57] Indeed, extreme weather events from heatwaves, floods, droughts to typhoons & bomb cyclones have disrupted power generation and distribution. We do not have to look far back in history, last year's events were evident. Below are a few examples:

Rising temperatures = rising extreme weather events = power disruption

Just last year…

- **European drought conditions have reduced and suspended hydropower as well as thermal power generation**. Reuters reported that energy production from run-of-river plants until the beginning of July was lower than the 2015-2021 average for many European countries, including Italy (-5,039 GWh compared to the average), France (-3,930 GWh) and Portugal (-2,244 GWh).[58]

European droughts & hot weather disrupted hydropower…

- **Nuclear power output was lowered in France due to high river temperatures**. As rivers warm due to rising temperatures and prolonged heatwaves, the ability for rivers to absorb water at higher temperatures after cooling is limited as further heating will damage wildlife. With several rivers in France reaching/passing their maximum temperature, nuclear power producer EDF cut power supply by at least 1GW.[59]

…and nuclear power generation…

- **China's Yangtze River faced the lowest summer rainfall in six decades**. According to the People's Daily, in Chongqing, 24 reservoirs and 51 rivers have dried up due to searing temperatures of >40°C for eight consecutive days.[60] Record heatwaves and low rainfall meant that electricity demand for air-conditioning rose whilst hydropower generation fell due to drought conditions lending complexity to drought management. With 80% of its electricity derived from hydropower, the Sichuan province was particularly affected.[60] It's hydropower generation plunged by 50% and a large number of industrial enterprises and factories were told to suspend production for 6 days to ensure that public basic needs of power and water were met.[60]

Prolonged heatwaves + drought in Yangtze caused hydropower in Sichuan to plunge by 50%…

….factories had to shut down causing disruptions in global supply chains

- **Pakistan's devastating floods** inundated more than a third of the country's districts – the UN and NDMA estimates around 33 million people were displaced and more than 1,500 were killed.[61] Connectivity around Pakistan was also cut – more than 100 bridges and 300 kilometres of roads were either damaged or destroyed. The army was deployed to stop the key power station from being flooded.[62] Despite valiant efforts, the estimated economic impact is US$30-35 billion – or over 10% of Pakistan's GDP.[63] See **"The Indus – a vicious water-energy-climate crisis"** in Chapter 3 for more.

Pakistan's severe floods affected
- **>33mn people**
- **>10% of its GDP**

- **USA bomb cyclones & atmospheric river wreak havoc on power**. Last year kicked off with blizzard conditions brought on by a 'bomb cyclone' along the US East Coast which led to transport chaos and power cuts for thousands.[64] This year, the West Coast suffered an 'atmospheric river' of non-stop rain causing floods and power disruptions across California.[65]

Extreme weather has led to power cuts for thousands across the USA

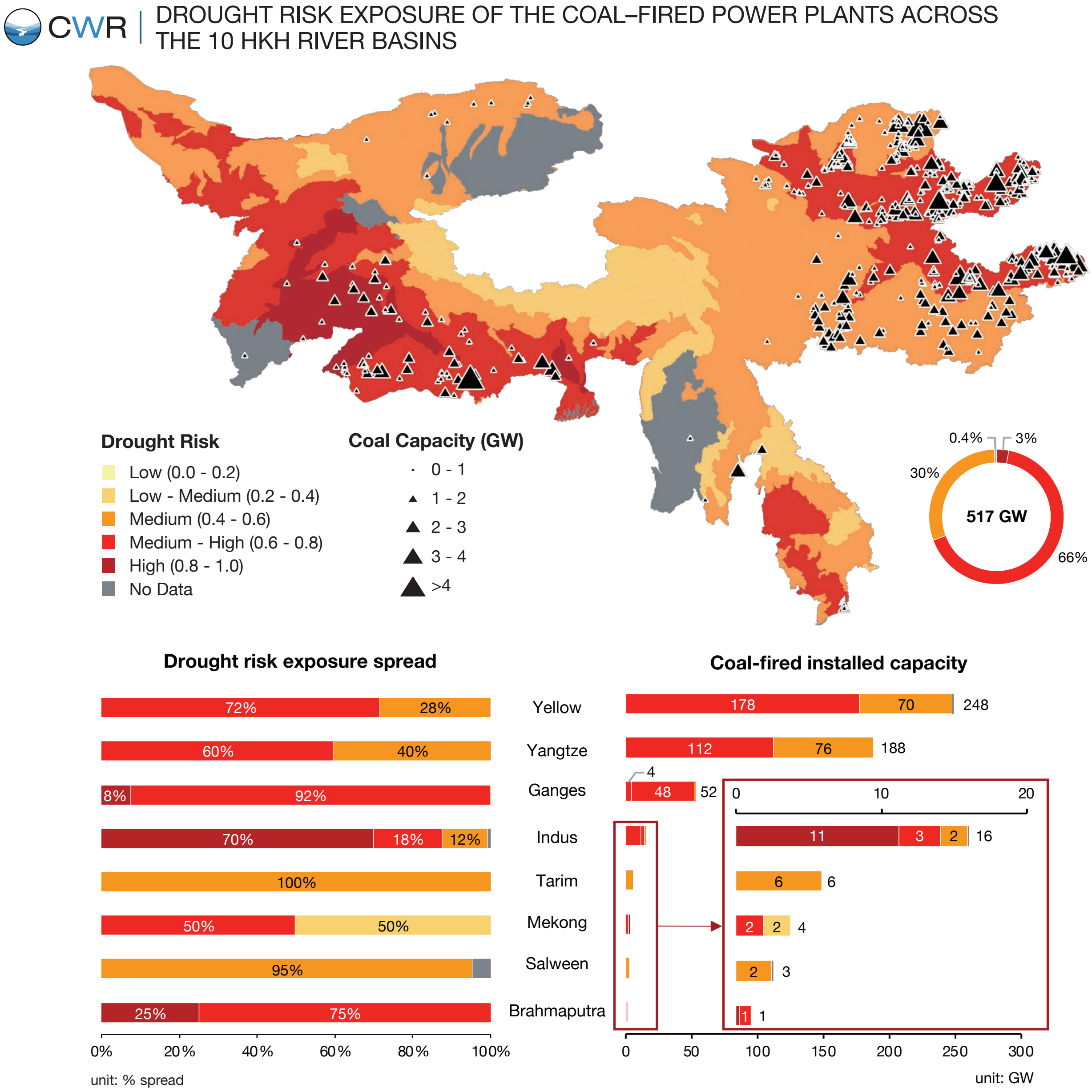
Around the world, extreme weather has wreaked havoc on power generation. Worst still, heatwaves and cold spells drove up electricity demand and hydro and nuclear cuts meant more coal was burned. This vicious cycle may be hard to break as more extreme weather events are forecasted ahead. Extreme weather will only exacerbate underlying risk exposure of coal-fired power to water risks – already, a scenario-based simulation study showed that 32% of the world's coal-fired power plants are currently experiencing water scarcity for at least five months or more in a year.[66]

32% of global coal-fired power already faces water scarcity for at least 5 months per year…

We therefore overlaid the coal fleet on the 10 HKH Rivers over WRI's Riverine Flood Risk and drought risk maps to gain a more complete picture of the risks ahead. It is clear from the analysis in the following pages that some areas are more prone to either droughts or floods, but there are **some regions that will be highly exposed to both droughts and floods**. With widening extremes, it is best to prepare for both too little and too much water. It is important to note that small amounts of GW facing drought/flood risk does not mean no risk. The exposure needs to be evaluated in the context of the national power on coal and rivers.

See maps on coal fleet exposure to floods & droughts exposure in the following pages…

At-a-glance drought risk exposure of the coal fleet located in the 10 HKH River Basins

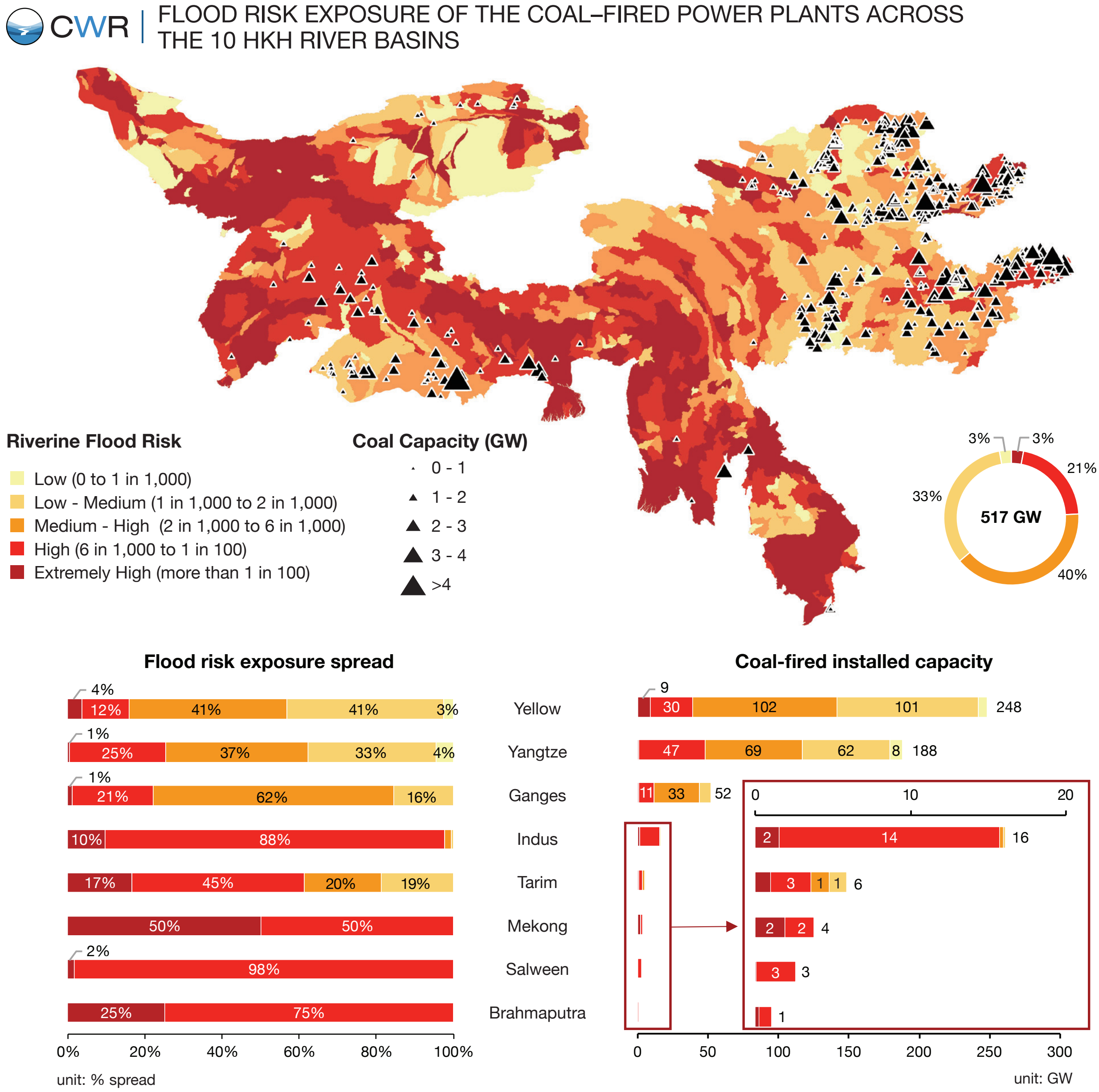


Source: CWR, Global Power Plant Database, FAO AQUAMAPS, Aqueduct Global Maps 3.0

Key points to note are:

- **The coal-fired fleet in the Brahmaputra, Ganges and the Indus face the highest drought risk**. 100% of the coal-fired power capacity in the Ganges and the Brahmaputra face 'Medium-High' to 'High' drought risk. Although the Brahmaputra's risk exposure profile is worse than that of the Ganges, its absolute exposure of 1GW is much less than that on the Ganges's 52GW. However, the Indus has the highest exposure to drought with 70% of its coal-fired power capacity located in 'High' drought risk areas.
- **The Yellow & Yangtze have better drought exposure profiles but have the most GW exposed to 'Medium-High' drought risk**. 72% of the Yellow and 60% of the Yangtze River's coal fleet face 'Medium-High' drought risk. However, due to the sheer size of the coal fleet on the Yellow and Yangtze, this means that a total of 290GW is located in 'Medium-High' drought risk areas; a further 146GW is located in 'Medium' drought risk areas. Including the 6GW on the Tarim, this means that almost 100% of China's coal-fleet capacity across the 10 river basins face at least 'Medium' drought risk.
- **Although the Mekong, Tarim and Salween face lower drought risks, they are still exposed**. These three rivers may be less at risk than the others but the coal fleet here still largely face 'Medium' drought risk. Half of the Mekong's coal fleet faces 'Medium-High' drought risk.

At-a-glance flood risk exposure of the coal fleet located in 10 HKH River Basins



Source: CWR, Global Power Plant Database, FAO AQUAMAPS, Aqueduct Global Maps 3.0

Key points to note are:

- **16% to 100% of the coal fleet in the 8 River Basins are in 'High' to 'Extremely High' flood risk areas**. In terms of flood risk profiles, the Mekong, Brahmaputra followed by the Salween are most at risk with 100% of their respective fleets located in 'High' to 'Extremely High' flood risk areas. On the other hand, the Yellow has the lowest exposure with only 16% exposed to 'High' to 'Extremely High' flood risk but the size of the fleet on the Yellow means that 39GW is exposed – this is over 9x the coal-fired installed capacity on the Mekong.
- **Of the 4 Priority Rivers, coal-fired power capacity in the Indus faces the highest flood risk** albeit with the smallest coal fleet among the four rivers. 98% of the coal fleet in the Indus is located in 'High' to 'Extremely High' flood risk areas. As can be seen from the previous page, 70% of the fleet in the Indus also faces 'High' drought risk.
- **The Yangtze has the most coal-fired power plants in 'High' to 'Extremely High' flood prone areas**. 26% or 48GW of the coal fleet in the Yangtze are located in 'High' to 'Extremely High' flood risk areas and a further 37% or 69GW is exposed to 'Medium-High' flood risk.
- **Droughts and floods co-exist in the same river basin**. Coal fleets in some of these river basins also face frequent drought risks highlighted in the previous page – see the following page on the Indus as well as the **"Water extremes: Managing the Yangtze and Yellow Rivers"** in Appendix 1.

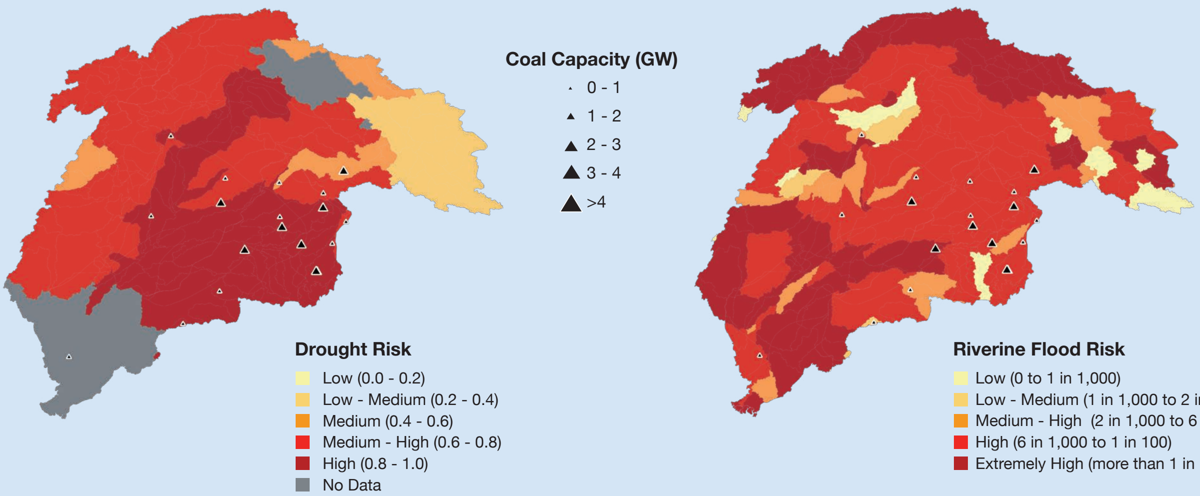
The Indus – a vicious water-energy-climate crisis

The mega floods in the Indus River Basin last summer serve as a warning of future compounding events. Understanding the complex and interlinked nature of water & climate risks and the magnitude of their impacts is a first step in finding solutions …

The Indus River Basin faced devastating floods last year – a victim of compounding events. There were prolonged 40°C heatwaves since April which meant more moisture was held in the air. This would have resulted in “above normal” levels of rain later during the monsoon from July to September. At the same time, intense heat also accelerated glacial melt in the northern mountainous regions which increased water flow into the basin. The melt was rapid leading to muddy flows upstream as well as glacial lake outbursts releasing more water than expected. All these coincided with a system of intense low air pressure in the Arabian Sea, bringing heavy rainfall to Pakistan’s coastal provinces.[67] Pakistan received almost 3x the average rainfall for the monsoon and the rainwater had nowhere to go flooding one third of the country’s districts displacing around 33 million people and costing 10% of its GDP.[61]

Yet, the worst is still to come? Last summer’s floods showed the dire impacts of compounding events, yet Pakistan’s reliance on the Indus shows that impacts could be worst still. Heatwaves will persist as global heating continues unabated. This means that higher upstream flows could be expected from 1) glacial melt which contribute 41% to the Upper Indus runoff mix; a loss of 20-24% of glacial areas is projected by 2050; and 2) snow melt which contributes 22% to the Upper Indus runoff mix; snow will melt faster due to heatwaves providing more runoff in the near term but in the longer term, the region will see snowfall losses. Snowfall losses for the next 50 years will double that of the past 50 years.[68] These trends point to an overall fall in river flow which adds to water stress; however, as the graphics below show, the basin will be subject to both droughts and floods.

CWR | DROUGHT AND RIVERINE FLOOD RISK OF COAL-FIRED POWER PLANTS IN INDUS



Source: CWR, Global Power Plant Database, FAO AQUAMAPS, Aqueduct Global Maps 3.0

High impact due to high clustering in the River Basin. The Indus is crucial to Pakistan – while accounting for only 25% of Pakistan’s surface water resources, a lion’s share of the national population live there (88%) and even more GDP (92%) is generated in the basin.[9] Pakistan cannot let the Indus fail but managing basin risks is easier said than done. We must invest in finding the basin’s baseline risks, a first step will be to plug data gaps, step up monitoring and multi-disciplinary research, so that we can assess socio-economic impacts of such risks on each basin and inform adaptation actions to futureproof the basin.

Tight water-energy-climate nexus but ultimately beyond Pakistan’s control. Even if Pakistan transitioned away from coal, it would not make a difference as the country only accounts for less than 1% of global GHG emissions.[69] Nevertheless, Pakistan should re-examine its coal fleet from an energy security perspective as over half of its coal fleet that lie in the Indus Basin are very vulnerable to extreme weather – of the 16GW of coal fleet that lie in the basin, 98% are located in ‘High’ to ‘Extremely High’ riverine flood zones and 70% are in ‘High’ drought zones. Rising water stress will also be an issue as 86% of this 16W lie in ‘Extremely High’ water stress areas.

Energy Policies for Water

From mountains-to-oceans

Chapter 4

CWR

Highway to climate hell with one foot on the accelerator

Rivers are running dry today, not tomorrow

50% chance of reaching 1.5°C in 2026 = we are already 80% of our way to the targeted 2100 climate future today…

Rapid warming means we are now seeing rivers running dry today, not tomorrow. With a 50% chance of reaching our 2100 target of 1.5°C by 2026,[16] our 2100 target climate future is here. Last year, we saw key river systems like the Rhine, Po, Colorado, Yangtze and Indus suffer from various types of water risks from droughts to floods.[35] UN Chief Antonio Guterres did not mince his words at the opening of COP27: *"we are on a highway to climate hell with one foot on the accelerator"*.[70] At 1.2°C of warming today,[71] we are already 80% of our way to the aspirational Paris target of 1.5°C and 60% of the way to the 2°C threshold by 2100.

Hotter world = rising chronic risks across rivers

Rising temperatures are also threatening river source regions – the Alps, Rockies and Himalayas are all seeing accelerated glacial/snow melt and/or less snowfall impacting river flows. Monsoon patterns are also disrupted as temperatures rise. These intensifying and compounding events point to rising chronic risks across river basins around the world and could trigger breakdowns in socio-economic systems that rely on them if the risks are not well managed.

We are not prepared for new extremes ahead… which will happen sooner than we think…

From Pakistan's devastating floods to the USA's bomb cyclones, it is now painfully clear that we are not prepared for the severity of climate disasters we're up against. Year-on-year, there are now record-breaking heatwaves, hurricanes, droughts or floods – all of which will be exacerbated by rising underlying chronic basin risks.

So act now! We cannot let our rivers fail

We must break out of the mindset that systemic river basin risk will only happen somewhere in the distant future. Rivers have been our cradles of civilisation; the lifelines around which we have built cities, farms, and economies. They have also been a mode of transport for centuries. We have tapped them for water, food and power – we cannot let them fail.

Asia must lead 'source-to-sea' energy policies for water & growth

We are running out of time to cut emissions…

Energy plays a key role in ensuring water security but we are running out of time – the window for decarbonisation is narrowing. The UN acknowledged at COP27 that there is no credible pathway to 1.5°C by 2100, yet we are still emitting more carbon than ever.

…the oil boom & new carbon bomb projects makes it worse

The current oil bonanza with over US$1trn in fossil fuel investments, including new carbon bomb projects mean that it is now ever more urgent to:

1) reverse the rise in emissions with direct carbon cuts and direct carbon removal; and

2) plan adaptation for impacts already locked-in as well as for imminent impacts on our 'policies and actions' pathway of 2.8°C , much of which is felt through water.

Mitigate for 1.5°C ≠ adapt for 1.5°C…

Do not make the mistake of aiming for 1.5°C and planning adaptation for 1.5°C. While we can aim to decarbonise to stay within 1.5-2°C we should plan adaptation for scenarios that we are actually tracking – according to the UN "policies currently in place with no additional action are projected to result in global warming of 2.8°C" by 2100; if we do not implement these policies we are on track for 4°C according the Climate Action Tracker.[2, 71]

The G7 is distracted with war… Asia must step up & lead the charge to net zero…

Asia, especially the HKH 16 will need to fast track its transition to ensure both water and energy security. While developing countries in Asia can blame others for eating up the carbon budget, it is clear that the G7 and the rest of the EU are not leading the climate movement. They are distracted with the war in Ukraine, which despite having brought about a drop in EU emissions, has led to an oil bonanza that will have repercussions for years to come. As there is no sign of peace talks at the time of writing, Asia must step up to take the lead in decarbonisation to rein in emissions and warming, after all it is our energy and water systems that are the most vulnerable to escalating water-related climate risks.

…impact is BIG as Asia accounts for over half of emissions + still power hungry

Asia can make a BIG difference! As Asia accounts for a large chunk of these emissions (53%),[72] so energy policies across developing Asia, which is still power hungry, are more critical than ever in determining climate outcomes. As the previous three chapters show, energy expansion decisions will impact water, economic and food security of multiple countries.

There will be tough trade-offs ahead and the responsibility for ensuring a future with water does not just lie with governments, but also businesses including financial institutions.

The future of Asia's rivers & energy are tied. Uncertainties over water availability could lead to energy insecurity across Asia. Conversely, energy policies in Asia will decide the future of water across the continent. The water-energy-climate nexus is tight – with around 50% of the installed capacity of the HKH 16 sitting in the 10 HKH River Basins – the future of Asia's rivers and energy are tied.

The future of Asia's rivers are tied to its energy policies

No river = no power. There is much at stake – development and energy expansion across the HKH must be considered through a waternomic lens. **Any action/policy must consider the river basin from 'source-to-sea' and they must be coherent, cohesive and urgent for water, energy and socio-economic growth**. To facilitate this path, we have laid out 8 broad recommendations so Asia can ensure that its coal habit will not cause its rivers to run dry faster. Before we dive into that, let's take a quick look at who should take urgent action…

No river = no power… waternomic policies must be coherent, cohesive & urgent

Who should take urgent action?

We recommend the 'Overall High Risk Group' identified in Chapter 2 to urgently re-examine their water and energy exposure on the 10 HKH Rivers and take action accordingly. This is because this group faces greater clustered risks in the 10 HKH River Basins – they are Laos, Afghanistan, Nepal, Bhutan, Myanmar, Cambodia, Pakistan and Tajikistan as per the table below. That said, it is clear from our analysis that China and India can provide the biggest momentum to fast track decarbonisation. While they fall in the 'Overall Medium-High Risk Group', their respective exposures are significant enough to warrant action and we encourage them to lead the region to accelerate transition to protect Asia's mighty rivers.

		National Exposure to HKH River Basins					
	Country	Surface Water Share	Population	National GDP	Total Installed Capacity	Coal-fired Power Capacity	Hydropower Capacity
Overall High Risk	Laos	High	Very High	Very High	Very High	Very High	Very High
	Afghanistan	High	Very High	High	Very High	Low	Very High
	Nepal	High	Very High	Very High	Very High	Low	Very High
	Bhutan	Med-High	Very High	Very High	Very High	Low	Very High
	Myanmar	Med-High	High	Med-High	Very High	Very High	Very High
	Cambodia	Low-Med	Very High	Very High	High	Low	Very High
	Pakistan	Low-Med	Very High	Very High	Very High	High	Very High
	Tajikstan	n.a.	Very High	Very High	Very High	Low	Very High
Overall Med-High Risk	China	High	Med-High	Med-High	High	Med-High	Very High
	India	Med-High	High	Med-High	Med-High	Med-High	High
	Bangladesh	Low	Very High	Very High	Low-Med	Very High	Low
Overall Low-Med Risk	Thailand	Med-High	Med-High	Low-Med	Low-Med	Med-High	High
	Uzbekistan	Low-Med	Med-High	Med-High	Low-Med	Low	Low
Overall Low Risk	Kyrgyzstan	Low-Med	Low	Low	Low	Low	Low
	Turkmenistan	Low	Low	Low-Med	Low	Low	Low
	Vietnam	Low	Low	Low	Low-Med	Low-Med	Low-Med

The 8 countries with 'Overall High Risk' profiles should re-examine their water & energy exposure…

… but it is China & India can lead the fast tracking of net zero

Key

< 10% low	Low
10-29% low-med	Low-Med
30-49% med-high	Med-High
50-69% high	High
>70% very high	Very High

Source: No River, No Power – Can Asia's rivers power growth in a changing climate?

There's an opportunity to leapfrog ahead as all these HKH 16 countries are still developing and still building out their energy systems to support development. They therefore can in "real-time" react to rising climate impacts and re-think their respective grid buildouts and act to futureproof their energy systems – these actions include choosing the right type of power, tech and policies that:

- uses less water so as to alleviate water stress and competition for water going forward;
- fast tracks decarbonisation so as to rein in impacts on the water cycle; and
- protects the power system/grid against future extreme weather shocks.

The opportunity to leapfrog ahead is here…

…the HKH 16 can make real-time adjustments to rising climate risk and rethink development

There is no time to waste …energy policies must ensure that our rivers don't run dry…

All the above will help 1) avoid stranding of power assets and 2) ensure water security as well as energy security for all stakeholders in the river basin.

At 1.2°C today, our 2100 water future is here today. There's no time to waste: we must all re-examine energy policies by basin and put in place those that ensure our rivers will still continue to power electricity generation as well as people and the economy.

Energy policies for a water secure future: 8 broad recommendations

Coal may be required to ensure energy security + balance the grid = trade-offs…

While urging rapid decarbonisation, we recognise countries may still need coal to ensure energy security as well as to balance the grid when other renewable sources of power vulnerable to water extremes like hydropower fail. The 8 broad recommendations provided below therefore recognises the need to make such difficult trade-offs.

Read these 8 broad recommendations with Appendix 1: Lessons from China…

As there's no one-size-fits-all policy for each country – the recommendations are intended to provide a broad framework for action; they are not detailed roadmaps for each country. To provide more context, we have also provided case studies through a single country lens of China – these are set out in **Appendix 1: Lessons from China** and should be read in conjunction with the recommendations below. Note that this does not mean that other countries are also not enacting similar policies in the water-energy-climate nexus.

CWR | 8 BROAD POWER STRATEGIES FOR WATER…

Water-Energy Climate
Understand this nexus to protect water supply for 1 in 2 Asians

Rethink Coal for Water
Choose the right type of power for river/water & energy security

H2O & CO2 Trade-offs
CO2 solutions are water-intensive & H2O solutions are carbon-intensive

Retrofit Coal Plants
Use water-friendly cooling tech to de-risk in high water stress areas

Build Resilience at Extremes
for both energy & water against escalating extreme weather

Basin Waternomics
Adopt source-to-sea basin approach to water, energy & economic planning

Dovetail National Plans
for water & energy security to make holistic policies & actions

Asia to Lead Transition
Asia's rivers are at stake, Asia must drive global decarbonisation

Source: CWR analyses based on "No River, No Power – Can Asia's rivers power growth in a changing climate?"

The above recommendations are expanded in the following pages…

1. **Understand the tight water-energy-climate nexus with higher granularity.** If we understood the complex interlinkages between water, power generation and climate change, we could start to devise smart policies that have multiple benefits. As the IPCC notes: *"Water is a crucial input for hydroelectric and thermoelectric energy production, which together account for 94.7% of the world's current electricity generation".*[57]

Understand that power needs water to generate…

…but water is a cross cutting issue and there is incomplete data at the nexus…

We hope that this report has helped unpack some of these risks. However, the lack of complete data of power units located in the 10 HKH River Basins means that there are limitations to the research including and not limited to:

- Reliance on the accuracy of the Global Power Plant database; many renewable power plants, such as wind and solar, that are relatively new are not reported and excluded from this database;
- Satellite imagery was used to determine cooling type; actual cooling type may not be what it shows;
- GDP based on night lights, for China heavy reliance on the industrial sector vs the service sector, may skew outcomes; and
- Lack of funding for this type of research means we have used 2015 data from our NWNG Report for GDP exposure which may have increased dramatically given overall GDP growth across Asia.

It should also be noted here that this report has also not included analysis of power generation impacts on groundwater over-extraction and water pollution. Such issues should be factored in a further studies – as it is, groundwater already faces major over-extraction challenges in India as well as in the North China Plain. Warmer water discharge into rivers and seas on biodiversity as well as the impact of hydropower dams are also not covered in this report. However, these are all important factors to consider when planning to retrofit power plants or expand power generation capacities.

Groundwater over-extraction, water pollution and impact of hydropower dams on rivers must also be considered…

In addition, there are research gaps regarding every component of river flow across the river basins which should also be addressed through more collaboration and funding of multi-disciplinary data & research gaps – please see box below.

…multi-disciplinary data gaps must also be plugged

There are clear gaps, but we have to start somewhere. We hope that stakeholders including the HKH 16 countries will build on this report to improve our understanding of a shared future – this will help the HKH 16 make better energy decisions for all our water futures tomorrow.

…but we have to start somewhere and we hope this report will inspire action!

! **More collaboration and funding of multi-disciplinary data & research gaps.** Clearly, it is important to understand the current and future exposure to water risks and the impact of climate change on the hydrological cycle across the 10 HKH River Basins. A key stumbling block is the multi-disciplinary nature of the action required from scientists, policy makers, businesses and engineers to financiers.

These various specialised disciplines tend to only operate 'in their own box'. A banker or a business owner is unlikely to crawl over research papers to search for natural risks that may impact their assets; but neither are scientists or engineers expected to know what would be considered a business risk and how water and climate risks could be factored into in to government/ corporate strategy or credit policy.

Another challenge is data availability; there is limited comparable data across countries and rivers. Moreover, river basin boundaries and regional borders are also not well defined or standardised, making comparative analysis difficult. We must strive to identify gaps in data/analysis so as to plug them with multi-disciplinary research and financial support.

Source: The above is extracted from CWR's report "No Water, No Growth – Does Asia have enough water to develop?", 2018

CWR

> 94% of installed capacity in the 10 HKH Rivers needs water to generate power…

…continued coal reliance & expansion can jeopardise this

Shifting power mix to PV solar & wind can help alleviate water stress

China & India can do the most to de-coal and they must…

The 10 rivers provide China with over half its national surface water, it cannot afford these rivers to fail…

It's aggressively changing power mix: 2030 target of +1.2TW of wind & solar PV will be achieved 5 years earlier…

… but China added coal to handle water extremes = tough trade-offs (see Appendix 1)

India also has aggressive renewables expansion plans but coal transition lags… (see later)

2. Rethink coal expansion & accelerate decarbonisation for water/river security. Almost all types of power generation require water to generate electricity. Indeed, over 94% of installed capacity located in the 10 HKH River Basins requires water to generate. The IPCC recommends: *"Shifting to a higher share of renewable sources less dependent on water resources for energy production could substantially reduce the vulnerability of this sector. Diversifying energy portfolios to reduce water-related impacts on the energy sector is another effective adaptation strategy with high mitigation co-benefits."* [57]

Given Asia's water challenges, it is important to rethink coal-fleet expansion and accelerate decarbonisation. While, coal is an important driver of energy security for the HKH 16 accounting for 63% of the 1,872GW of its total installed capacity, it is important to recognise the vulnerability of their coal fleets to growing water risks.

Around half of the HKH 16's total installed capacity or 865GW is clustered in the 10 HKH River Basins. Continuance/expansion of the coal fleet could lead the HKH 16 to shoot itself in the foot as burning coal will accelerate climate change, exacerbate water scarcity and increase water risks across the 10 HKH River Basins – these provide water to one in two Asians and support over US$4trn of GDP annually.

Coal is also the dominant power source in the 10 HKH River Basins, accounting for 60% of the total installed capacity located there. Countries that can effect the biggest change on this front are China and India – they should be incentivised to act as they both fall in the 'Overall Med-High Risk' Group as per our analysis in the previous chapter and have material exposures:

- **China has the largest coal fleet** – 47% of this is located in the 10 HKH River Basins; primarily, the Yellow (248GW), Yangtze (188GW) and the Tarim (6GW). China has already started to de-coal but it can and must do more as it has the most to lose – beyond coal, half of China's total installed capacity is located in the 10 HKH River Basins which are also home to 44% of its population. Given that the 10 HKH River Basins account for 51% of its national surface water resources, it cannot afford to have these rivers fail.

  China's plans to de-coal therefore includes water caps for coal as well as source-to-sea policies termed as "mountains-to-oceans" management.[73] National policy is also now shaped by river/watershed as opposed to by province. China also aggressively upped its renewables ambitions last year and is now expected to reach its 2030 target of 1.2TW of total wind and solar PV capacity five years earlier.[18] For more on China's efforts on this front, please see **Appendix 1: Lessons from China – "Overview on actions to de-coal 2011-2019" and "Dual carbon targets & fast tracking decarbonisation since 2020"**.

  However, it is important to note that despite efforts to optimise its energy mix, China expanded its coal fleet in late 2022 to add supporting capacity to handle hydropower failure caused by water extremes – see **Appendix 1: Lessons from China – "Water extremes: Grid flexibility & adding "just in case power""**. More on building resilience for water extremes in point 5 below.

- **India has the second largest coal fleet** – 33% of this is located in the 10 HKH River Basins, primarily the Ganges (52GW), Indus (14GW) and the Brahmaputra (1GW). Similar to China, coal-fired power capacity accounts for around two-thirds of national installed capacity. India has committed to reach net zero by 2070: although it has aggressive progress on renewables expansion, coal transition lags – more on this in **"India's Long-Term Low-Carbon Development Strategy"**.

3. Watch out! Carbon capture is water intensive & some carbon offsets won't help water.

It is important to note that direct cuts in coal-fired power are better for water security as carbon capture is water intensive; so first aim for direct emission cuts via transition. However, we recognise that it may be difficult to completely de-coal from an energy security standpoint, so for coal-fired plants that are key to support base load and energy security, do maximise energy efficiencies as well as consider CCS.

For coal plants that are key for energy security…

aim for max efficiency & consider CCS

But beware, as discussed in Chapter 3, the water use for power plants with CCS is significantly higher than those without CCS so do make sure that water use and availability is taken into account when investing in carbon capture tech. Indeed, the IPCC AR6 WG2 notes: *"Many mitigation measures, such as carbon capture and storage, bioenergy and afforestation and reforestation, can have a high-water footprint."* [57]

…but CCS is water intensive

However, if water issues in direct emissions capture are resolved, then direct carbon capture is better than buying carbon offsets to achieve carbon neutrality. Here, it is important to understand the varying quality of carbon offsets. Recent research into Verra, the world's largest carbon standard for voluntary carbon markets has found that more than 90% of their rainforest credits from a significant share of projects were likely "phantom credits".[74] This means that they are not genuine carbon reductions and will not help tame escalating water risks.

If water is not a constraint, CCS is better than buying carbon offsets…

Watch out for timing issues with carbon offsets…

There are also timing issues – some carbon offsets are calculated over the lifetime of the project whereas we need rapid cuts today (not tomorrow) to put the brakes on escalating water risks. So while carbon offsets/trading may help achieve neutrality and set a price on carbon to create an economic incentive to reduce emissions, they will not put the brakes on irreversible water trends – such as glacial melt.

…some don't deliver CO2 cuts today = won't put the brakes on glacial melt

Sadly, overshooting 1.5°C, a key tipping point will lock-in more glacial melt and other feedback loops like the ice-albedo effect and permafrost thaw – all these will result in more carbon emissions. When it comes to reining in water risks, it is important not to overshoot key temperature tipping points which trigger irreversible trends – see box below.

Overshooting 1.5°C will trigger irreversible impacts…

!

Tipping points & locking in irreversible impacts. Once runaway glacial melt has started, it will take a Little Ice Age to reverse it – so it is best not to trigger them at all. Therefore, we must do our best to stay within 1.5-2°C. Companies which opt for forest offsets as they protect forests plus cutting carbon emissions should take these considerations into account. According to the ICCI's State of the Cryosphere Report 2022, our current CO2 emissions growth pathway of around 2-3ppm per year or 4-5°C by 2100 and rising will lock-in the following irreversible impacts which will be existential for humankind:

- **Mountain glaciers:** with mid-latitude glaciers, 90% will be gone by 2100 and snowfall will be extremely limited outside polar regions and high altitudes. As it is, Switzerland lost a shocking 6% of its glacier melt over the summer of 2022 – if this rate persists, the Swiss Alps will lose half of its glacier mass in a decade. Glacier loss will impact river flows across the world and their loss means there will be less buffer against droughts and increase in GLOFs.
- **Permafrost:** at >4°C annual permafrost emissions will be on par with the annual emissions of China today. As it is, permafrost emissions at 1.1°C is on par with annual emissions of Japan today. Such emissions will accelerate warming.
- **Arctic sea ice:** ecosystem collapse will be apparent by 2030. The Arctic is already warming 3-4x faster than the global average – the loss of sea ice means the loss of the ability to reflect most of the sun's rays back into space to cool the planet, accelerating warming.
- **Sea level rise:** West Antarctic Ice Sheet collapse would be inevitable & potentially rapid – 2m of sea level rise by 2100 and 5m by 2150 is possible.
- **Polar oceans:** The shutdown of the Atlantic Meridional Overturning Circulation (AMOC) cannot be ruled out, mass extinction of marine species – cod, herring and salmon are extremely unlikely to survive in the wild; weather would likely be extreme and unpredictable.

Source: "ICCI's Report State of the Cryosphere 2022 – Growing Losses, Global Impacts"

For at-risk coal-fired power plants located in severe water stress areas, we recommend upgrading cooling tech…

…this helps alleviate power sector water risk exposure and ease competition for water

4. Retrofit at-risk plants with cooling tech to alleviate water stress; but beware of carbon trade-offs.

For at-risk coal-fired power plants located in 'High' and 'Extremely High' water stress areas, we recommend upgrading cooling tech. This will help alleviate water stress and depending on cooling tech, low/no water conditions will not strand the power assets and they can continue generating electricity in the event of low water availability/droughts.

Also, such moves can help ease rising competition in water in the river basin. According to the IPCC, *"Global freshwater demand for the energy sector is projected to increase under all 2°C scenarios due to the rapid increase in electricity demand in developing countries. Despite the water shortage and climate change impacts, industry and energy sectors' share in global water demand has been projected to rise to 24% by 2050, which will increase the competition among various water-use sectors."*[57]

By choosing the right cooling tech or retrofitting power plants to be more water efficient the energy sector is taking prudent steps to ensure water not just for the sector but also for other stakeholders. Our analysis shows that there is room for improvement to save water by shifting to less water-intensive cooling technologies for coal-fired power on the Ganges and the Indus:

Most room for improvement in the Ganges & Indus…

- **Ganges**: 83% of the coal-fired power capacity in this basin is located in 'High' to 'Extremely High' water stressed regions: 13% of this is once-through freshwater cooling (highest water risk); 86% is closed-loop cooling; only 1% is air cooled.
- **Indus**: 86% of coal-fired power capacity in this basin is located in 'High' to 'Extremely High' water stressed regions: 6% of this capacity is once-through freshwater cooling while 94% is closed-loop cooling. There are no air-cooled plants in 'High' to 'Extremely High' water stressed zones in this basin.

India & Pakistan can drive the retrofitting of plants from once-through to air-cooling in severe water stress areas…

While Pakistan only has a total of 16GW of coal-fired power located on the Indus, India has 67GW – of which 52GW is in the Ganges, 14GW is in the Indus and 1GW is in the Brahmaputra.

Together, India and Pakistan can drive the push towards less water-intensive cooling tech for the 83% and 86% of these power plants that are at-risk to high water stress. This should help 1) futureproof such power plants against future droughts/water scarcity; plus 2) alleviate future water stress especially as 1.5-2°C of warming points to an overall fall in river flow for both the Indus and Ganges.[9]

They can learn from China's policies… once-through is banned in water stressed areas + mandatory retrofit/closure of such plants

They can take a leaf out of China's policies – China banned once-through cooling in water stressed areas driving mandatory retrofitting/closure of such plants. Also, since May 2004, the country required new power plants in the water-scarce Northern regions to adopt air-cooling; indeed our analysis showed 19% of the coal-fleet located in 'High' and 'Extremely High' water stress areas in the Yellow River Basin to be air-cooled. This number is higher in the Tarim River Basin: 32% of the coal fleet located in 'High' water stress areas are air-cooled. For an idea of China's policies on water related to coal mining and thermal power generation please see **Appendix 1: Lessons from China – "Water use & pollution caps for coal extraction & coal-fired power"**.

But Beware! Air-cooling = lower generation efficiency + more CO_2

However, while air-cooling is not water intensive, it does result in lower generation efficiency and more carbon emissions as well as higher costs. Trade-offs between saving water today at the expense of more carbon emissions and water tomorrow must be carefully considered when crafting policies. That said, water savings can be deployed for use in CCS to cut emissions.

5. Build resilience for water & energy against extreme weather.

We have seen the ability of numerous floods/droughts/storms/hurricanes over the recent years to disrupt power generation bringing brown/blackouts to affected areas, sometimes for days. As these become more extreme, resilience to such escalating and compounding risks must be stepped up.

Extreme weather disrupts powergen…

On the energy front, improvements in coordinated power dispatch must be made and more flexibility should be built into grid balancing. Ultimately, an efficient grid delivering "just enough" power may not work; with extreme weather events, causing disruptions in hydropower, there may be a rising case for adding "just in case" power. Perversely, this means that coal-fired capacity may be added to ensure that power generation is not disrupted – see **Appendix 1: Lessons from China – "Water extremes: Grid flexibility & adding "just in case power""**.

…power systems must be adapted

There may case for adding "just in case" to cope with extreme weather events

Nevertheless, both types of power require water to generate so understanding current and future water flows is important as this can inform better management of water to prevent prolonged brown/blackouts when hit with extreme weather. Monitoring of river flows, rainfall, snowfall/melt and glacial melt are a good start. However, there will be no one-size-fits all solution here as run-off components differ and different basins will have different risks; even different areas of the same basin will be subject to different risks.

No one-size-fits all solution – different basins will have different risks…

In addition to event-driven acute risks, chronic risks such as rising water scarcity and sea level rise must be also considered in adaptation planning as these chronic risks have the ability to amplify acute risks. Power assets should also be stress tested for such risks as well as the risk of compounding events like in the case of Pakistan.

= must understand river flows & underlying chronic risk

We must prepare for widening extremes in floods and droughts that could happen in a short space of time. Take China for example: in 2021, parts of the Yangtze saw record-high rains and floods only to face record droughts the year after. Not surprisingly, China has started to take action – see what it is doing to prepare for more extreme weather ahead in **Appendix 1: Lessons from China – "Water extremes: Managing the Yangtze and Yellow Rivers"**.

= must prepare for both ends of water extremes…

Adaptation financing which could limit adaptation options must also be addressed with longer timeframes in mind to deal with accelerating risks, otherwise efforts to build resilience could end up with maladaptation. Please see box below. Finally, adaptation as well as disaster management plans for urban and rural areas along the river are not separate but part of a holistic approach to river management from source-to-sea – this brings us to the next point...

Adaptation planning goes hand-in-hand with disaster management

Avoid maladaptation…

! **Beware of maladaptation! With accelerating climate threats, aim for transformative adaptation.** According to the IPCC AR6, our current decision-making on adaptation is *"driven by short-term thinking or vested interests, funding limitations, and inadequate financial policies and insurance".* As a result *"actions that focus on sectors and risks in isolation and on short-term gains often lead to maladaptation if long-term impacts of the adaptation option and long-term adaptation commitment are not taken into account."*

Other points worth noting from the IPCC on adaptation are:

"Financial constraints are important determinants of soft limits to adaptation across sectors and all regions (high confidence). Although global tracked climate finance has shown an upward trend since AR5, current global financial flows for adaptation, including from public and private finance sources, are insufficient for and constrain implementation of adaptation options especially in developing countries (high confidence)."

"Most observed adaptation is fragmented, small in scale, incremental, sector-specific, designed to respond to current impacts or near-term risks, and focused more on planning rather than implementation."

"Many initiatives prioritize immediate and near-term climate risk reduction which reduces the opportunity for transformational adaptation."

"To minimize maladaptation, multi-sectoral, multi-actor and inclusive planning with flexible pathways encourages low-regret and timely actions that keep options open, ensure benefits in multiple sectors and systems and indicate the available solution space for adapting to long-term climate change."

Source: The above are extracted from "IPCC Sixth Assessment Report Working Group 2 – Climate Change 2022: Impacts, Adaptation and Vulnerability"

There's a powerful case for the HKH 16 to curate a waternomic roadmap…

6. 'Source-to-Sea' approach to water, energy & economic planning for national & transboundary rivers.

Water is clearly essential for growth across agriculture, industry and power generation and therefore many cities, agricultural regions and industrial zones are clustered along rivers. Asia's major rivers are its lifelines – they cannot fail.

As noted in an anthology of work in ***"Water Security Under Climate Change"*** published by Springer Nature: *"Policy decisions should thus wed economic planning to water resources and pollution management; this concept is called 'waternomics'. In developing Asia, there is a powerful case for countries to curate a waternomic roadmap, especially since the locational nature of water and climate risks points to a significant clustering of economic risk exposure in vulnerable regions – specifically, major river basins and coastal economic hubs."*[75]

'source-to-sea' waternomic management is vital

A way to ensure river basin security is 'source-to-sea' waternomic management of the river. The first step toward this is to re-organise national/state/provincial economic planning to focus on basin-level development planning and innovations. This means that in addition to the above 5 steps to ensure energy security, agricultural water use and pollution to ensure food security should also be considered by river basin. This is key as agriculture is the largest user as well as the largest polluter of water.

Similar to power mix, also rethink crop mix & industry mix along the river

India has Ganga policies…

Beyond efficiencies, similar to power mix, crop mix as well as industry mix along the river should also be considered and these should be managed holistically to ensure that upstream industries/cities/agri/power use do not have negative impacts on downstream users. In India, there are multiple policies and efforts focused on cleaning up and managing water along the Ganges. These are explained in more detail later in **"India's National Water Policies"**.

…China already has holistic development pilots for the Yangtze and Yellow River Basins

In China, multiple river basins/watersheds are already focused on regional holistic development pilots – these include the Yangtze River Economic Belt (YREB) (along the Yangtze River), the Capital Two Zones Plan (the Zhangjiakou watershed) and the Greater Bay Area (GBA) (around the Pearl River). Such reorganisations may prove useful for future resilience and ministerial reforms were even put in place to effect these. As there may be valuable structural lessons here for other HKH 16 countries, we have provided an overview on these for the Yangtze and Yellow in **Appendix 1: Lessons from China – "Mountains-to-oceans waternomic management for the Yangtze & Yellow Rivers"**.

Waternomics should also be applied to the Mekong…

Such delineation of waternomic planning at the river basin level **should also apply to transboundary rivers** – see box below.

Waternomic planning should also apply to transboundary rivers. Countries along the transboundary rivers should look beyond hydrological management and cooperate on economic development, power expansion as well as agricultural policies as they are all inextricably tied. The Lancang-Mekong Cooperation (LMC) is an attempt at this.

Established in 2016, it brings together the six countries along the river and expands beyond traditional transboundary water management to include five priority areas: connectivity, production capacity, economic cooperation, water resources, and agriculture & poverty alleviation. Note that the LMC does not compete with but complements the Mekong River Commission (MRC) whose core functions include: *"data acquisition, exchange and monitoring; analysis, modelling and assessment; basin planning support; forecasting, warning and emergency response; implementation of the five MRC procedures for basin management; and dialogue and facilitation."*[76]

Indeed, such cooperation is in line with views expressed by the MRC as one of the key challenges for the next decade – see quote below. The MRC iterates as part of its strategy, the importance of the LMC for a deeper and more comprehensive collaboration across all the 6 countries along the river – Cambodia, China, Laos, Myanmar, Thailand and Vietnam.[76]

*"**A sense of urgency is growing** among stakeholders on the need to move basin development towards more "optimal" and sustainable opportunities that address long-term needs, including water, food, and energy security. Experience from other regions suggests that joint management and development, with cost and benefit sharing agreements will be necessary if the people of the Mekong region are to transition to middle/high income status in a manner that is in long-term balance with the basin's ecosystems."*

Basin Development Strategy for the Mekong River Basin 2021-2030

7. Dovetail national water & energy security plans for holistic policies & actions.

According to the IPCC AR6 WG2: *"If we don't rein in carbon emission, 3bn and 4bn people could face chronic water scarcity at 2°C and 4°C of warming.*[57] Our climate is changing: every component of river flow from glacial ice melt, snowfall to rainfall are affected by climate change; and such impacts are accelerated by the use of coal-fired power. In turn, too much or too little or even too warm river flows could strand power assets. These interdependencies demand the dovetailing of national water and energy security policies, especially since escalating and compounding water risks plus increasing demand for water point to more difficulties in managing water resources.

3-4bn people could face chronic water scarcity if warming continues…

…as energy plans could accelerate such impacts, national water & energy security plans should dovetail

No doubt, climate change clearly poses a major challenge to national and global water security. Yet many countries do not have a water security plan that takes into account the latest climate science, let alone one that dovetails with energy security. This is not just a developing country issue – developed countries are also not prepared. Take New Zealand for example: compounding events at the start of 2023 caused an estimated NZ$10bn in losses.[77] Developed and developing countries are all not ready for the climate we have today let alone the climate we will face as global heating continues.

Many countries (including developed countries) are not prepared…

Sadly, as warming is continuing, it is prudent to draw up a national water security plan for a changing climate. This should at minimum cover water source protection, basin monitoring water use, water pollution as well as building resilience against new water extremes plus stepping up disaster management. As water cross-cuts, waternomic development and water use for power and agriculture should be considered holistically. Adaptation to extreme weather impacts should also be considered. All this will be a tough balancing act as both water scarcity and competition for water rises in the future. [75] On these fronts, China has made a start – see box below.

…it's prudent to draw up a national water security plan…

…with basin focus as no river = no power

Moreover, as power choices impact water and the lack of water could strand power assets, energy security plans should dovetail into the national water security plan but this is generally not the case at the moment – energy plans are typically prioritised over water security plans. We recommend the opposite – water security should decide energy security, not the other way around. There's simply too much at stake if the rivers run dry.

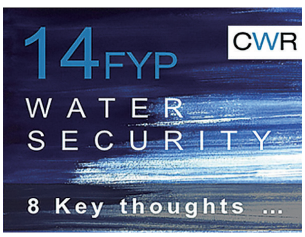
Water security should decide energy security, not the other way around…

Elevation of water to national security levels will make it easier to prioritise financing to ensuring water availability & resilience against rising & compounding extreme weather. The more water is seen as "the backbone to development", more money will be allocated towards its protection. Governments in collaboration with the private sector should also put in place incentive structures to shore up resilience to rising water risks.

…this will help raise adaptation finance to weather extremes ahead

Finally, it is important to consider the impact of coastal threats at the river deltas to coastal power assets. Moreover, there is saltwater intrusion into freshwater systems as well as mass migration due to rising seas.

Don't forget rising seas!



China's first-ever national 14th Five Year Plan for Water Security (Water 14FYP) also factored in climate change.

Released in 2022, the Water 14FYP recognised many significant challenges with water from spatial distribution to its continued ability to drive economic growth and made it clear that water is a top priority for China's next 100 years of development. There is momentum from the top to drive mindset shift to view water & nature as the backbone of national prosperity.

There was also strong recognition of managing water from mountains-to-oceans plus a push to fortify flood measures to cope with 1 in 100-200 year events. Also covered are deep reforms across energy & industrial mix, transportation, new digital watersheds and more – we have provided an overview in **Appendix 1: Lessons from China – "14FYP for Water Security – 8 key thoughts".**

Here, it is important to note that it is the view of many experts that water resources will be impacted no matter how much resilience we build,[75] the key is to minimise impacts – it's about how fast can we get up after we've been hit. Because of clustering of assets in river basins, tough choices will have to be made regarding resilience against extreme weather. Efficiencies may have to be traded in as nations adopt a *"just in case"* rather than a *"just enough"* approach to both water resource as well as power supply management to cope with rising uncertainties in a changing climate. See how China tackled trade-offs in **Appendix 1: Lessons from China – "Water extremes: Grid flexibility & adding "just in case power"" .**

8. Beyond the HKH 16 countries, Asia must step up to lead global decarbonisation.

Water is how we feel climate change…

Water is the resource most vulnerable to climate change and it is how we feel climate change – 26 out of 35 Climatic Impact Drivers identified in IPCC AR6 WG1 are water-related and no region will be unaffected. Adapting to changes in the water cycle is therefore essential for survival; and a national water security plan is a first step towards ensuring that communities and cities continue to thrive in a changing climate.

Asia is the most vulnerable region = we must act…
- **to adapt**
- **to cut emissions today not tomorrow**

However, for a water secure future, we must also take aggressive action to rein in emissions to put the brakes on climate impacts and rising water risks. Sadly, the momentum to reduce emissions has stalled: nearly 200 countries promised to update their NDCs at COP26, but only 24 countries actually did by COP27.[78]

Yet, the oil sector is booming…

While the Russia-Ukraine war has led to an unprecedented expansion of renewables by the EU, it has also led to an oil bonanza with over US$1trn invested in fossil fuel infrastructure and extraction last year including numerous new "carbon bomb" projects.[8] Five oil majors (Exxon, Chevron, Shell, BP and TotalEnergies) raked in US$200bn of combined profits in 2022 and now, even oil majors like BP have just announced it will scale back on its climate ambitions.[8,79]

…but the IPCC says we can't slowdown warming without the oil sector

Yet, it is clear from the IPCC AR6 WG3 that we cannot deliver mitigation without the oil sectors. Unfortunately, at the time of writing this report, it does not look like the oil boom will end because despite various parties trying to table peace talks, the end of the Russia-Ukraine war remains in the horizon. Indeed, the USA is on track to set new record levels in oil production for the next two years – its set to pump an average of 12.4mn and 12.8mn barrels per day for 2023 and 2024 respectively.[5]

Asia must also act to defuse geopolitics as it can fast track a 4°C world…

Asia must therefore step up to fill the leadership vacuum in the global climate fight. The HKH 16, with heavyweights China and India, can pave the way in balancing the ever-rockier geopolitical landscape and steer it away from SSP3 scenario towards peace and a greener safer future – see box below. The only war we should all be fighting is a war on climate change.

HKH 16 must deliver water & energy in the 10 HKH Rivers…

+ talk permafrost…

The HKH 16 must not only balance water and energy security in the 10 HKH River Basins, they must actively participate in all conversations as well as start a conservation about permafrost. The future of Asia's water is at stake, Asia can no longer afford to sit on the side-lines, Asia must step up to lead climate action.

! **Asia must act to avoid IPCC scenario SSP3 "Regional Rivalry" & runaway permafrost emissions + deliver deep rapid emissions cuts.** We need emissions cuts today, not tomorrow. Any additional emissions today will not only further narrow the window for action, but will have a negative impact on Asia's water future. So Asia cannot sit on the side-lines – we must act and there's no time to waste as we now have even less time to rein in emissions to avoid triggering tipping points.

Given the ever-increasingly tense geopolitical landscape around the world, we could well be heading down IPCC scenario SSP3 – "Regional Rivalry" – defined by trade wars and a resurgence of nationalism points to >4°C of warming by 2100.[80] At this level, the implications for water are dire and we will set off feedback loops that will be unstoppable – at 4°C we will likely lock-in emissions from permafrost thaw of around 10Gt/year – this is equivalent to China's annual emissions today![81]

Permafrost thaw is indeed an outlier. As we didn't expect it to happen so soon, it was not included in the carbon budget. However, at 1.1-1.2°C of warming today, cryosphere scientists warned that emissions release from the current thaw is already equivalent to Japan's GHG emissions annually.[81] At 1.5°C we will be committing to permafrost thaw releasing yearly emissions as large as the GHG emissions of India today; at 2°C annual emissions will be equivalent to the EU's. [81] Given there's no credible pathway to 1.5°C,[2] plus there's a 50% of reaching this in 2026,[16] global decarbonisation efforts must be stepped up tremendously.

As the IPCC AR6 WG3 noted, deep cuts are not enough – they also need to be rapid,[82] yet irreversible permafrost thaw and the oil bonanza are doing the opposite, bringing us closer to "climate hell". Moreover, continued and persistent rhetoric from the USA branding Russia and China as the enemy is not helpful. The plain truth is that we simply cannot resolve climate change without China, the largest emitter or without Russia, the country with the largest swathe of Arctic permafrost which if thawed could derail all our global decarbonisation efforts so far.

Urgent call for the HKH 16 to lead collaborative action

It's urgent: we should all be terrified as the path we are heading toward right now could well be >4°C. In addition to the above 8 recommendations, we must strive for peace not war. Time is not on our side – we have to set our differences aside and collaborate with each other toward a water and energy secure Asia. Failing to prepare and apply brakes on emissions would lead to unthinkable consequences.

Time is not on our side… we need deep + rapid emission cuts…

As the region most vulnerable to climate impacts, Asia must be clear-eyed about the dangers ahead. We should heed UN Secretary General Antonio Guterres' words: *"We are in the fight of our lives, and we are losing"*; right now *"we are on the highway to climate hell with our foot still on the accelerator"*. In the future *"we would see ever fiercer competition for fresh water, land and other resources"* and if we fail to put on the brakes, *"We would witness a mass exodus of entire populations on a biblical scale"*.

Asia must be clear-eyed on dangers ahead…

Guterres also described the IPCC AR6 WG2 report on impacts, vulnerability and adaptation as *"an atlas of human suffering and a damning indictment of failed climate leadership"*. The G7/EU have failed us; it is high time Asia steps up to take the lead in the climate space as well as the lead in defusing rising geopolitical tensions.

…and step up to fill the climate leadership vacuum

In developing Asia, we have the luxury of real time adjustments in our development models to rein in emissions as well as tackle climate impacts that we already face and will face. We must grasp the opportunity to fast track transition as well as prepare and adapt to escalating water risks. This requires daunting and mammoth undertakings from multiple stakeholders but embark on this journey we must.

For a water & energy secure future… …Asia must grab the chance to adjust development in real-time

Climate change poses a major challenge to national and global water security. Now is the time for the HKH 16 to put in place sensible energy policies that will protect and not destroy our rivers.

We must not fail if we are to thrive

If we do not fail our rivers,
our rivers will not fail us.

They will continue to be Asia's cradles of civilisation

India's Long-Term Low-Carbon Development Strategy

India published its Long-Term Low-Carbon Development Strategy (LTLCDS) in 2022 building on its commitment to reach net zero emissions by 2070; its NDCs were updated as follows:[83]

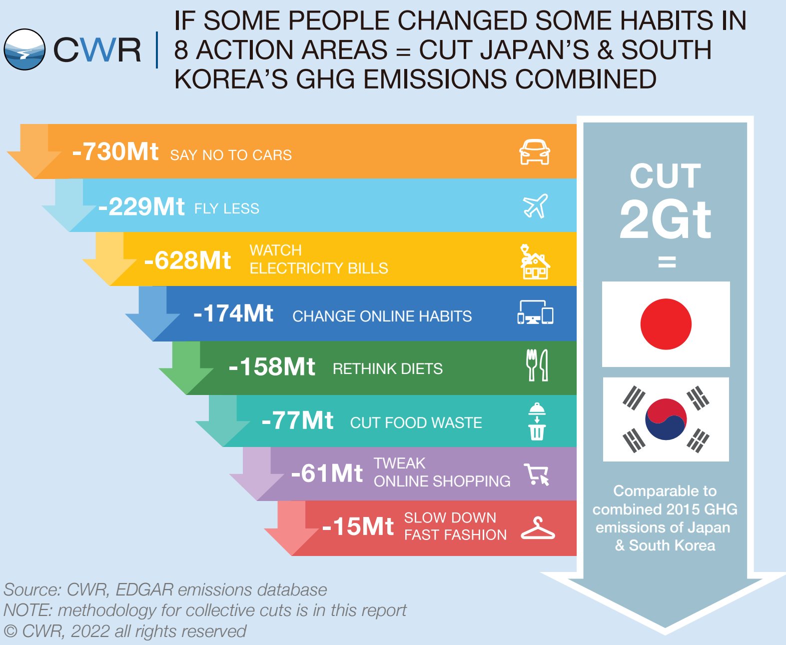
- Meet 50% of India's cumulative electric power installed capacity from non-fossil sources by 2030;
- Reduce the emission intensity of GDP by 45% below 2005 levels by 2030; and
- Propagate a sustainable way of living based on the traditions and values of conservation and moderation, through a mass movement for LiFE – Lifestyle for Environment.

It is evident that India has been aggressive with its renewables build out including tapping the nation's hydropower potential. In 2021, renewables grew from 134GW to 147GW and there are plans to double this in the next 5 years.[18,20] A three-fold rise in nuclear installed capacity by 2032 is also planned.[83]

In the LTLCDS, India has simultaneously recognised that it has contributed little to global warming and it still has significant energy needs for its development. As such the plan also has a "LiFE movement"; India is also calling nations across the world to join in making LiFE a global movement for planet and the people. Indeed individual habit change can make a difference – according to the Co-Chair of the IPCC AR6 WG3 report, Priyadarshi Shukla, it can cut 40-70% of GHG emissions.[84] CWR's work showed that if enough people carry out 8 simple habit changes, we could save 2GTCO2e, equivalent to the emissions of Japan and South Korea combined[85] – see infographic below.

However, balancing energy security and decarbonisation will be difficult – India's coal consumption stood at 1.05bn tonnes in 2021 and coal demand is only expected to peak between 2030-2035; [86,87] indeed, India's Coal Minister admitted that coal will continue to play an important role in India until at least 2040.[87] This means that climate impacts will continue to accelerate and India must therefore pay attention to water as it makes policies to expand renewables, strengthen the grid, explore low carbon tech, improve demand-side management and optimise the energy mix for energy security.

The good news is that India recognises the need to build climate resilience in the LTLCDS: it understands that it will shoot itself in the foot if it does not decarbonise: *"As a developing country with a long coastline, vulnerability to monsoon disruption, high dependence on agriculture for livelihoods, and possible impacts on water systems, among other kinds of exposure to climate extremes and consequent hazards, India is likely to bear a considerable added development burden from the impact of global warming."* That said, India's energy and water security plans could be more interwoven.



Source: CWR, EDGAR emissions database
NOTE: methodology for collective cuts is in this report

India's National Water Policies

India, in recognising chronic water issues developed a National Water Policy (NWP) in 1987. Since then the Indian NWP has been revised twice, in 2002 and in 2012. Although India was an early pioneer in adopting a NWP, water experts such as Chetan Pandit (former #2 in India's Central Water Commission) and Professor Asit K. Biswas, a leading authority and advisor to governments on water, environment and development-related issues, have opined that they "have had no impact whatsoever on water management" – see box below.

India's Water Policies: Just Feel Good Documents?

However, more than 30 years after the first NWP, far from helping India in modifying her water management practices to achieve the desired social, economic and environmental outcomes, successive NWPs have had no impact whatsoever on water management. Driven by a compulsion to be politically correct, while also being influenced by fashionable ideas paraded in international water seminars, all the versions of NWPs have promoted ideas that are un-implementable in the Indian context.

For example all the NWPs have endorsed basin as a unit for all planning, and have recommended establishment of River Basin Organisations (RBOs) as the platform where all the stakeholders in a basin are represented, and where such basin planning can be done. NWP 2012 went a step further and stated that comprehensive legislation needs to be enacted to establish RBOs. However, after three decades of espousing basin as a unit for all planning, no basin is being planned or developed thus, and there isn't even one interstate RBO.

Source: Extracted from CWR's article "India's Water Policies: Just Feel Good Documents?" by Chetan Pandit & Asit k. Biswas, 18 April, 2019. https://www.chinawaterrisk.org/opinions/indias-water-policies-just-feel-good-documents/

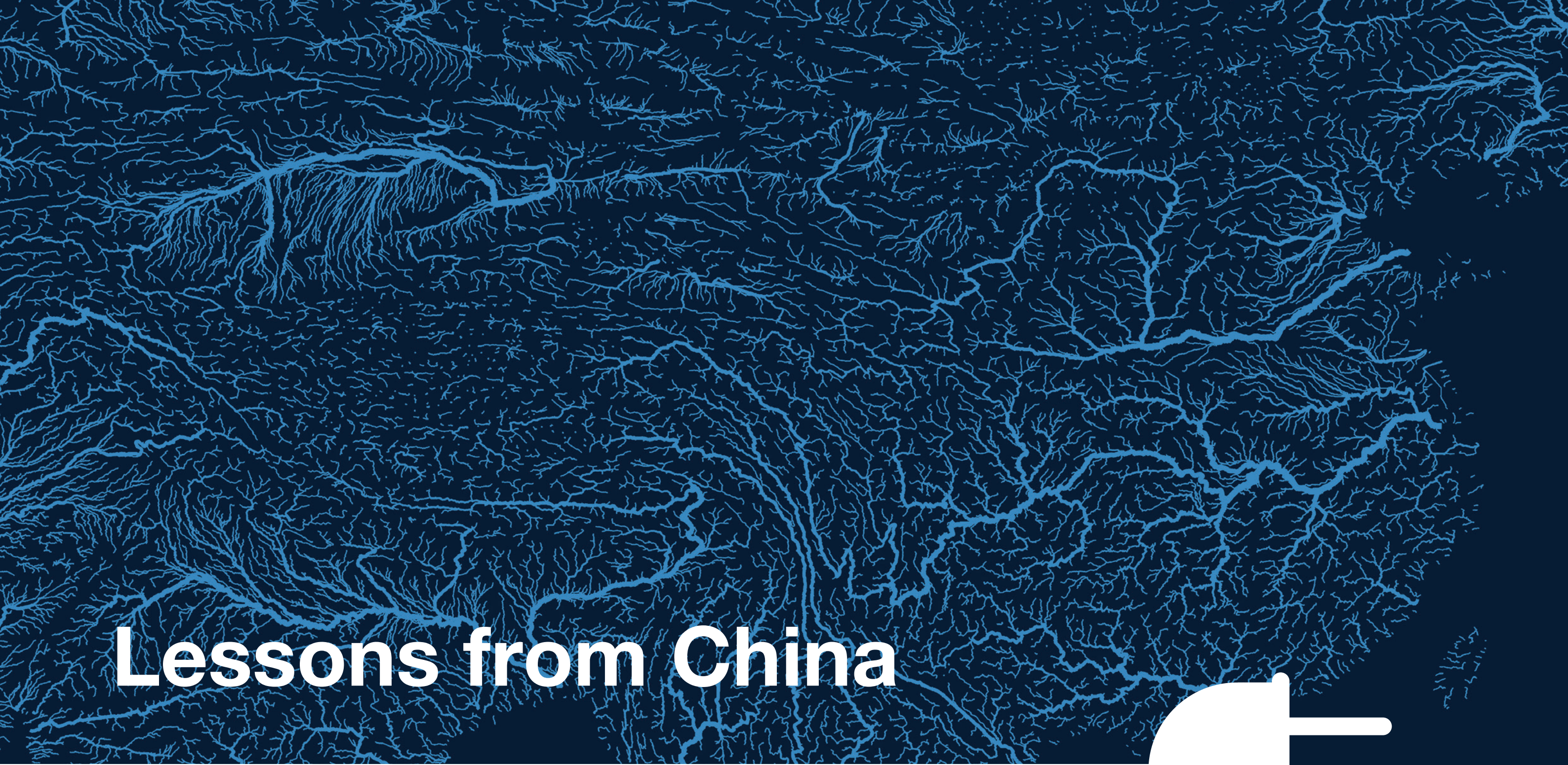
The authors provided advice for the next revision of the NWP, which at the time of writing this report was undergoing revision and review. According to the Times of India, the Policy, drafted by the 11-member committee constituted by the Ministry, has opined that it will be impossible to meet the basic water needs of millions of people for drinking and irrigation purposes, without a "radical change" in the pattern of water demand.[88] The water policy expert leading the new draft, Dr Mihir Shah said that the new NWP will shift away from a supply-centric approach involving dam construction and groundwater extraction, to the management of the demand and distribution of water. It would leverage nature rather than have a "command and control" relationship with nature; and blindspots in groundwater planning and gaps in blue-green infrastructure are also expected to be addressed.[89] With climate change, Shah noted that the past is no longer a reliable indicator of what is to come and there is a pressing need to build in agility, resilience, and flexibility in water management with drying rivers and groundwater depletion.[89]

Indeed, it is clear from the LTLCDS that climate impacts on water resources are well-recognised. The LTLCDS noted that India receives nearly 80% of its annual rainfall during the southwest monsoon season from June to September[83] and that rainfall distribution and intensity have a significant impact over different socio-economic sectors, especially agriculture and hydrology. Warmer weather is also putting additional stress on water and power usage – 2019 was the 7th warmest year on record since 1901; 11 out of 15 warmest years recorded were between 2005-2019. Himalayan rivers will also see increased short-term stream flow but long-run downstream dry-season shortages.[90] Droughts are also expected to increase in frequency, spatial extent and severity; while flood propensity is projected to increase over the major Himalayan river basins.[91]

Besides the NWP, India is also implementing a host of water-related policies and projects including:

- **National Water Mission** – aims to ensure integrated water resource management, help conserve water, minimize wastage and ensure more equitable distribution both across and within states. This should dovetail with the new NWP and is one of the 8 core missions under the 'National Action Plan on Climate Change' (NAPCC) that is focused on promoting the understanding of climate change, adaptation and mitigation, energy efficiency and natural resource conservation. The NAPCC was introduced in 2008.
- **Namami Gange Programme** – was launched in 2014 to restore "the wholesomeness of the river" by managing water use to ensure continuous flow, tackling pollution as well as ecological conservation.[92]
- **Composite Water Management Index** – created by NITI Aayog, this index ranks the performance of states in India on their resources management to help assess and improve the performance in efficient management of water resources.

While a good start, the Namami Gange does not approach the management of the river through a national waternomic lens. However, the Composite Water Management Index can be used as a framework to effect such for the states along the river. Hopefully the next NWP will address such issues and further unsilo water management as it dovetails these into the National Water Mission. Nevertheless, India faces an uphill battle with water pollution and groundwater over-extraction – both issues not addressed in these report.



Lessons from China

Appendix 1

- Overview on actions to de-coal 2011-2019
- Dual carbon targets & fast tracking decarbonisation since 2020
- Water use & pollution caps for coal extraction & coal-fired power
- Mountain-to-oceans management for the Yangtze & Yellow Rivers
- Water extremes: Managing the Yangtze and Yellow Rivers
- Water extremes: Grid flexibility & adding “just in case power”
- 14FYP for Water Security – 8 key thoughts

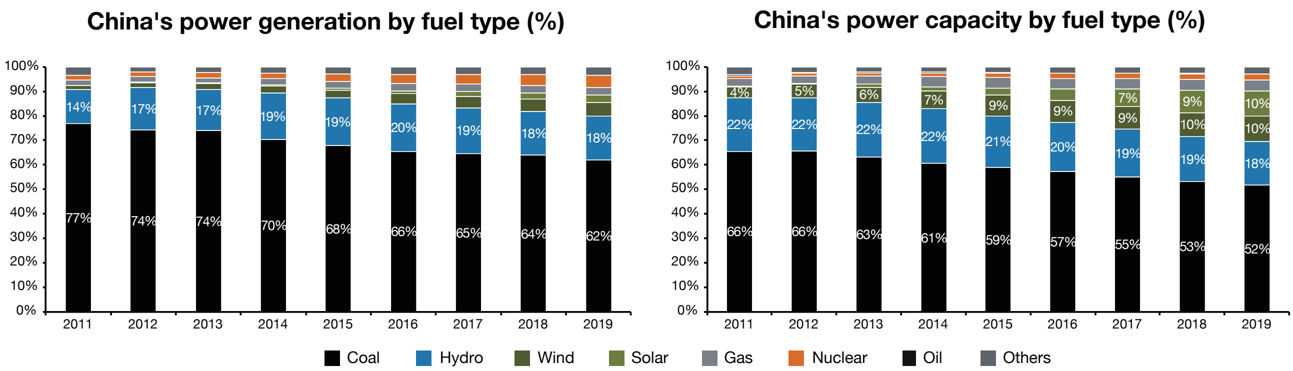
CWR

Overview on actions to de-coal 2011-2019

China's large coal reserves mean that coal plays a key role in national energy security. However, since China's commitment last year to become carbon neutral by 2060, the country has been making strides to control coal usage. In fact, such reforms started since the 12th Five Year Plan 2011-2015 (12FYP) which aimed to *"rationally control total energy use"*. During the 12FYP, new coal projects were strictly controlled in key pollution control regions and total energy use control was conducted in pilot regions.[93] The **"12FYP for Coal Industry"** also indicated that coal consumption should be controlled to around 3.9bn tonnes/year.[94]

With the ensuing 13th Five Year Plan for 2016-2020 (13FYP), China capped its coal consumption at 4.1bn tonnes/year and coal share of energy consumption at 58%.[95] Through a mix of plant efficiency upgrades and coal control, China came under this target with 3.97bn tonnes in 2020, but the IEA expects coal consumption to increase to around the coal cap number of 4.1bn tonnes by 2021.[96]

Indeed, during both the 12FYP and 13FYP, China increased its renewable energy shares in both power generation and capacity. Coal shares decreased from 77% to 62% for power generation (kWh) (see left chart below) and 66% to 52% for power capacity (GW) (see right chart below). Note that hydro power shares remained relatively stable while nuclear and gas have increased slowly. However, wind and solar energy both saw rapid growth in installed capacity but relatively slower progress in power generation, probably due to curtailment.

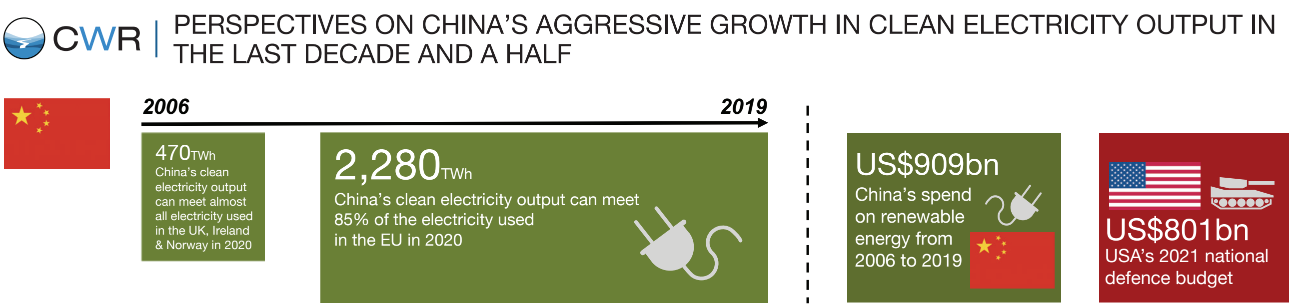


Source: CWR, China Electricity Council

That said, China has made great efforts to promote the consumption of renewable energy including introducing green power certificates,[97] renewable energy quotas[98] and Ultra-High Voltage (UHV) power transmission projects.[99]

China has now built 20 UHV channels and become one of the most advanced countries in UHV. In the Central Economic Work Conference in 2018, UHV power transmission projects were included in "new infrastructure" together with 5G, big data, AI, and so on. As of 2019, the share of renewables in the 20 existing UHV channels varies from 0-100% though on average is 52.4%. Such grid upgrades have meant that 6 out of 20 UHV channels are already transmitting 100% renewable energy.[100]

To appreciate the immense growth in renewables, China's clean power electricity output has grown from 470TWh in 2006, at the start of the 11FYP (equivalent to powering almost the entire power generation of the UK, Ireland & Norway in 2020)[101] to 2,280TWh[102] in 2019 towards the end of its 13FYP (equivalent to powering 85% of the entire electricity generation of the EU at 2,668TW)[103]. Underpinning this expansion was China's investment of US$909bn in renewable energy from 2006 to 2019.[104] While this a huge spend, this expenditure over a decade and a half was only 13% higher than the USA's annual national defence budget of US$801bn in 2021.[105] China's renewable expansion became more aggressive from 2020 onwards – please see the following page.



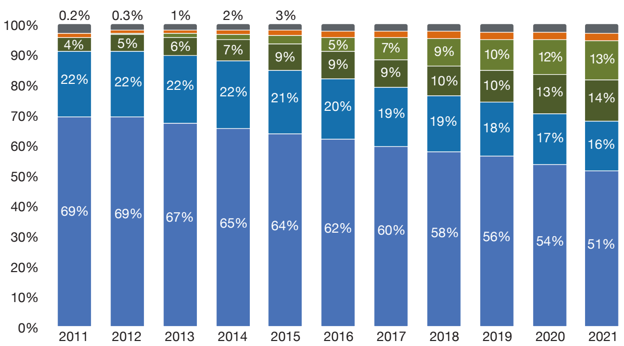
Source: CWR, CEC, EIA, Eurostat "Statistics Explained", Bloomberg, Peter G. Peterson Foundation

Dual carbon targets & fast tracking decarbonisation since 2020

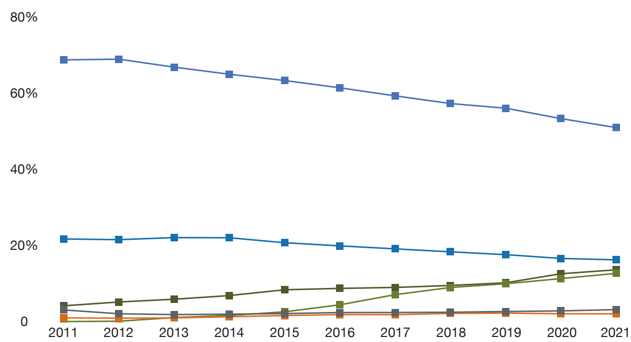
In 2020, President Xi Jinping announced China's "dual-carbon" targets to 1) peak carbon emission before 2030 and 2) achieve carbon neutrality before 2060. One of its major strategies is to put in place a "1+N" policy framework where "1" refers to the overarching principles of all forthcoming policies for combating climate change, while "N" refers to numerous solutions for peaking emissions as well as multiple policy measures for key sectors and industries.

A key part of China's dual carbon strategy is to increase the non-fossil fuel share of energy consumption as power and energy related sectors contribute almost 90% of its GHG emissions.[106] As can be seen in the charts below, China has been changing its power mix by ramping up hydro, wind and solar from a 26% share in 2011 to 43% in 2021. This means that renewable installed capacity grew by 2.65x from 281GW to 1,026GW in just a decade; pushing coal capacity down from 69% in 2011 to 51% in 2021.

China's power capacity by fuel type (%)



China's power capacity by fuel type (%)



Thermal (coal, oil & gas) | Hydro | Wind | Solar | Nuclear | Others

Source: CWR, China Electricity Council

It's worth noting here that while China's coal-fired power installed capacity mix has shrunk, new permits to build new coal-fired power plants were granted in 2022 to cope with future water extremes – more on this in "Water extremes: Grid flexibility & adding "just in case power"" in Appendix 1. However, this does not stop China's ambition in energy transition. The IEA has revised up its estimate for China's renewable expansion by 35% following the 14th Five Year Plan on Renewable Energy – indeed, China's 1.07TW expansion now accounts for almost half of the new global renewable power capacity of 2.4TW over 2022-2027.[18] China is now expected to reach its 2030 target of 1.2TW of total wind and solar PV capacity five years earlier.[18] For perspective, China's clean electricity output in 2022 reached 2,960TWh – this already surpassed the EU's 2021 total electricity generation of 2,785TWh – please see infographics in **"Renewables Expansion: China & India vs. rest of the world"**.

Indeed, despite an expansion in coal-fired power as well as an increase in GDP of 3% in 2022, the IEA estimated that China's energy related carbon emissions have shrunk by 23MtCO2 last year. By comparison, emissions from other emerging markets and developing countries rose by 206MtCO2.[22,107] Carbon savings would have been greater if not for the drought in 2H2022 which forced China to use coal to close the power gap caused by low hydropower supply – Carbon Brief estimated that China achieved carbon reduction of some 380MtCO2 for the 12 months from July 2021 through to June 2022.[21] Hopefully China's carbon emissions will remain flat/fall in 2023 as China opens up post-COVID – by 2030, China targets to have 25% of its energy from non-fossil sources.[108]

Also, it's important to note that around two-thirds of China's electricity is consumed by industry and because China is the world's manufacturing hub, a material share of these emissions is driven by global supply chains. Regardless, China as the largest global emitter can do more to help steer the current global policies and action pathway away from 2.8°C towards 2°C. Indeed, rapid deep cuts are needed as current global geopolitical conflicts do not bode well and could send us down a "Regional Rivalry Scenario" which the IPCC has warned can lead to >4°C. Moreover, emissions from permafrost thaw have yet to be accounted for in the global carbon budget – at 1.2°C today, we have already unlocked permafrost thaw on par with Japan's annual GHG emissions; on our current warming trajectory (3°C) annual permafrost emissions will be on par with GHG emissions of the USA.

While China's energy transition continues to build momentum, there is still a long way to green its economy. Besides changing its power mix, China is also driving higher penetration in electric vehicles and high speed rail transportation as well as pushing technology advances to improve efficiencies. Moreover, the high speed rail network is expected to cannibalise domestic flight travel and smart ports are also expected to help rein in maritime emissions.[109]

That said, coal is likely to remain crucial in ensuring China's energy security. As coal mining as well as coal-fired power generation requires water, China can and must do more to safeguard both water and energy security by implementing water policies for coal extraction as well as waternomic policies for power and economic expansion – policies put in place so far on these fronts are discussed in more detail in the following pages.

Water use & pollution caps for coal extraction & coal-fired power

In striving for a Beautiful China, the nation has been undergoing a period of re-balancing its economic growth with the degradation of its environment. To ensure water security, China has also been managing the use of its limited water resources through national, provincial and sectoral water use caps as well as waternomic targets.

Central to ensuring national water security is the "Three Red Lines", a series of water policies that rein in pollution and impose national and provincial quotas on water use as well as stipulate water efficiency gains. The energy sector, as the largest industrial user of water, plays a central role. Decisions made today to power China, do not just have implications for climate change, they impact water resources. With water and energy security being of 'utmost importance', managing China's tight water-energy nexus in the North is high on the government's agenda. China's tight water-energy-climate nexus has been well-recognised for some time. The table below extracted from our earlier report shows key water related policies and regulations for coal mining and thermal power.

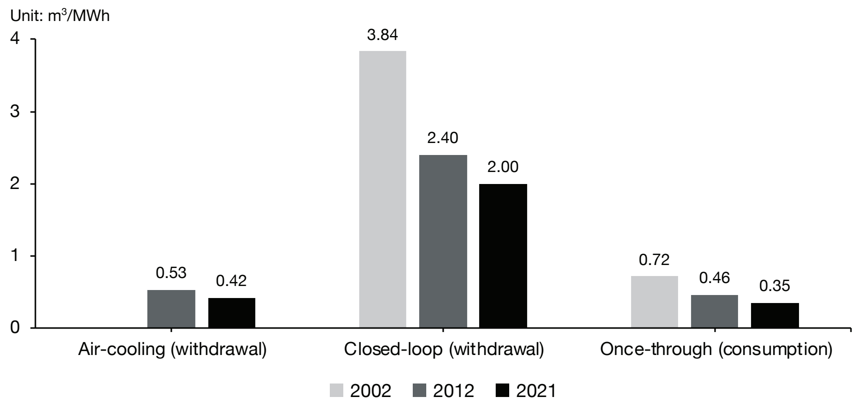
Key recent water related policies and regulations for coal mining and thermal power generation

Action Plan for Prevention and Control of Water Pollution State Council April 2015	- Necessary anti-seepage treatment for coal mines - Advancing comprehensive utilization of mine water - By 2020, the advanced level of the water quota standard should be enforced - No new water permits in areas where water use reached the quota level - Strengthening license management with more focus on water discharge - Abandoned mines, drilled wells and water intake wells should be closed backfilled - No new water permits for thermal power plants failing to fully use potential reclaimed water
Promoting Safe and Sustainable Development and Clean, Effective Use in the Coal Industry NEA, MEP, MIIT December 2014	- By 2020, recycling rate of mine water should reach 95%, 80% or 75% according to the local water scarcity
Opinions on Water Resources Assessment in Large-scale Coal & Power Base Development Ministry of Water Resources December 2013	- No groundwater should be used in coal bases - Waste water should be fully reused after meeting the recycling standard - Planning of large mines requires a demonstration of water resources availability - In Northern regions, coal-fired power plants must first utilize mine water and recycled water
12th Five Year Plan of Coal industry NDRC March 2012	- By 2015, the mine water recycling rate should reach 75% nationally (80% in Eastern area, 68% in Central area, 80% in Western area) - In the large and medium mines, fully use the mine water - Coal processing plants must adopt closed-loop recycling system
Opinions of the State Council on Applying the Strictest Water Resources Control System State Council January 2012	- Strictly levy the water resource fee - Control of the withdrawal and consumption of underground water - Shut down self-owned wells

Source: The above is extracted from CWR's report "Toward Water Risk Valuation – Investor Feedback on Various Methodologies Applied to 10 Energy Listco's", 2016

China has also set a series of standards, targets and quotas/norms concerning water use for various industries – these can also vary from province to province depending on water stress/availability. In 2021, Chinese authorities updated the water use norms for thermal power plants.[110] As the chart below shows, there is a clear trend that the regulation is becoming more and more stringent – demanding less water per unit of power produced across cooling types. This is good news for water and we expect coal-fired power plants to be making these water savings upgrades. Incidentally, we could see a rise in investment in coal-fired power plants due to such technical upgrades for water.

Norm of water use for thermal power



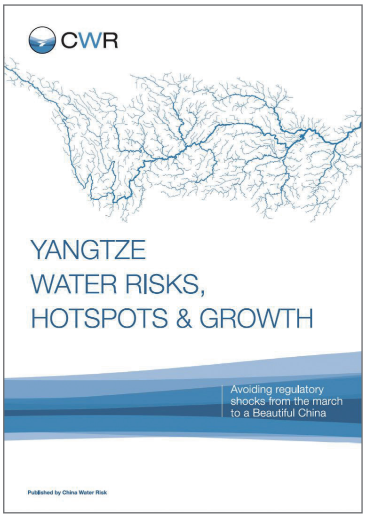
Note: Norms are set by capacity, the norms shown in this chart are the most stringent norms applied to large capacity units
Source: CWR based on State Administration for Market Regulation, Standardization Administration of China

Mountains-to-oceans waternomic management for the Yangtze & Yellow Rivers

In 2022, China issued the 14th Five-Year Plan for Water Security (Water 14FYP). Although China has multiple water policies and strategies, it is the first-ever FYP for water security. The Water 14FYP sets out an 'overall comprehensive plan' for water in the next five years. So, it is not an individual plan per se but an 'umbrella plan' for all previous key water policies. The Water 14FYP also clearly recognises that climate change exacerbates existing issues and creates new problems: *"With economic and social development and the impact of global climate change, existing challenges for water security still need to be addressed, yet new emerging issues are becoming more and more urgent."*

Rivers play a key role in managing and ensuring water security – the Water 14FYP aims to *"strengthen the protection and restoration of river source areas"*. Specifically mentioned – *"China's Water Tower"*, *"Zoige Prairie Wetland"* and *"Qinling"* – important ecological zones for the Yellow and Yangtze. The ecological protection of rivers and lakes will continue to be strengthened. Specifically, targets for ensuring the ecological flow of 282 key rivers and lakes will be set, and new water intake permits will be suspended in water stressed/scarce regions in the Yellow River basin. To facilitate ecological protection, cross-provincial eco-compensation mechanisms for key river basins will be established and national parks will be set up.

Given the clustering of economies and population, it is not surprising that China's focus is on the Yellow and Yangtze Rivers. These rivers are seen as the backbone to China's development and featured heavily in President Xi's 2022 New Year Speech – he dedicated more words to water and nature than the prosperity and stability of Hong Kong and Macao. For a detailed look into how China views the waternomics of its key rivers, please see our report *"Yangtze Water Risks, Hotspots & Growth"*.



*"A Yellow River well harnessed is a millennia-long aspiration of the Chinese people. Over the past few years, I have visited all nine provinces or autonomous regions on the upper, middle and lower streams of the Yellow River. From the Yellow River and the Yangtze River, two "mother rivers" of the Chinese nation, to the limpid Qinghai Lake and the mighty Yarlung Zangbo River; from the South-North Water Diversion, known as a project of the century, to the Saihanba forest, shown as a patch of green on the map; from the northward trek and homecoming of elephants in Yunnan Province, to the migration and return of Tibetan antelopes — all these remind us that **"If we do not fail Nature, Nature shall never fail us""***

President Xi Jinping, 2022 New Year Speech

The action is holistic from mountains-to-oceans – five national parks that are home to nearly 30% of key terrestrial wildlife species in the country have been established; one of these is Sanjiangyuan, the source region of 3 key rivers – the Yangtze, Yellow and Mekong. And there are plans afoot to add more. Indeed Premier Li expressed in his 2021 work report that China aims to *"move faster to build major ecological shields, develop a national park-based nature reserve system, and expand forest coverage to 24.1% of China's total land area."* By 2025, nature reserves and national parks are expected to account for more than 18% of the national land area plus 100 million mu (6.7mn hectares/ 67,000km^2) will receive desertification land treatment. These are grand efforts – land treated for desertification alone is half the size of England and China's nature reserves and national parks will eventually protect areas larger than France, Germany, Spain, Switzerland, and the UK combined.

The Water 14FYP also focuses on ramping up resilience for water shocks with inland & coastal flood defences. The record floods in the Yangtze in 2021 as well as the record drought in 2022 are concerning and the Water 14FYP includes adaptation measures such as reinforcing flood control infrastructure, strengthening embankments of key rivers, lakes and reservoirs and realising adequate flood plains. The new flood protection targets have also been set to withstand one in 100-200 year flood levels to *"ensure the safety of people's lives, property and stable operation of economy and society"*. Building flood resilience in the Water 14FYP starts from the mountain source regions, rural areas to large urban areas along the rivers to coastal cities; again, echoing a mountains-to-oceans approach.

To reduce and prevent damages and disruptions from future record-breaking floods, China will move to centralise flood control protection for flood zones covering an area of 800,000km^2; upping protection for the 860mn people who live there. For a size perspective, this centralised flood control zone is larger than the land area of Turkey. 819 flash-flood-prone valleys have also been identified for action. Other innovative measures such as using digital watersheds for flood control and forecasting in major river basins are also on the task list. The Water 14FYP also notes that controlling floodwaters by optimising flood storage and retention zones can help buffer water supply and food production against external shocks; China can continue agricultural production despite floods or droughts.

*For more on the Water 14FYP, please see **"14FYP for Water Security – 8 key thoughts"***

Water extremes: Managing the Yangtze and Yellow Rivers

In recent years, extreme weather events have become more frequent in major rivers globally due to climate change, which has disrupted water supply, power generation and economic activity. This includes the recordbreaking floods and droughts in the Yangtze and the Yellow…

The Yangtze River faced the lowest summer rainfall in six decades.[60] In 2022, 24 reservoirs and 51 rivers in Chongqing dried up due to searing temperatures of >40°C for eight consecutive days. Record heatwaves and low rainfall meant that electricity demand for air-conditioning rose whilst hydropower generation fell due to drought conditions lending complexity to drought management. With 80% of its electricity derived from hydropower, the Sichuan province was particularly affected. Its hydropower generation plunged by 50% and a large number of industrial enterprises and factories were told to suspend production for 6 days to ensure that public basic needs of power and water were met.[60] Tesla, Toyota, and Foxconn were among companies reported to have temporarily suspended operations at some plants, disrupting global supply chains.[111] On top of this, the extreme drought affected at least 830,000 people along the river as well as close to 1.5 million acres of farmland.[60]

The Yellow River suffered "once in a thousand years" rain that caused devastating floods in Henan Province. On July 2021, the amount of rainfall received in the hardest-hit city, Zhengzhou, reached 624.1mm – almost as much as the city typically receives in a year.[112] The flood affected nearly 14.8mn and killed 398 people in Henan and caused over RMB120bn in direct economic loss.[113] Water, electricity, internet as well as train services across multiple areas in Henan, were suspended due to the flooding.[114] Apart from this, the flood also affected 2.5mn acres of crop fields and killed millions of livestocks.[115]

For more on the extremes events in rivers, please see CWR's article "Rivers are Running Dry Today", by Debra Tan & Sophie Lam 24 October, 2022

China: Waterproofing infrastructure to protect against future shocks

China's 14th Five Year Plan for Water Security (Water 14FYP) provides a framework as to how China will approach water security in the future including adaptation measures such as reinforcing flood control infrastructure, strengthening embankments of key rivers, lakes and reservoirs, and realising adequate flood plains and the building of digital watershed (see below).

The new flood protection targets have also been set to withstand one in 100-200 years flood levels to *"ensure the safety of people's lives, property and stable operation of economy and society."* Building flood resilience in the Water 14FYP starts from the mountain source regions, rural areas to large urban areas along the rivers to coastal cities; again, echoing a mountains-to-oceans approach.

Flood & drought control measures mentioned in the Water 14FYP…

- Accelerate the construction of control hub projects in the major river basins – Improving flood control capabilities in watershed areas including the Yangtze and the Yellow
- Accelerate the optimisation, adjustment and construction of flood storage and detention areas
- Strengthen the construction of flood drainage capacity in key flooded areas
- Promote the construction of intelligent water conservancy projects – Implement the intelligent transformation of the joint dispatching system of the Yangtze River reservoir group, and the construction of a safety monitoring system for flood control projects in the lower reaches of the Yellow River
- Strengthen the construction of water safety monitoring systems including building of digital watersheds
- Strengthen the construction of water source projects – enhance the ability to respond to severe droughts, persistent droughts, and sudden water security incidents
- Establish a comprehensive management and coordination mechanism for river basins

Digital watershed for flood monitoring

In recent years, especially since the Water 14FYP, China is determined to promote innovations that include the full monitoring of its watersheds from mountains-to-oceans using new technologies from 5G, remote sensing to unmanned ships and underwater robots. China's aim is to accelerate the construction of 'digital watersheds' for all its major river basins/water sources. There are currently two digital watershed pilots to monitor key flood control areas in the Huai and Hai Rivers; when successful, they will be replicated to other regions.

It is important to note that these digital watersheds are not just early warning systems. Beyond flood defence systems, they also help build data to strengthen China's water conservancy information network. Ultimately, digital watersheds will help monitor, forecast and manage water resources more efficiently – from the allocation of water use/discharge permits, preventing & controlling pollution, improving water quality to maximising irrigation savings.

Source: Extracted from CWR's article "First-ever 14FYP for Water Security – 8 Key Thoughts", by Debra Tan & Chien Tat Low, 23 March, 2022

Water extremes: Grid flexibility & adding "just in case power"

The summer drought in the Yangtze River Basin highlighted power generation's exposure to a liquidity crunch. Sichuan province was the most affected as 80% of the province's annual power consumption needs are met by hydropower. Prolonged heatwaves and drought led to what the State Grid called a *"dual shortage"*:

1. **Failing to meet peak demand:** temperatures between 4-6°C above normal led to high use of air-conditioning resulting in the province setting new records six times in August. Peak power reached 65GW by 21 August 2023; a >25% rise in peak power from the previous year; and

2. **Failing to generate power:** poor rainfall and drought conditions curtailed hydropower production as the Yangtze River faced the lowest summer rainfall in six decades.[60] According to the People's Daily, in Chongqing, 24 reservoirs and 51 rivers had dried up.[60] The Lantau Group (TLG) estimates that Sichuan's hydropower fleet was operating at an average capacity factor of roughly 20%, around half that of 2021 but a quarter of that in 2020.[116]

This significant rise in peak power is challenging even without the significant power supply shortage – for perspective, 60GW is roughly the winter peak demand of the UK.[116]

While it was clear that Sichuan could not even meet its local demand, it also had to to meet agreements to export power to other provinces – Shanghai, Jiangsu, Zhejiang and Jiangxi. TLG noted that existing coal and solar capacity even if running at full capacity would not have been able to provide enough buffer. Residential, commercial and agriculture were prioritised leading to industrial power cuts. As the world's factory sits on the Yangtze River, the power cuts affected the supply chains of Tesla, Toyota, and Foxconn amongst others.[111,117]

Tempering vulnerability to hydropower risks by adding more coal as "just in case power": The summer drought showed that China's power supply is clearly vulnerable to water risks and given that these events will likely escalate and become the norm, it is important to stress test and re-examine existing capacity mix and build out plans. While the build out of a UHV line to connect Sichuan to Xinjiang's renewable base will provide buffer by 2025, other provinces are taking action by adding coal.

Weeks after Sichuan's power crises was resolved, Guangdong approved 17GW of new coal-fired capacity that was not originally in its 14FYP. Experts from TLG noted that this could well be an addition of "just in case" power as it would be enough to cope with a 50% decrease in production of hydropower exported to Guangdong from Yunnan.[118] Note that Yunnan also suffered a drought in 2022.

Indeed, China's coal power plant permits grew dramatically in 2022 with new permits reaching the highest level since 2015.[119] According to a briefing by CREA, 50GW of coal power capacity started construction in China in 2022; >50% increase from 2021 – many of these projects had their permits fast-tracked and moved to construction in a month. Overall, CREA noted that 106GW of new coal projects were permitted in 2022 – 168 units across 82 different sites – the majority of these were permitted after the summer. Not surprisingly, the largest add was in Guangdong, Jiangsu, Anhui, Zhejiang and Hubei; besides Guangdong, the other four provinces are part of the Yangtze River Economic Belt.

We are of the view that such additions of power are to help China cope with future water extremes rather than an expansion of the coal fleet as base load power. Indeed, provinces permitting these new coal power plants have classified them as "supporting" power capacity to ensure grid stability and the integration. While the jury is still out, hopefully the overarching view of water security will encourage their use as supporting capacity and not as base load. CREA also noted *"The massive additions of new coal-fired capacity don't necessarily mean that coal use or CO2 emissions from the power sector will increase in China. Provided that growth in non-fossil power generation from wind, solar and nuclear continues to accelerate, and electricity demand growth stabilizes or slows down, power generation from coal could peak and decline".*

While China has been responsive in adapting to climate risks, adding new coal plants "just in case" of future vulnerability and running them at low capacity is an expensive way to provide power resilience. Albeit sub-optimal, this trend will likely continue as China will continue to err on the side caution by overbuilding to tackle rising water extremes as well as to provide power to meet higher peak loads due to higher temperatures.

Regardless, more flexibility can be built into the grid as well as contractual exports to other provinces when faced with power supply shortages. For example, Sichuan's grid is set up to export, not import power. In addition, better monitoring of river flow as well as more flexibility toward holistic management of the hydropower fleet may also help smooth river flow and therefore power generation during extreme water events. All in all, a more holistic approach toward power management – across power types, grid transmission and the new "just in case" infrastructure – is needed to cope with new water extremes. As these extremes are not going away, given the interlinkages of water and power, China should move to dovetail its water and energy security plans.

14FYP for Water Security – 8 key thoughts

Below are excerpts taken from an article on CWR's website published on 23 March 2022 by Debra Tan & Chien Tat Low titled ***"First-ever 14FYP for Water Security – 8 Key Thoughts"*** *– the article can be found at: https://www.chinawaterrisk.org/resources/analysis-reviews/first-ever-14fyp-for-water-security-8-key-thoughts/*

Water 14FYP is an 'umbrella plan' that holds together all water policies and actions

Before we dive in, it is important to understand that the Water 14FYP sets out an 'overall comprehensive plan' for water in the next five years. So, it is not an individual plan per se but an 'umbrella plan' for all previous key water policies. These include the *"Most Stringent Water Management System"*, *"Promoting Comprehensive Treatment of Groundwater Overexploitation"* and *"The Water Ten"* to water permits, ecological red lines/zones, water resource tax and so on.

In short, the plan provides a framework as to how China will approach water security in the future. This approach gives comfort that beyond ensuring a stable supply of water, China's making holistic, regional and transformative efforts on the waterfront. Because water is how we will feel climate change, the Water 14FYP also signals that China is well ahead in water adaptation and the IPCC AR6 WG2's "Climate Resilient Development" – more on this later.

This means that to get on top of the full extent of China's efforts on water, you will need to read all the other plans. As we have written extensively on each of these key water policies, we will not go through them again here but instead, share 8 key water thoughts from this year's 'direction of travel' from the Two Sessions as well as the Water 14FYP…

1. **Water = top priority for the next 100 years of development**

   The first thing that springs to mind is that water is a #1 priority. Released by the NDRC and the Ministry of Water Resources, the Water 14FYP kicks off with reference to President Xi Jinping's thoughts on water: *"put water savings first, balance regional differences, strengthen systematic governance and push forth with a two-handed approach."* The two-hands refers to the complementary actions of using market forces and government regulations to allocate water resources efficiently and fairly.

   With this, we know that the plan not only signals strong political will toward ensuring water security but that challenges due to the spatial distribution of water and the economy are also recognised. So naturally, as water is essential for growth, waternomic challenges are iterated in the plan: *"The unique natural physical geography, climatic conditions, water resource characteristics and socio-economic conditions make our country one of the most demanding and difficult countries in the world to control water."* If you are not aware of China's challenges, check out at-a-glance challenges in our infographics in the Big Picture.

   Here, it is important to remember that the 14FYP sets the direction of travel for the next 100 years. The fact that a grand umbrella plan has been put in place with the Water 14FYP signals the importance of the resource for the next "100-year" phase – it is definitely needed to fuel China's dream to build *"a great modern socialist country that is prosperous, strong, democratic, culturally advanced, harmonious and beautiful."*

2. **Water is key to stability, rural revitalisation + food security**

   Stability is of paramount importance to China and water is a key ingredient for *"ensuring stability"*. Indeed, Premier Li Keqiang stressed the importance of *"pursuing progress while ensuring stability"* several times in his 2022 work report.

   Water is also essential for agricultural and rural development and the Water 14FYP dovetails into China's 2022 No.1 Central Document which focuses on rural revitalisation. Now that its population has been lifted out of absolute poverty, China is working to ensure that they don't fall back into poverty.

   The plan aims to strengthen the water supply guarantee for the 270 million rural population plus there is an entire section on rural water conservancy and *"developing water-saving irrigation vigorously"* to support high-quality and modern agricultural production. Agricultural water pollution due to excessive fertiliser use will also be dealt with and irrigation tech will be harnessed to improve all these efforts – monitoring agri water use and pollution plays a key part in realising China's **'digital watershed'** – more on this later.

   Besides these, China will also be using crop mix to manage water, moving away from water intensive crops in stressed regions. Moreover, drought resistant seeds will be promoted to ensure food security plus to maximise water resource use, integrated farming such as the use of rice and aquaculture resulting in *"double crops"* is encouraged.

   All these efforts to support China's rice bowl will be increasingly important as climate change impacts both water availability and food production. So does the Water 14FYP deal with climate change? Yes, it does…

3. Water 14FYP is a holistic adaptation plan to ensure availability + protect against future shocks

The Water 14FYP does recognise that climate change exacerbates existing issues and creates new problems: *"With economic and social development and the impact of global climate change, existing challenges for water security still need to be addressed, yet new emerging issues are becoming more and more urgent".*

Water lies at the heart of everything. We cannot survive without it yet climate change will make its availability more uncertain. This was made abundantly clear in the 2022 IPCC AR6 WG2 report on *"Impacts, Adaptation and Vulnerability"* – see 8 dire impacts here. Also, the IPCC says water is how we will feel most climate impacts. So going forward, we must simultaneously ensure water availability to survive and protect from acute shocks (e.g. blizzards/storms/floods/droughts) and chronic trends (rising scarcity/humidity/seas).

The first-ever 14FYP for Water Security does just that with key tasks that address core adaptation issues around water – from ensuring water supply to building resilience to water shocks. Ensuring water supply includes improving water savings, pipe leakages, irrigation, alternate supply source from diversion to reuse, outright bans in stress regions, tackling pollution plus more; whereas building resilience includes upping action on floods, droughts, soil erosion, watershed restoration & protection and so on.

The Water 14FYP also makes it clear that groundwater overexploitation and pollution are well understood; as is groundwater's increasing vulnerability to climate change. For more on this, check out our World Water Day article on groundwater… in case you missed it this World Water Day is all about making the invisible visible.

Naturally, if water is well managed, cascading climate risks will also be curtailed as water is a trigger point for other impacts such as food, energy, economic growth, migration, disease and so on. Therefore, in a way, you could look at the Water 14FYP as an adaptation plan.

If China can 'control water' it can limit its impacts from imminent water and water-related climate risk. This may sound grand but that is the plan … and the plan is holistic and transformative. For an idea of how grand, look no further than source protection as part of its "mountains-to-oceans" approach to managing rivers…

4. Grand protection plans – Ecological zones, China's Water Tower & National Parks

We have long talked about the need to manage water from its source in the mountains to the oceans and there is a strong recognition of this is in the Water 14FYP which aims to *"strengthen the protection and restoration of river source areas".* Specifically mentioned are – *"China's Water Tower", "Zoige Prairie Wetland"* and *"Qinling"* – important ecological zones for the Yellow and Yangtze.

Further downstream, the ecological protection of rivers and lakes will continue to be strengthened. Specifically, targets for ensuring the ecological flow of 282 key rivers and lakes will be set, and new water intake permits will be suspended in water stressed/scarce regions in the Yellow River basin. To facilitate ecological protection, cross-provincial eco-compensation mechanisms for key river basins will be established and national parks will be set up.

Here, it's worth noting that China's first group of national parks made it into Li Keqiang's work report alongside China's mission to Mars. Five national parks that are home to nearly 30% of key terrestrial wildlife species in the country have been established; one of these is Sanjiangyuan, the source region of 3 key rivers – the Yangtze, Yellow and Mekong.

There are plans afoot to add more. Last year, Premier Li expressed in his 2021 work report that China aims to *"move faster to build major ecological shields, develop a national park-based nature reserve system, and expand forest coverage to 24.1% of China's total land area"*. By 2025, nature reserves and national parks are expected to account for more than 18% of the national land area plus 100 million mu (6.7mn hectares/67,000km^2) will receive desertification land treatment.

These are grand efforts – land treated for desertification alone is half the size of England and China's nature reserves and national parks will eventually protect areas larger than France, Germany, Spain, Switzerland, and the UK combined.

5. Ramping up resilience for water shocks with inland & coastal flood defences

In 2021, record-high rains in Zhengzhou, Henan brought huge losses to China. Not surprising then, that the Water 14FYP includes adaptation measures such as reinforcing flood control infrastructure, strengthening embankments of key rivers, lakes and reservoirs and realising adequate flood plains.

The new flood protection targets have also been set to withstand one in 100-200 years flood levels to *"ensure the safety of people's lives, property and stable operation of economy and society"*. Building flood resilience in the Water 14FYP starts from the mountain source regions, rural areas to large urban areas along the rivers to coastal cities; again, echoing a mountains-to-oceans approach.

Coastal regions that *"are economically developed, densely populated, with high social wealth"* will be prioritised for defences against coastal flooding including storm surges. These include important cities, economic zones and critical infrastructure in coastal areas.

Again, the action is transformative. To reduce and prevent damages and disruptions from future record-breaking floods, China will move to centralise flood control protection for flood zones covering an area of 800,000km^2; upping protection for the 860 million people who live there. For a size perspective, this is centralised flood control zone is larger than the land area of Turkey.

819 flash-flood-prone valleys have also been identified for action. Other innovative measures such as using digital watersheds for flood control and forecasting in major rivers basins are also on the task list…more on this in later in **'digital watershed'**.

The Water 14FYP also notes that controlling floodwaters by optimising flood storage and retention zones can help buffer water supply and food production against external shocks; China can continue agricultural production despite floods or droughts. More resilience means fewer shocks, which means more stability … and more stability in both water and food supply is what it's all about. To deliver this, the whole watershed will need to be monitored effectively which brings us to the next point…

6. Governance strategies: Building 'Digital Watersheds' & using 'Rivers Chiefs' and litigation

None of the above, be it ensuring supply, ecological protection or flood/drought prevention work without governance which is pervasive throughout the Water 14FYP. Besides improving government efficiencies and reform, updating standards, ensuring compliance and so on, the plan expands on monitoring innovations.

These innovations include the full monitoring of its watersheds from mountains-to-oceans using new technologies from 5G, remote sensing to unmanned ships and underwater robots. China's aim is to accelerate the construction of 'digital watersheds' for all its major river basins/water sources. There are currently two digital watershed pilots to monitor key flood control areas in the Huai and Hai Rivers; when successful, they will be replicated to other regions.

It is important to note that these digital watersheds are not just early warning systems. Beyond flood defence systems, they also help build data to strengthen China's water conservancy information network. Ultimately, digital watersheds will help monitor, forecast and manage water resources more efficiently – from the allocation of water use/discharge permits, preventing & controlling pollution, improving water quality to maximising irrigation savings.

The public is also tapped for this grand monitoring exercise. An example of this is the "River Chief System" – an institutional innovation by China to curb water pollution by assigning more than one million "river and lake chiefs" to keep all rivers and lakes free of visible pollution. According to the Water 14FYP, more than 164,000 violations and problems have been solved since the programme started in 2018. The overall national surface water quality has also improved steadily.

Besides public participation in water governance, China is also promoting public interest litigation relating to environmental and ecological protection to test the new laws. In 2020, there has been a surge in public interest environmental lawsuits in China – the courts saw 103 public interest environment lawsuits initiated by social organisations; another 3,454 environmental suits were brought by prosecutors. These rates were up by 78% and 82%, respectively compared to the previous year.

With more cases expected in the future, China has built 1,993 judicial institutions specialising in handling lawsuits on environmental-related cases. As you can see, China's ramping up on multiple fronts and on all fronts it is transformative. But this is not just the Water 14FYP…

7. It's transformative! Read it with the 14FYP, the AR6 WG2 & Climate Resilient Development Report

With an entire plan dedicated to water adaptation, we argue that China is already one-step ahead on adaptation. But there is more … China is already practising "Climate Resilient Development" touted by the AR6 WG2 in its "grand redesign" of China … not just in the Water 14FYP but in the actual 14FYP.

Adaptation and transformation are built-in to every aspect of the 14FYP with the overall guidance of reaching an *"ecological civilisation" and achieving "common prosperity"* – these are very much in line with the AR6 WG2's values of protecting ecosystems, the vulnerable, avoiding inequitable outcomes and equitable adaptation.

So it's not just the Water FYP but the entire 14FYP is indeed transformative, demanding deep reforms across all areas. From energy mix, resource management, optimising industrial mix and management, high quality development, agricultural reform, transportation and city hubs to societal transformation as well as ecological protection and restoration – the 14FYP covers it all; and water is an integral part of this next phase development.

It is important to understand this because the 14FYP for Water Security should not be read in isolation; it is linked to other development plans – if you have not read it, we recommend you check out the 14FYP here in Chinese or here in English.

Another point to note here is financing, a key stumbling block to effective adaptation. The Water 14FYP includes financing mechanisms such as eco-compensation, differentiated tariffs, water resource tax and permits (use & discharge) to help facilitate better allocation of water resources.

And, it is innovative: for water scarce regions where no new water permits will be issued due to over exploitation of water resources, the Water 14FYP encourages water rights trading to help meet new water use demand, without adding new pressure to local water resources. Pilot REITS for water infrastructure projects will also be conducted in future – this is a whole new world.

8. Philosophy matters! People-first = low-regret adaptation + Water is the backbone of China's prosperity

China's strive towards an ecological civilisation and common prosperity (aka Climate Resilient Development) is not going away, but here to stay. Another advantage in a changing climate is China's people-centric philosophy, which was on full display during COVID.

People-first means that China will always use low-regret scenarios when planning resilience. This means it will always opt for transformative over incremental adaptation which would stand it in better stead for accelerating and intensifying climate risks ahead.

This is good news for water, the resource most vulnerable to climate change. But people-first also means water-first, as no water, no food. So while China may be slow at getting there (it is 1.4bnn people after all), it is not greenwashing when it comes to water – it really does view water and nature as the backbone of China's prosperity.

In case you are still doubting, seeing water or nature as a 'backbone' to development was entrenched in President Xi's 2022 New Year Speech – he dedicated more words to water and nature than the prosperity and stability of Hong Kong and Macao …

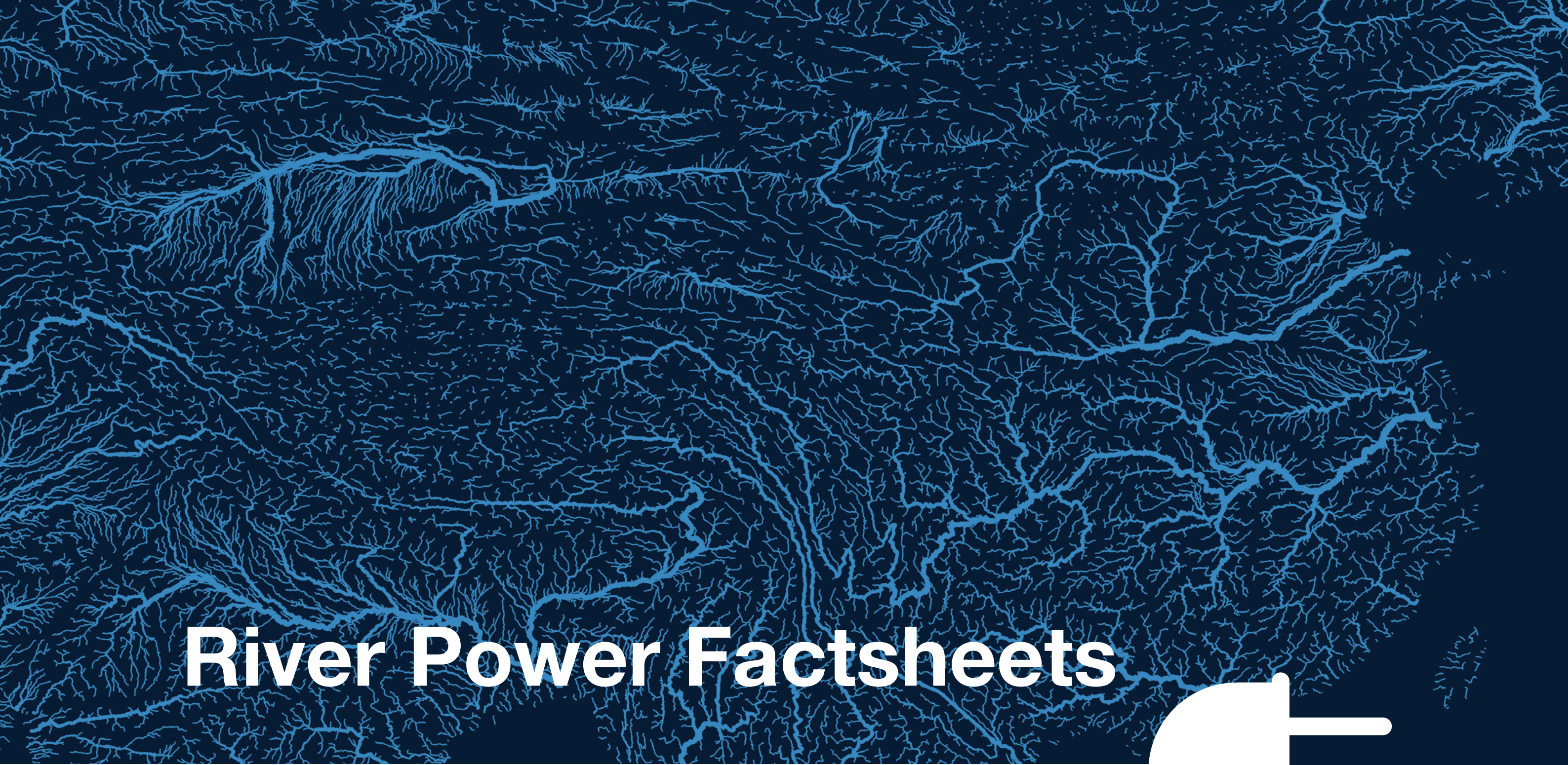
*"A Yellow River well harnessed is a millennia-long aspiration of the Chinese people. Over the past few years, I have visited all nine provinces or autonomous regions on the upper, middle and lower streams of the Yellow River. From the Yellow River and the Yangtze River, two "mother rivers" of the Chinese nation, to the limpid Qinghai Lake and the mighty Yarlung Zangbo River; from the South-North Water Diversion, known as a project of the century, to the Saihanba forest, shown as a patch of green on the map; from the northward trek and homecoming of elephants in Yunnan Province, to the migration and return of Tibetan antelopes — all these remind us that **"If we do not fail Nature, Nature shall never fail us""***

President Xi Jinping, 2022 New Year Speech

"Mother Rivers" are central to the prosperity of the Chinese civilisation and it will do whatever it takes to protect them. Essentially, the Water 14FYP is here to ensure that China does not fail water, so that water does not fail the Chinese people for the next 100 years.

Climate change means that there will be choppy times ahead, but if executed well, this Water 14FYP "adaptation plan" will set China up for "smoother sailing" in the future.

Source: CWR's article "First-ever 14FYP for Water Security – 8 Key Thoughts" by Debra Tan & Chien Tat Low, 23 March 2022. https://www.chinawaterrisk.org/resources/analysis-reviews/first-ever-14fyp-for-water-security-8-key-thoughts/



River Power Factsheets

Appendix 2

- Amu Darya
- Brahmaputra
- Ganges
- Indus
- Irrawaddy
- Mekong
- Salween
- Tarim
- Yangtze
- Yellow

CWR

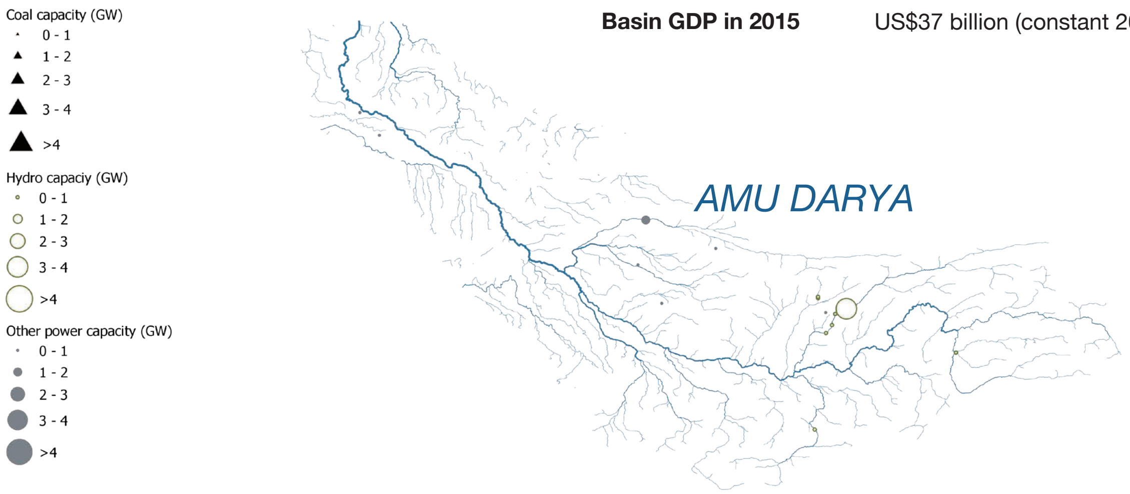
AMU DARYA RIVER

Amu Darya River, also called Amu or Amo River, is a major river in Central Asia. It originates from glaciers in the Pamir Mountains and Tian Shan, and flows 2,550km through four countries before emptying into the Aral Sea.

The river basin is especially vital for Tajikistan as sizeable population, economy and power installed capacity are clustered there. The Amu Darya is also materially important to Uzbekistan and Afghanistan, whilst Turkmenistan is less reliant on the basin. Hydropower and gas-fired power are the dominant power types on this river.

THE AMU DARYA RIVER BASIN

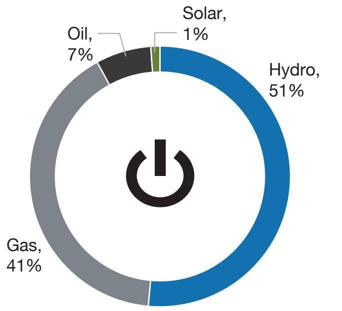
Length	2,550 km
Basin Area	0.52-0.65 million km^2
Annual flow	47-109 billion m^3
Flow through	Afghanistan, Tajikistan, Turkmenistan, Uzbekistan
Share of ice & snow melt in upper reach	N/A
Average surface water resources	52 billion m^3
Basin Population	28 million
Basin GDP in 2015	US$37 billion (constant 2010 price)



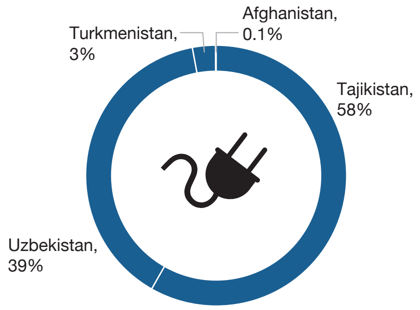
Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

9 GW OF INSTALLED POWER CAPACITY ON THE AMU DARYA

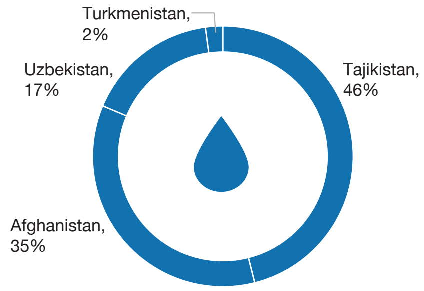
Installed capacity by power type



Installed capacity by country



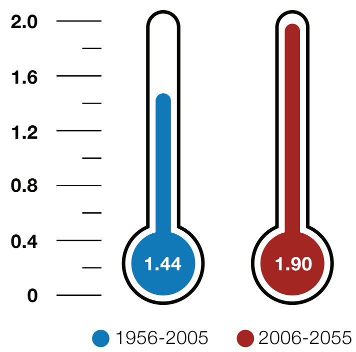
Surface water resources by country



CLIMATE CHANGE: PAST & FUTURE TREND

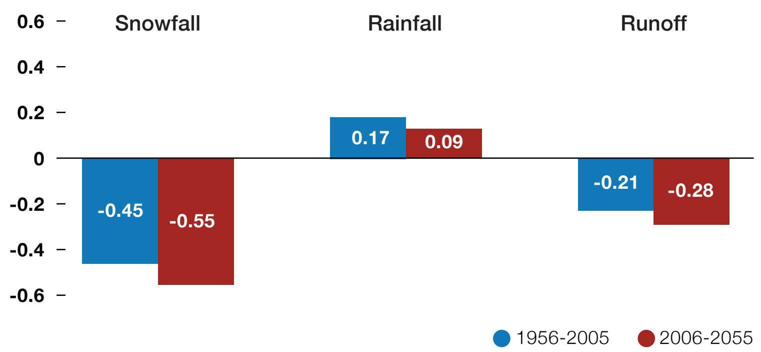
Temperature Change (°C)

(RCP4.5)



Hydrological Changes (mm/year)

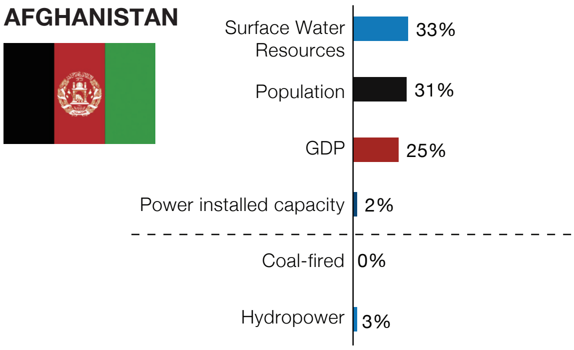
(RCP4.5)

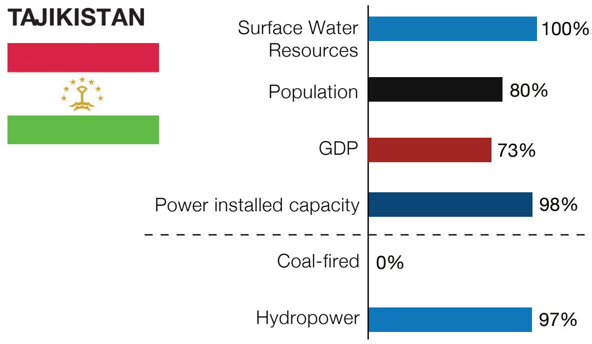


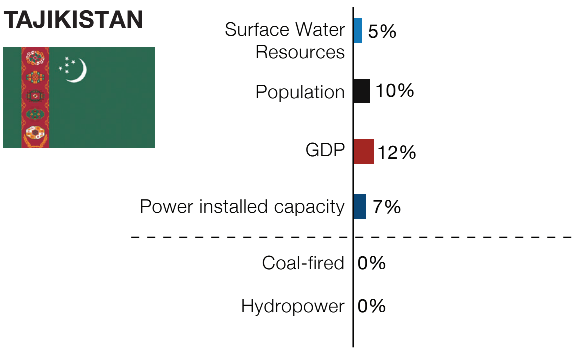
Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

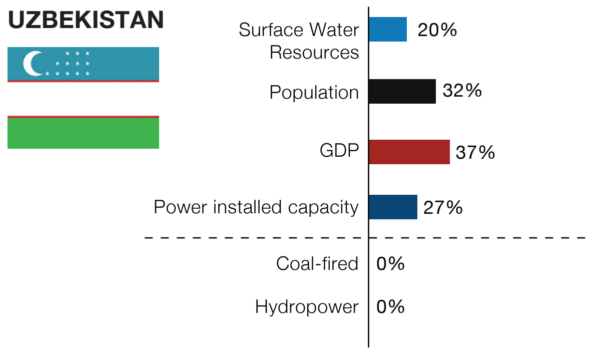
AMU DARYA RIVER

KEY COUNTRY EXPOSURE





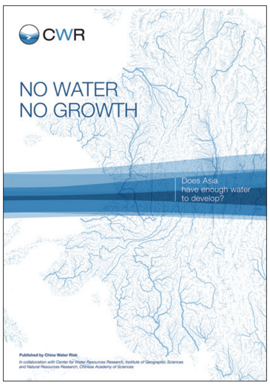




Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***



This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

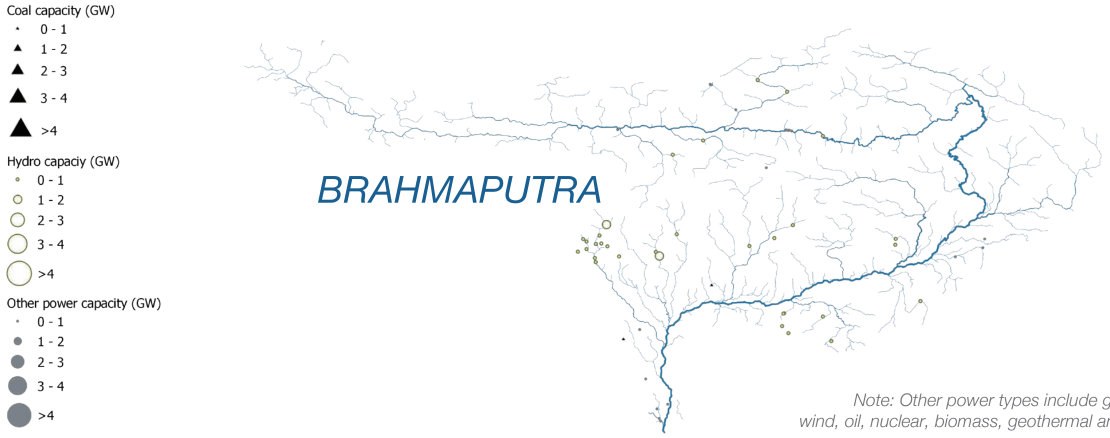
BRAHMAPUTRA RIVER

Brahmaputra River, also known as Yarlung Tsangpo, originates from the Angsi glacier in northern Himalayas in Tibet. Famous for its abundant water resources, it flows through China, Bhutan, India and finally Bangladesh, where it merges with the Ganges and later the Meghna before emptying into the Bay of Bengal.

The river is crucial for Bhutan as almost all its GDP as well as its entire population and power installed capacity are clustered there. Bangladesh is also significantly exposed to basin risks, whereas India and China (with the most GW in the basin) are less reliant from national perspectives. Installed capacity in this basin is dominated by hydropower.

THE BRAHMAPUTRA RIVER BASIN

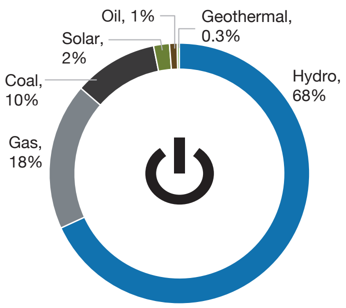
Length	2,896 km
Basin Area	0.53-0.65 million km²
Annual flow	538-815 billion m³
Flow through	China, India, Bhutan, Bangladesh
Share of ice & snow melt in upper reach	25-35% of runoff
Average surface water resources	550 billion m³
Basin Population	163 million
Basin GDP in 2015	US$168 billion (constant 2010 price)



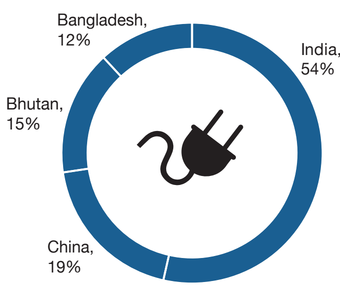
Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

10 GW OF INSTALLED POWER CAPACITY ON THE BRAHMAPUTRA

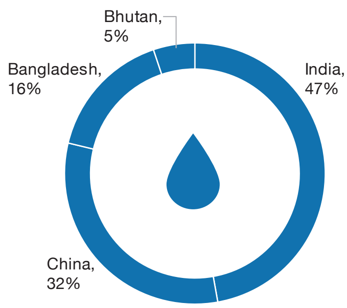
Installed capacity by power type



Installed capacity by country



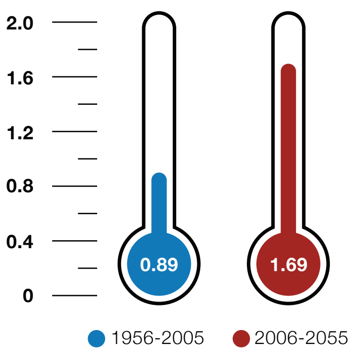
Surface water resources by country



CLIMATE CHANGE: PAST & FUTURE TREND

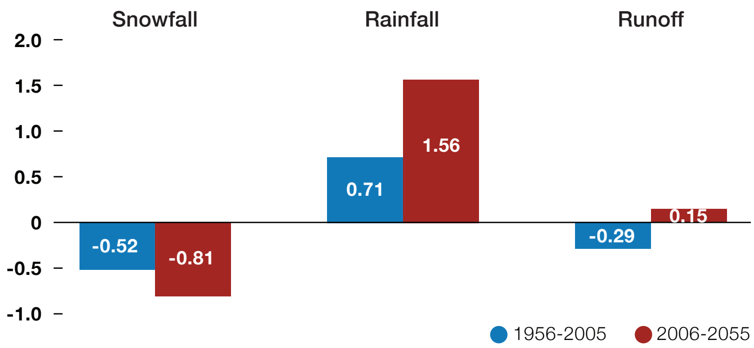
Temperature Change (°C)

(RCP4.5)



Hydrological Changes (mm/year)

(RCP4.5)

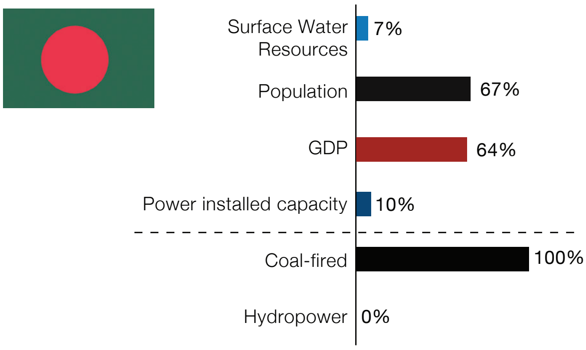


Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.

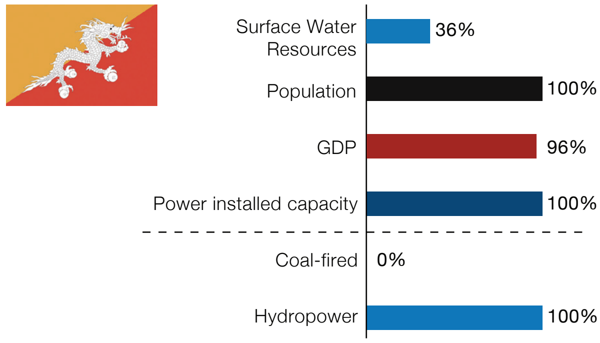
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

KEY COUNTRY EXPOSURE

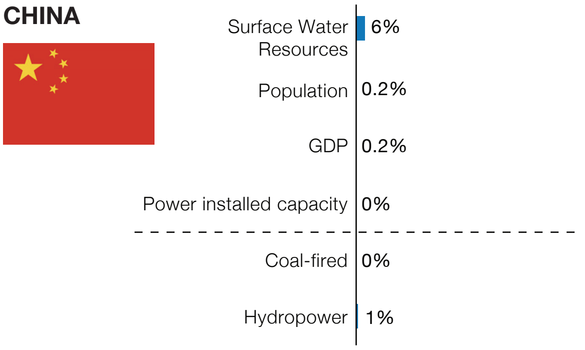
BANGLADESH



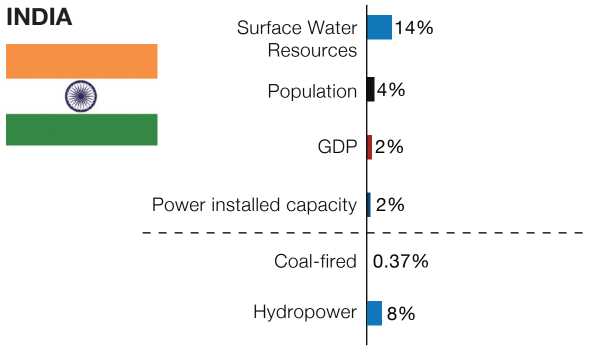
BHUTAN



CHINA



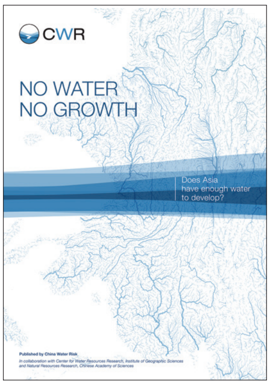
INDIA



Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***



This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

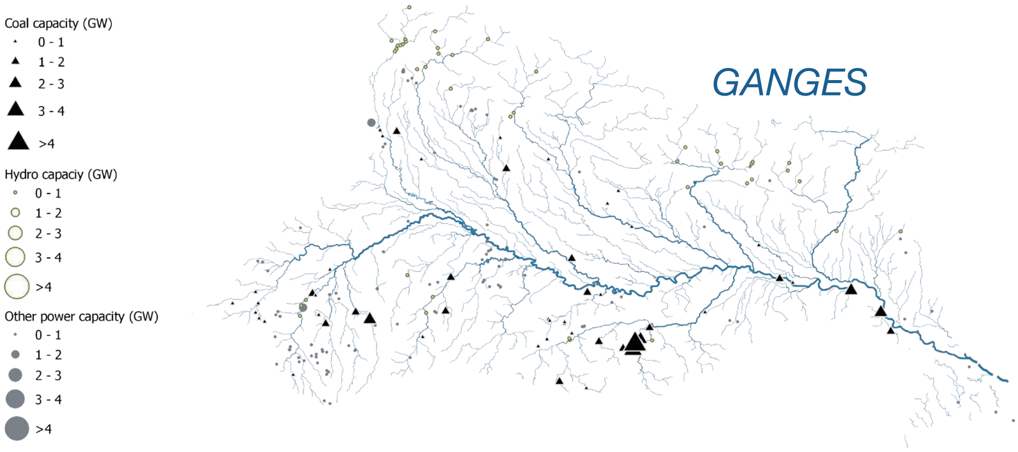
GANGES RIVER

The Ganges, also known as Ganga, is one of the most sacred rivers to Hindus. Starting in the western Himalayas in the Indian state of Uttarakhand, it flows south and east through the Gangetic Plain of North India, before emptying into the Bay of Bengal.

This basin is integral for Nepal as almost all its GDP and population as well as 100% of its power installed capacity are clustered there. However, it is India that has the most GW on this river and coal-fired power is the dominant power type along the Ganges. As India is also very reliant on the river, protecting the Ganges features in its Long-Term Low-Carbon Development Strategy & National Water Policies.

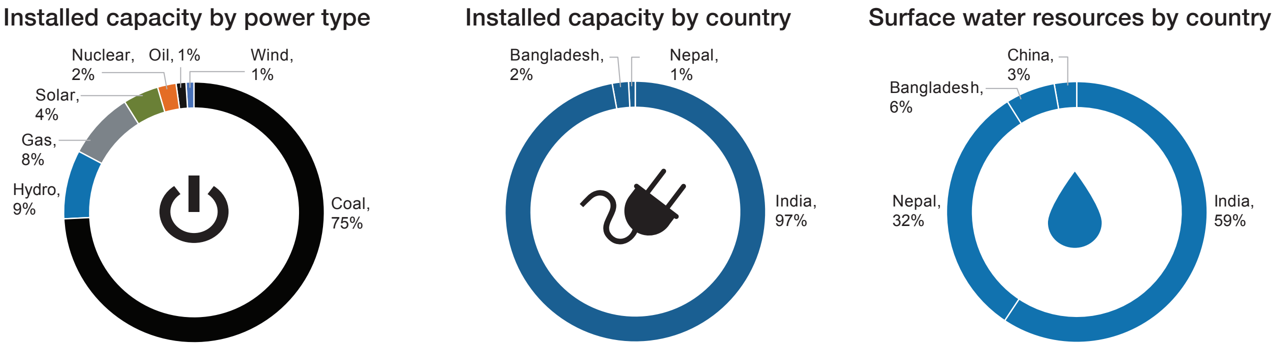
THE GANGES RIVER BASIN

Length	2,600 km
Basin Area	1.00-1.11 million km^2
Annual flow	318-422 billion m^3
Flow through	Bangladesh, China, India, Nepal
Share of ice & snow melt in upper reach	20% of runoff
Average surface water resources	388 billion m^3
Basin Population	614 million
Basin GDP in 2015	US$790 billion (constant 2010 price)

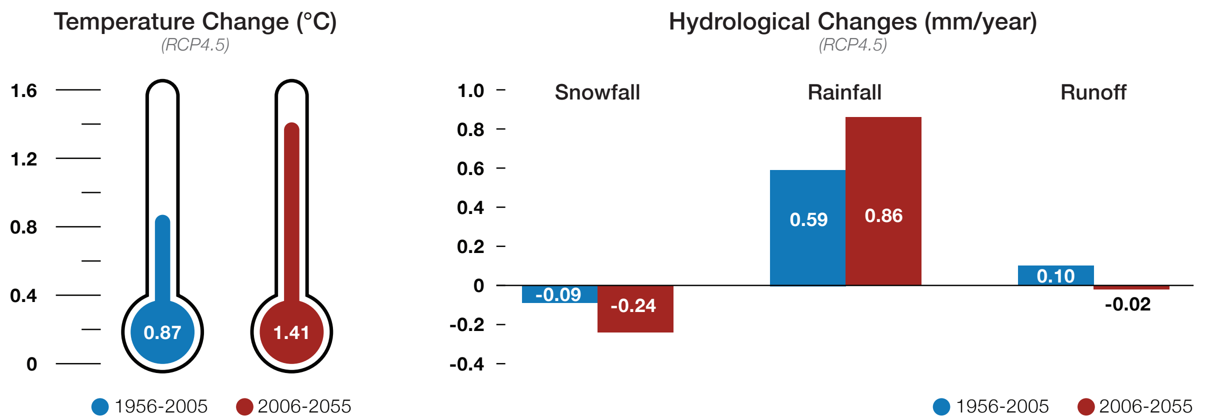


Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

70 GW OF INSTALLED POWER CAPACITY ON THE GANGES



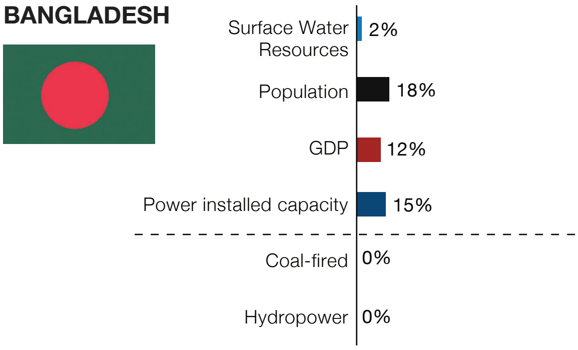
CLIMATE CHANGE: PAST & FUTURE TREND

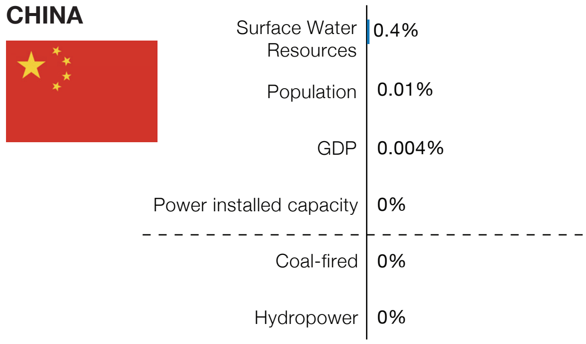


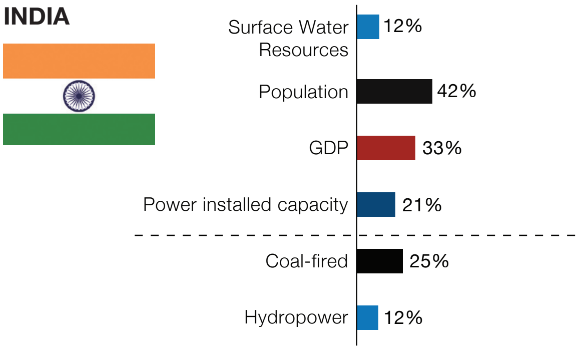
Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

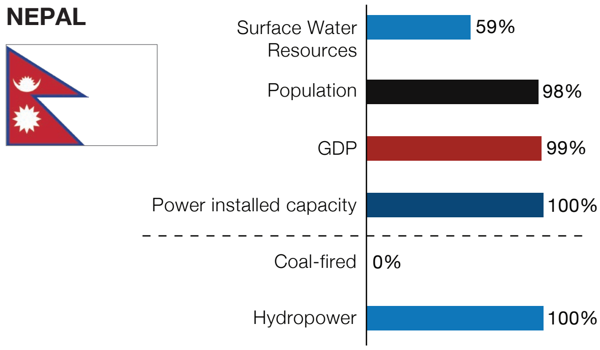
GANGES RIVER

KEY COUNTRY EXPOSURE





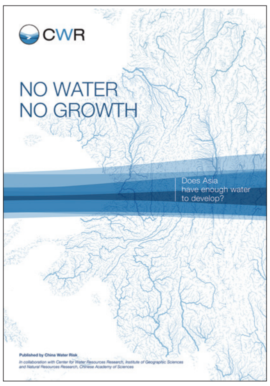




Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***



This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

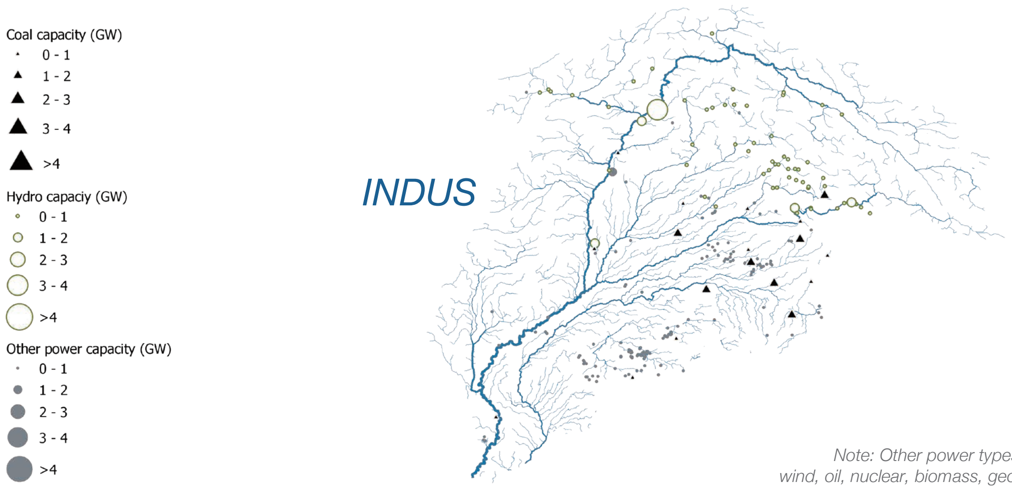
INDUS RIVER

Indus River originates from high mountain lakes on the Third Pole and runs through China, India, Afghanistan and Pakistan before emptying into the Arabian Sea.

The 2022 Indus floods devastated Pakistan: over 30mn people were displaced and its GDP was impacted by around 10%. Indeed, the Indus is crucial for Pakistan as significant shares of GDP, population and installed capacity are clustered there. The Indus is also important to Afghanistan while India with the most GW on the river is less reliant from a national perspective. Hydropower, followed by coal-fired power dominate power install capacity in this basin.

THE INDUS RIVER BASIN

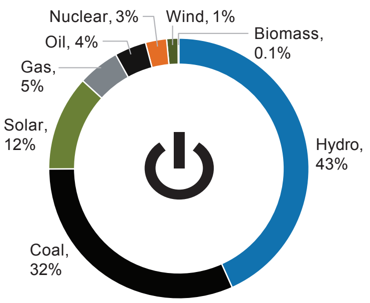
Length	2,880 km
Basin Area	1.08-1.26 million km^2
Annual flow	146-197 billion m^3
Flow through	Afghanistan, China, India, Pakistan
Share of ice & snow melt in upper reach	62-79% of runoff
Average surface water resources	155 billion m^3
Basin Population	276 million
Basin GDP in 2015	US$380 billion (constant 2010 price)



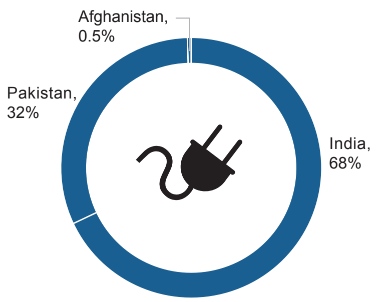
Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

51 GW OF INSTALLED POWER CAPACITY ON THE INDUS

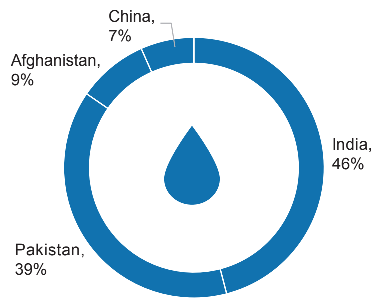
Installed capacity by power type



Installed capacity by country



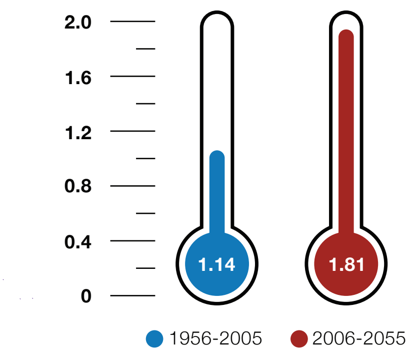
Surface water resources by country



CLIMATE CHANGE: PAST & FUTURE TREND

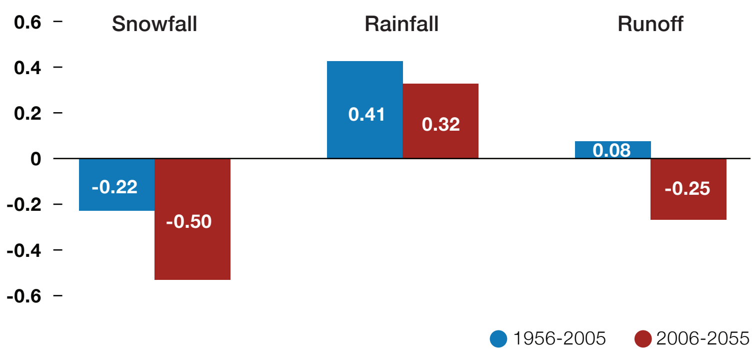
Temperature Change (°C)

(RCP4.5)



Hydrological Changes (mm/year)

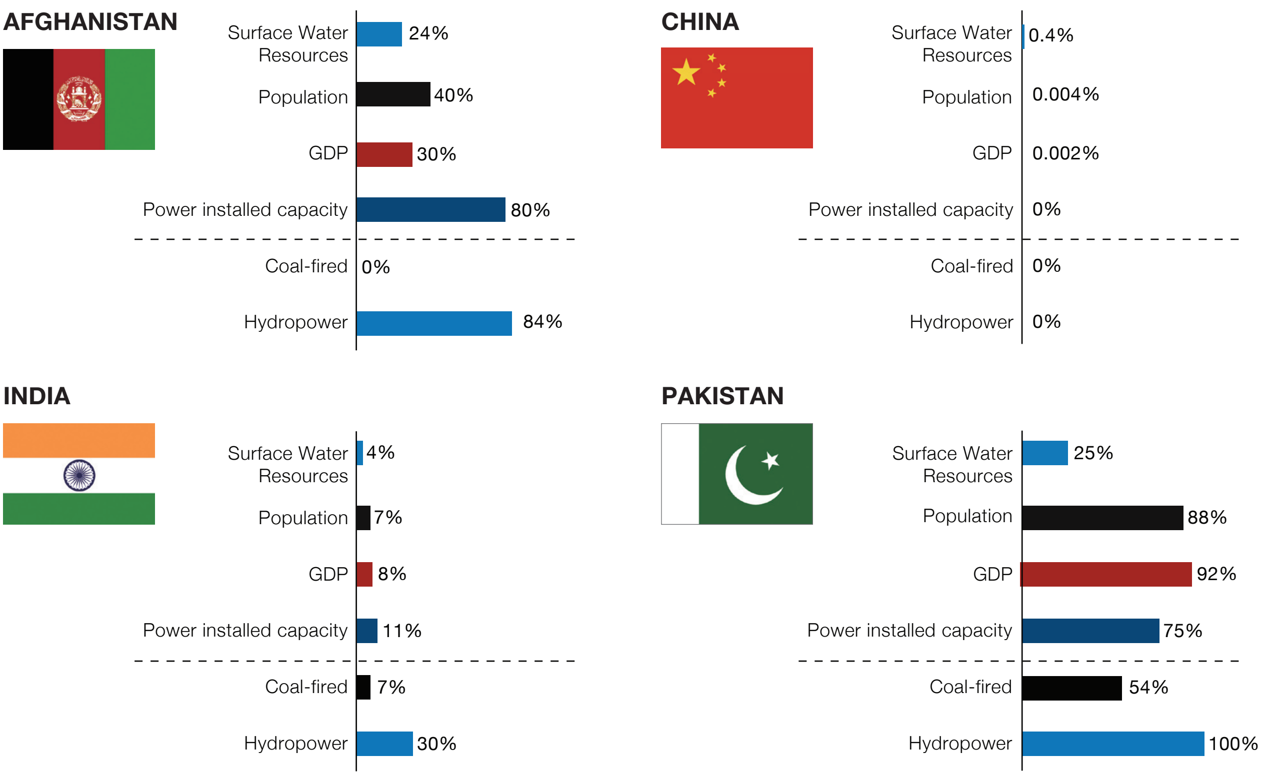
(RCP4.5)



Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

INDUS RIVER

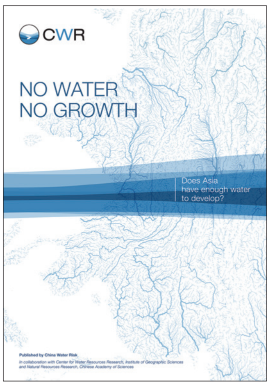
KEY COUNTRY EXPOSURE



Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***

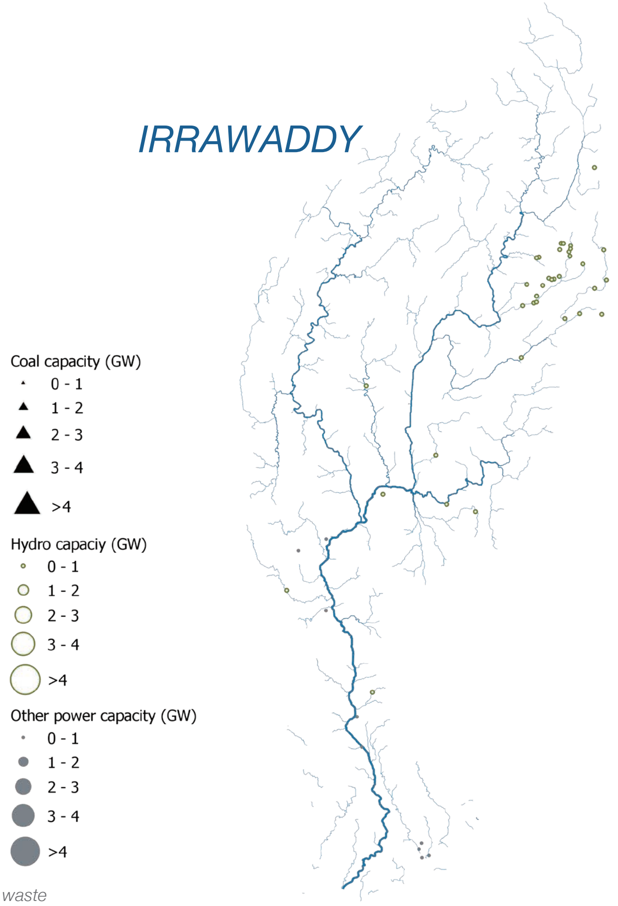


This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

IRRAWADDY RIVER

Irrawaddy River, also spelt as Ayeyarwady or Ayeyarwaddy, flows from north to south mainly through Myanmar and empties into the Andaman Sea.

With only a tiny portion of the river in China, the Irrawaddy is the largest river in Myanmar and sizeable shares of its population, GDP and installed capacity are clustered there. The river is also the most important waterway for transportation. Hydropower dominates the power generation capacity in this river basin.



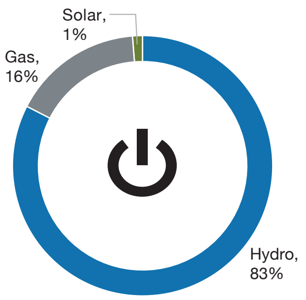
THE IRRAWADDY RIVER BASIN

Length	2,300 km
Basin Area	0.40-0.43 million km^2
Annual flow	343-566 billion m^3
Flow through	China, India, Myanmar
Share of ice & snow melt in upper reach	N/A
Average surface water resources	344 billion m^3
Basin Population	30 million
Basin GDP in 2015	US$38 billion (constant 2010 price)

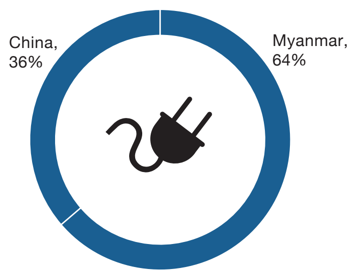
Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

4 GW OF INSTALLED POWER CAPACITY ON THE IRRAWADDY

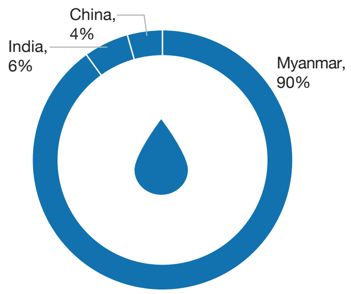
Installed capacity by power type



Installed capacity by country



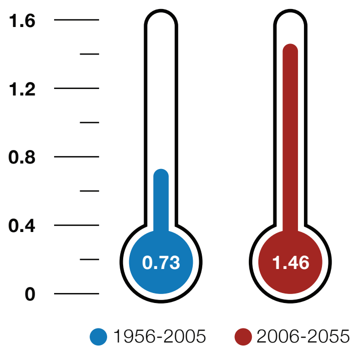
Surface water resources by country



CLIMATE CHANGE: PAST & FUTURE TREND

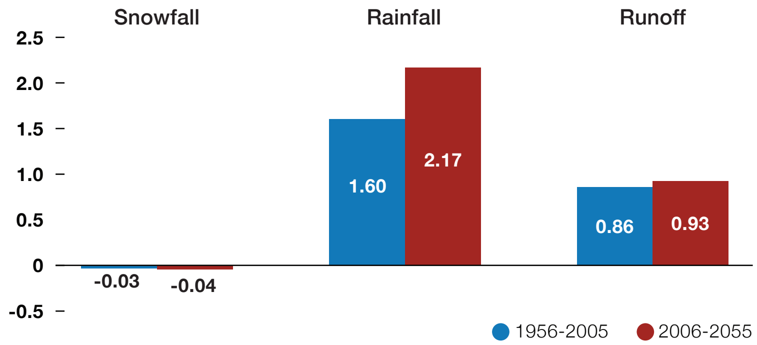
Temperature Change (°C)

(RCP4.5)



Hydrological Changes (mm/year)

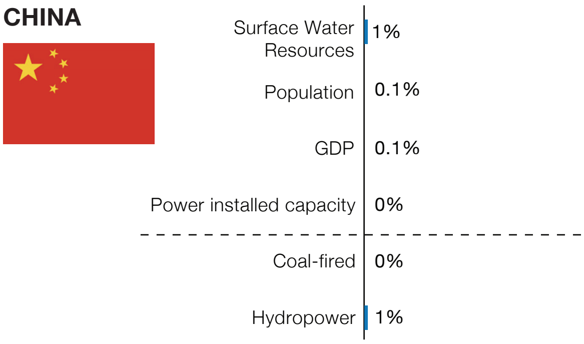
(RCP4.5)

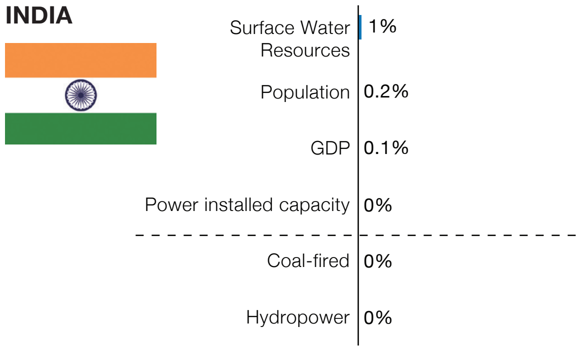


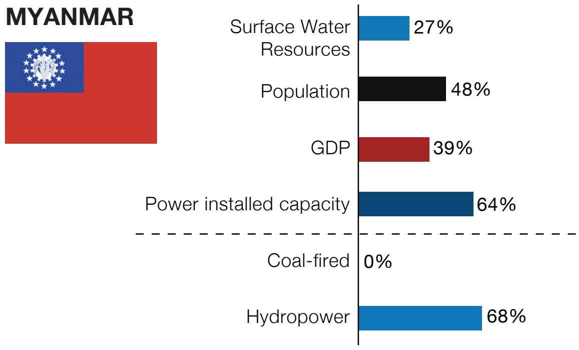
Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

IRRAWADDY RIVER

KEY COUNTRY EXPOSURE



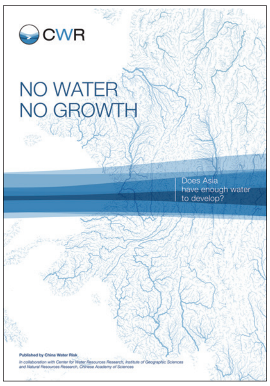




Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***

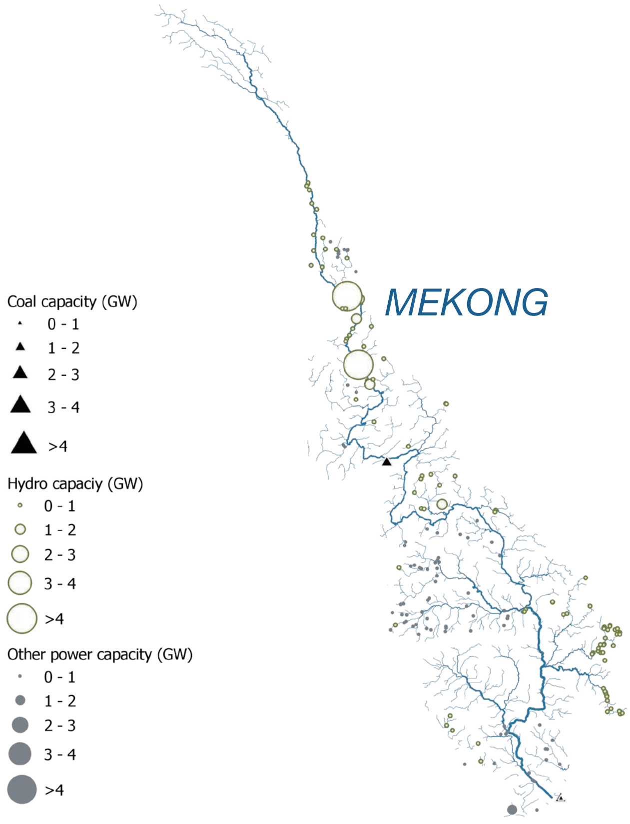


This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

MEKONG RIVER

Mekong River flows over 4,800 km through six countries. Due to its seasonal variation in water level and the range of wetland habitats, the river is rich in biodiversity and productivity. The ecosystems supported by the river are fundamental to the viability of natural resource-based rural livelihoods of a population of 60mn people living in the Lower Mekong Basin.

To achieve optimal basin development, the six riparian countries are cooperating through various stakeholder groups such as the Lancang-Mekong Cooperation & the Mekong River Commission. Together, they are working to expand beyond transboundary water management to include improving connectivity, production capacity, economic cooperation, agriculture, water resource management and poverty alleviation. Hydropower clearly dominates the power generation capacity in this river basin.



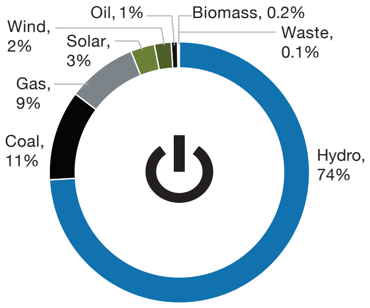
Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

THE MEKONG RIVER BASIN

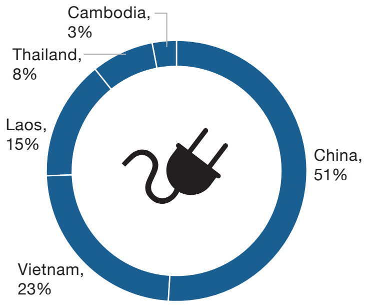
Length	4,800 km
Basin Area	0.81-0.90 million km²
Annual flow	390-492 billion m³
Flow through	China, Myanmar, Laos, Thailand, Cambodia, Vietnam
Share of ice & snow melt in upper reach	22-33% of runoff
Average surface water resources	588 billion m³
Basin Population	57 million
Basin GDP in 2015	US$160 billion (constant 2010 price)

34 GW OF INSTALLED POWER CAPACITY ON THE MEKONG

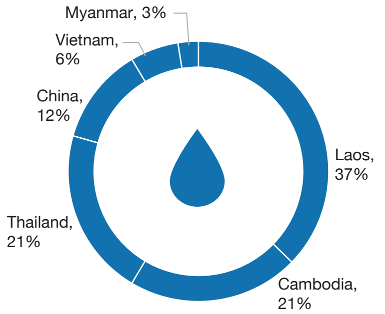
Installed capacity by power type



Installed capacity by country

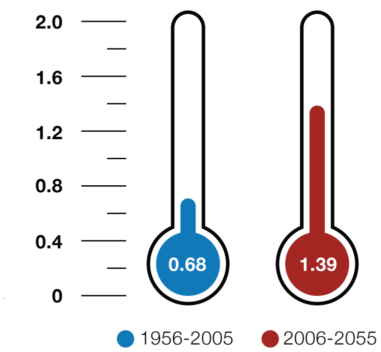


Surface water resources by country

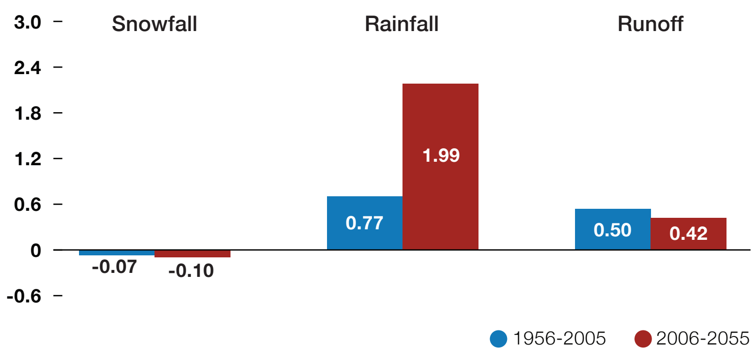


CLIMATE CHANGE: PAST & FUTURE TREND

Temperature Change (°C)
(RCP4.5)



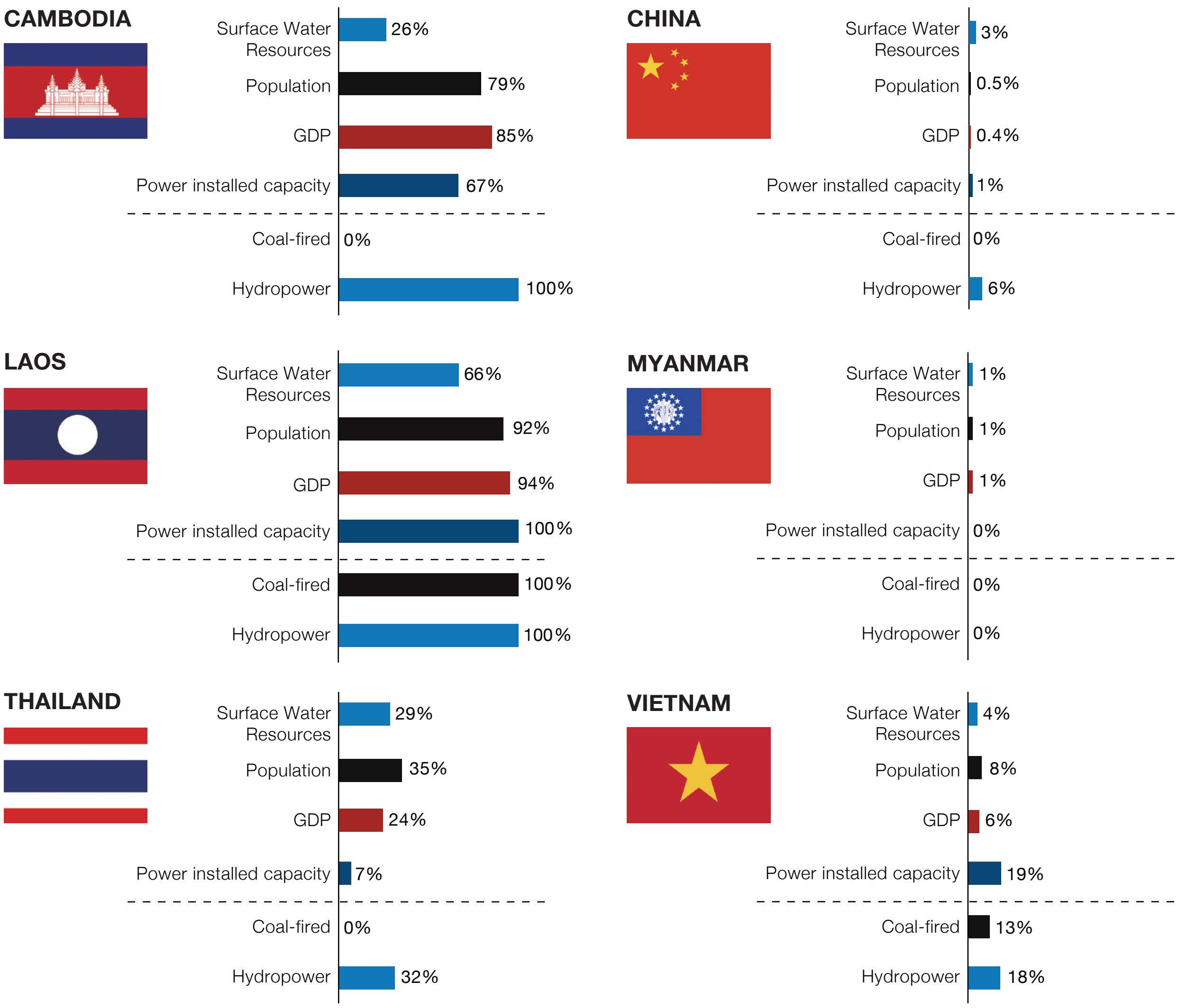
Hydrological Changes (mm/year)
(RCP4.5)



Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

MEKONG RIVER

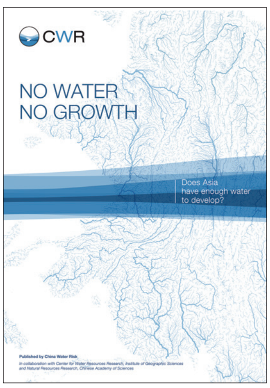
KEY COUNTRY EXPOSURE



Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***



This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

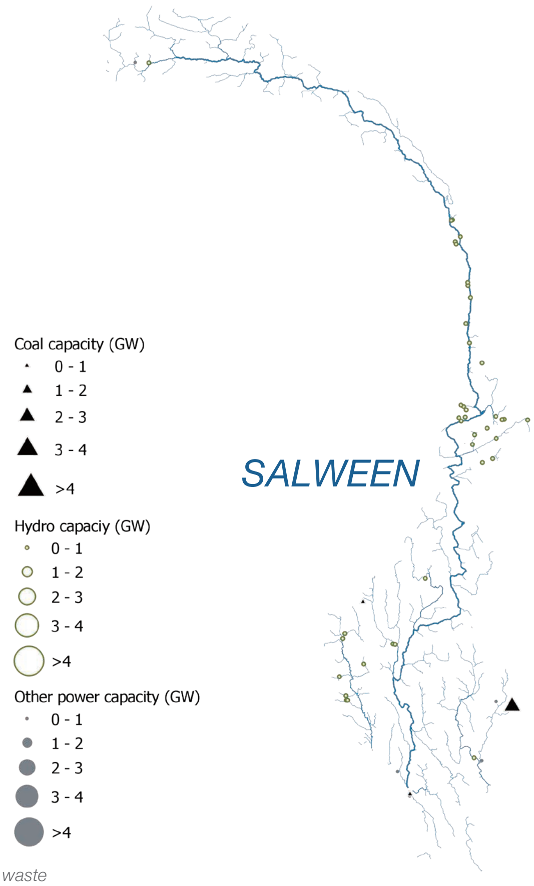
SALWEEN RIVER

Salween River, also known as Nu River in China, cuts through rugged mountainous regions in the Tibetan Plateau and Yunnan Province in China, and then flows through Myanmar and Thailand before emptying into the Andaman Sea.

Although Thailand has the most GW on the Salween, of the three riparian countries, this river is most important for Myanmar, followed by Thailand; China is the least reliant. Coal-fired power has the largest share of GW in this the river basin followed by hydropower.

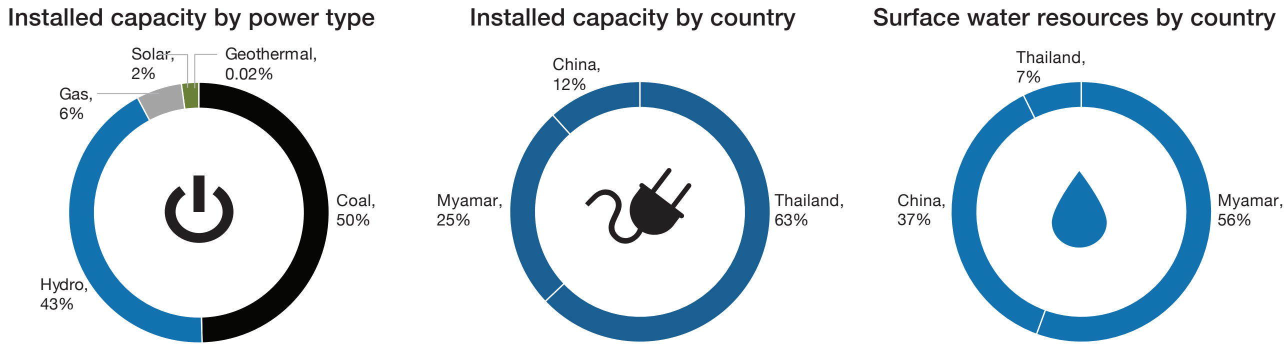
THE SALWEEN RIVER BASIN

Length	2,400 km
Basin Area	0.27-0.36 million km²
Annual flow	114-207 billion m³
Flow through	China, Myanmar, Thailand,
Share of ice & snow melt in upper reach	25-36% of runoff
Average surface water resources	140 billion m³
Basin Population	9 million
Basin GDP in 2015	US$23 billion (constant 2010 price)

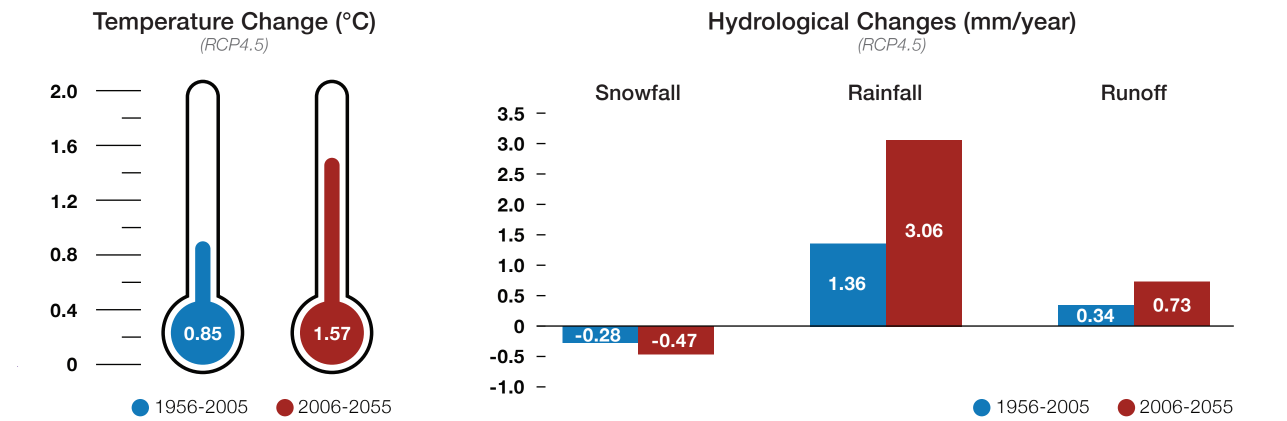


Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

5 GW OF INSTALLED POWER CAPACITY ON THE SALWEEN



CLIMATE CHANGE: PAST & FUTURE TREND



Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

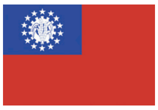
SALWEEN RIVER

KEY COUNTRY EXPOSURE

CHINA

Surface Water Resources	2%
Population	0.3%
GDP	0.2%
Power installed capacity	0.04%
Coal-fired	0%
Hydropower	0.2%

MYANMAR



Surface Water Resources	7%
Population	9%
GDP	6%
Power installed capacity	33%
Coal-fired	100%
Hydropower	31%

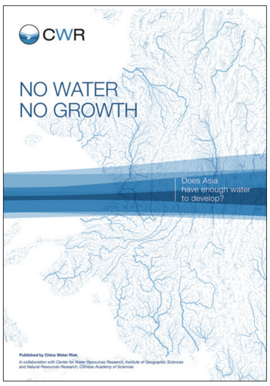
THAILAND

Surface Water Resources	2%
Population	0.8%
GDP	0.4%
Power installed capacity	8%
Coal-fired	46%
Hydropower	20%

Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***



This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

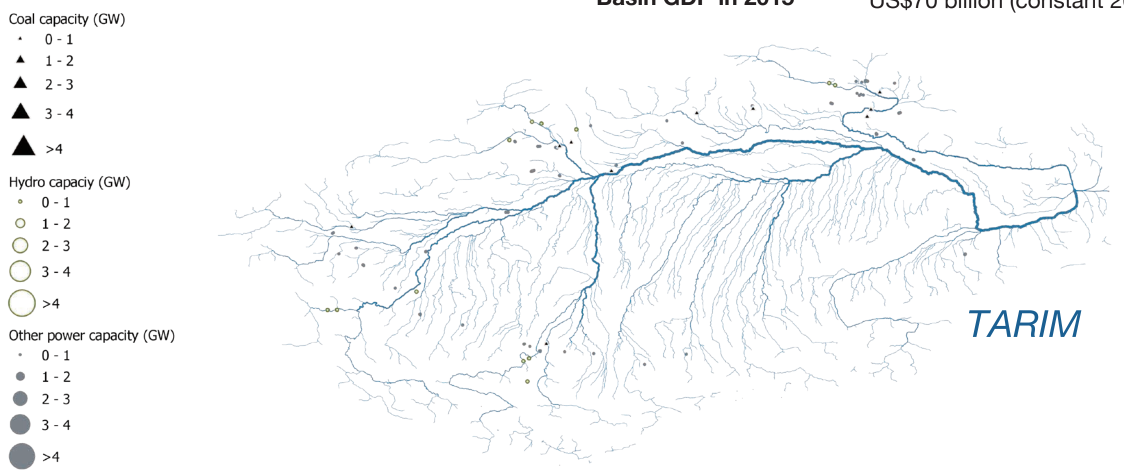
TARIM RIVER

Tarim River is the main river in the Tarim Basin, a desert region between the Tian Shan and Kunlun Mountains. The main river and most of its tributaries originate in the Karakorum and Kunlun Mountains. It is also the longest inland river in China.

Both riparian countries face low risk and reliance on the Tarim from a national perspective as tiny shares of population, GDP and power installed capacity are clustered along the river. That said, the river is very important to China's Xinjiang Uygur Autonomous Region. In 1991, the Tarim River Basin Bureau was set up to coordinate and manage its ecological protection.

THE TARIM RIVER BASIN

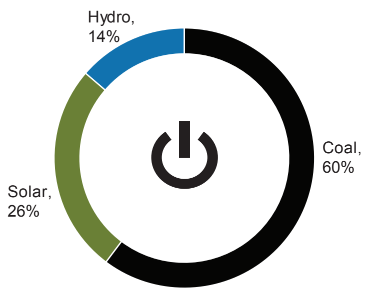
Length	1,321 km
Basin Area	0.93-1.15 million km^2
Annual flow	10-43 billion m^3
Flow through	China, Kyrgyzstan
Share of ice & snow melt in upper reach	42% of runoff
Average surface water resources	27 billion m^3
Basin Population	11 million
Basin GDP in 2015	US$70 billion (constant 2010 price)



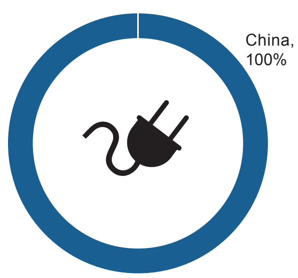
Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

10 GW OF INSTALLED POWER CAPACITY ON THE TARIM

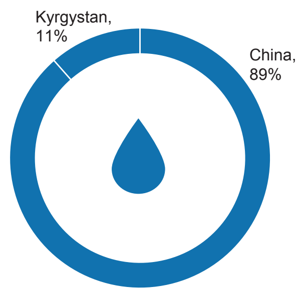
Installed capacity by power type



Installed capacity by country

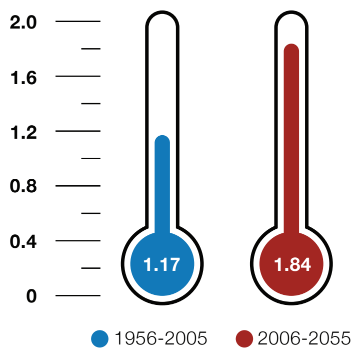


Surface water resources by country

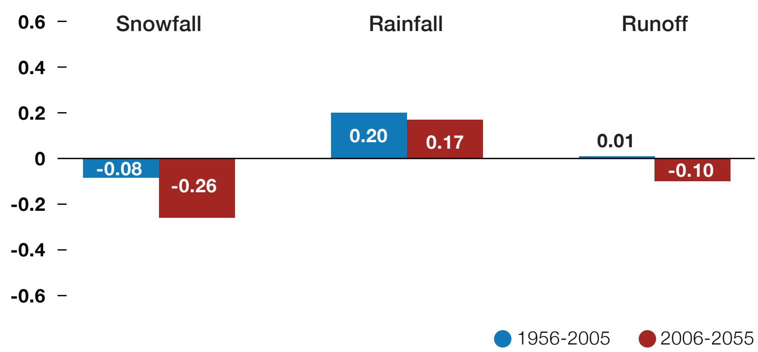


CLIMATE CHANGE: PAST & FUTURE TREND

Temperature Change (°C)
(RCP4.5)



Hydrological Changes (mm/year)
(RCP4.5)



Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

TARIM RIVER

KEY COUNTRY EXPOSURE

CHINA

Surface Water Resources	1%
Population	1%
GDP	1%
Power installed capacity	1%
Coal-fired	1%
Hydropower	1%

KYRGYZSTAN

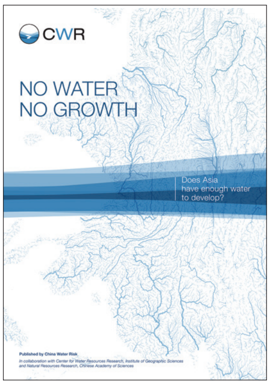
Surface Water Resources	15%
Population	1%
GDP	1%
Power installed capacity	0%
Coal-fired	0%
Hydropower	0%


Photo by Dreamstime

Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***



This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

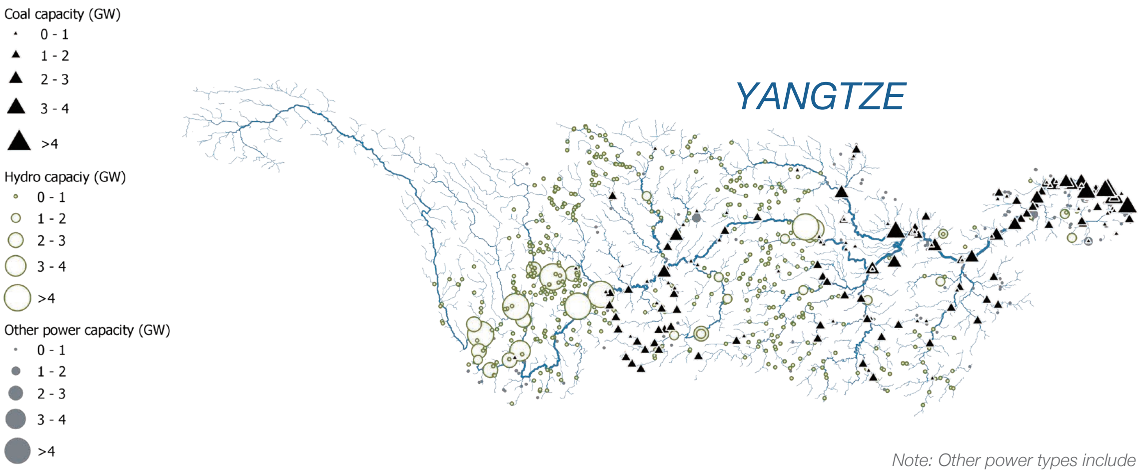
YANGTZE RIVER

Yangtze River is the longest river in China and the third longest in the world. Originating from the Tanggula Mountain Pass on top of the Qinghai Tibetan Plateau, it is a natural dividing line between the North and the South, and runs over 6,300km before reaching the East China Sea near Shanghai.

Beyond the basin, there is the Yangtze River Economic Belt (YREB) comprising the 9 provinces and 2 municipalities along the river; close to 600mn people live in the YREB. The YREB is not just China's socio-economic powerhouse, but the heart of global supply chains. Coal-fired power and hydropower are the key power types on this river.

THE YANGTZE RIVER BASIN

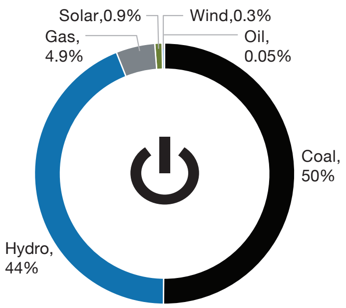
Length	6,300 km
Basin Area	1.72-2.07 million km^2
Annual flow	666-971 billion m^3
Flow through	China
Share of ice & snow melt in upper reach	29% of runoff
Average surface water resources	937 billion m^3
Basin Population	458 million
Basin GDP in 2015	US$1,981 billion (constant 2010 price)



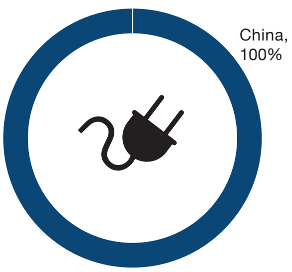
Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

373 GW OF INSTALLED POWER CAPACITY ON THE YANGTZE

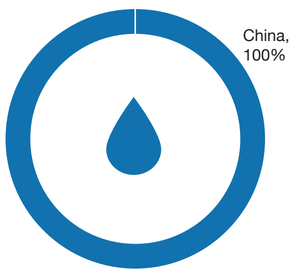
Installed capacity by power type



Installed capacity by country

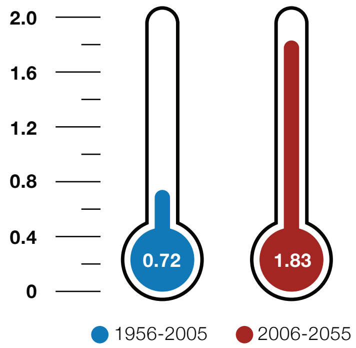


Surface water resources by country

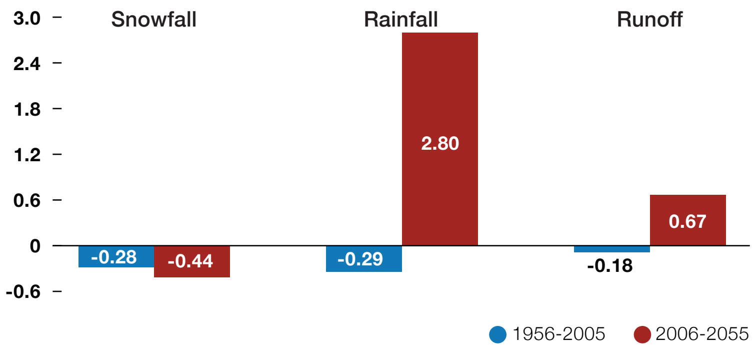


CLIMATE CHANGE: PAST & FUTURE TREND

Temperature Change (°C)
(RCP4.5)



Hydrological Changes (mm/year)
(RCP4.5)



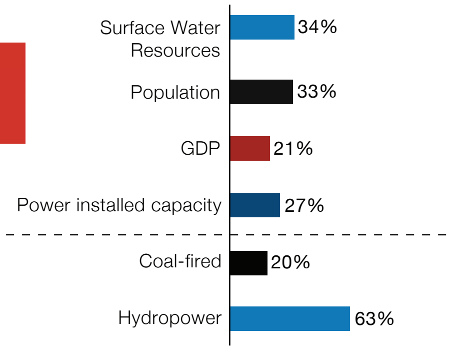
Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.

This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

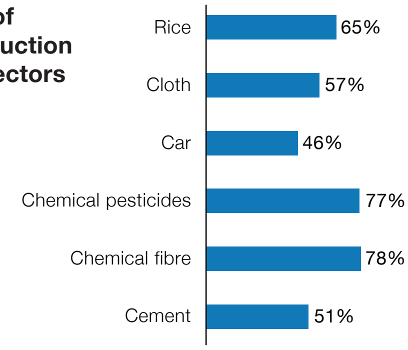
YANGTZE RIVER

KEY COUNTRY EXPOSURE

CHINA

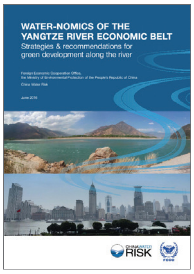


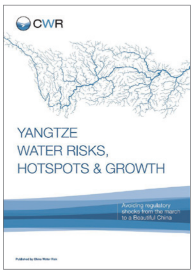
YREB share of national production across key sectors



The Yangtze River and the provinces and municipalities it serves (YREB) are clearly important to China. In addition to the above shares of national production, the YREB also houses over 40% of China's population and GDP. For perspective, if the YREB was treated as a country, it would have ranked 3rd in the terms of population; it would also be the 3rd largest economy in the world. It is not surprising then that President Xi set this river on a holistic path of ecological protection and green development. Since 2014, various policies have been introduced along the river including the setting of waternomic targets (GDP targets tied to water use and water pollution) for each province and municipality.

Read more on the Yangtze River policies and actions from CWR's ***"Water-nomics of the Yangtze River Economic Belt"*** – CWR co-authored this report with the Foreign Economic Cooperation Office of the Ministry of Environmental Protection of the People's Replublic of China; and our co-authored article ***"Benchmarking Water Resource & Water Environment Indicators for Policy Strategies in the Yangtze River Economic Belt." (长江经济带水资源水环境指标评估及对策)*** in the Journal of Beijing Normal University (Natural Science). In addtion check out CWR's report: ***"Yangtze Water Risks, Hotspots & Growth – Avoiding regulatory shocks from the march to a Beautiful China"***.

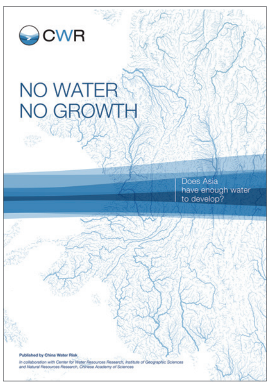




Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***



This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

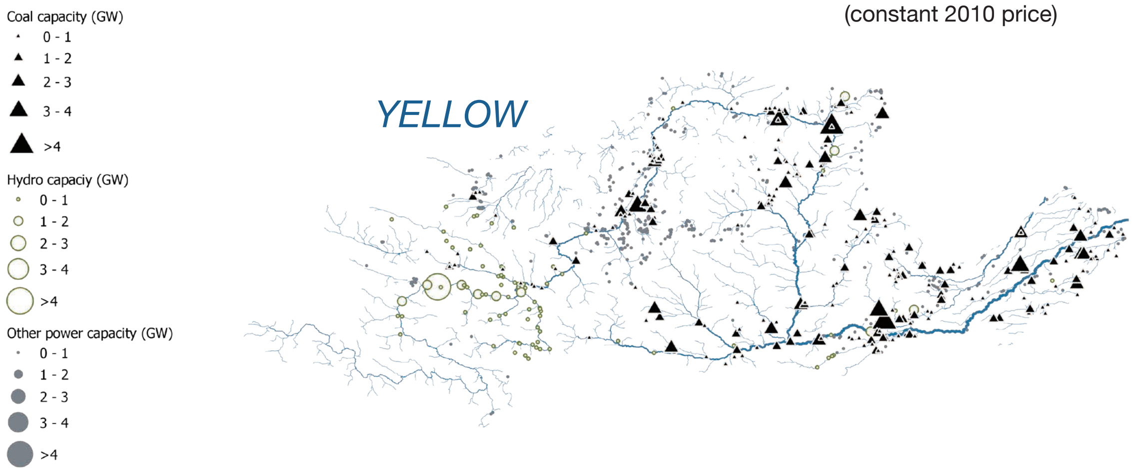
YELLOW RIVER

Yellow River is the second longest river in China and originates from the Yueguzonglie Basin on the Qinghai-Tibet Plateau. It flows over 5,400km through Losses Plateau and the North China Plain before entering the Bohai Sea.

The Yellow River, considered the "mother river" of the Chinese civilization and like the Yangtze, it is prioritised for ecological protection. The river flows through 7 provinces and 2 autonomous regions which are home to the North China Plain, China's key coal bases as well as the world's largest rare earth mine.

THE YELLOW RIVER BASIN

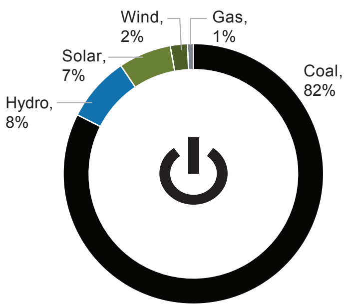
Length	5,400 km
Basin Area	0.76-1.07 million km^2
Annual flow	50-107 billion m^3
Flow through	China
Share of ice & snow melt in upper reach	23% of runoff
Average surface water resources	66 billion m^3
Basin Population	275.8 million
Basin GDP in 2015	US$696 billion (constant 2010 price)



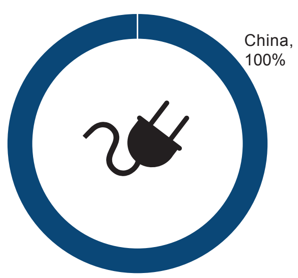
Note: Other power types include gas, solar, wind, oil, nuclear, biomass, geothermal and waste

301 GW OF INSTALLED POWER CAPACITY ON THE YELLOW

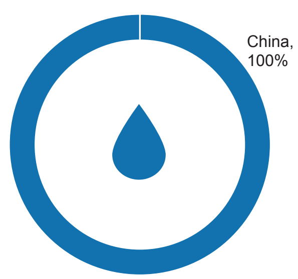
Installed capacity by power type



Installed capacity by country

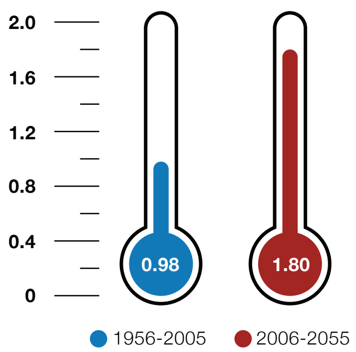


Surface water resources by country

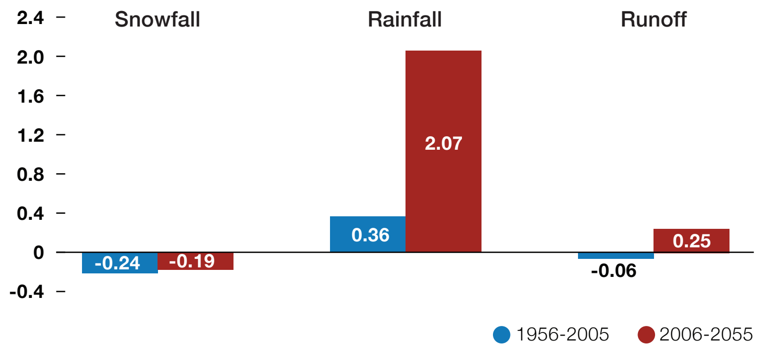


CLIMATE CHANGE: PAST & FUTURE TREND

Temperature Change (°C)
(RCP4.5)



Hydrological Changes (mm/year)
(RCP4.5)

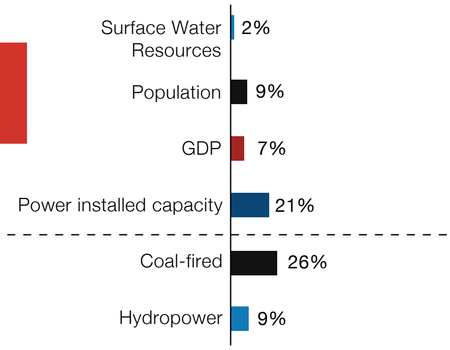


Source: CWR, CWR's Report "No Water, No Growth – Does Asia have enough water to develop?", 2018, Center for Water Resources Research, Chinese Academy of Sciences, Global Power Plant Database.
This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

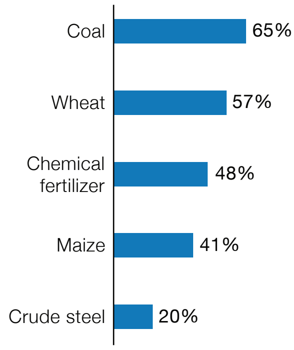
YELLOW RIVER

KEY COUNTRY EXPOSURE

CHINA



Share of national production across key sectors in the provinces/ autonomous regions along theYellow River



President Xi Jinping
2022 New Year Speech

"A Yellow River well harnessed is a millennia-long aspiration of the Chinese people. Over the past few years, I have visited all nine provinces or autonomous regions on the upper, middle and lower streams of the Yellow River.

From the Yellow River and the Yangtze River, two "mother rivers" of the Chinese nation, to the limpid Qinghai Lake and the mighty Yarlung Zangbo River; from the South-North Water Diversion, known as a project of the century, to the Saihanba forest, shown as a patch of green on the map; from the northward trek and homecoming of elephants in Yunnan Province, to the migration and return of Tibetan antelopes — all these remind us that "If we do not fail Nature, Nature shall never fail us""

In August 2022, China introduced the ***"Yellow River War-Action-Plan for Ecological and Management"***, which includes actions to safeguard the river. Subsequently, in October 2022, the Yellow River Protection Law, China's second legislation on a specific river basin after the Yangtze, was adopted.

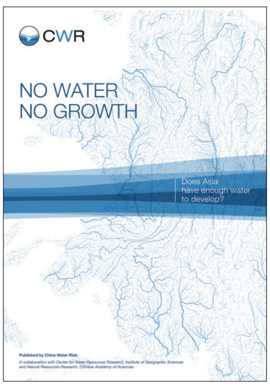
Key targets set for 2025 under this War-Action-Plan are:

- Forest coverage in the river basin area will reach 21.58%;
- Soil conservation rate will reach 67.74%;
- 700,000 hectares of natural forests will be restored;
- 1.36mn hectares of desertified land will be comprehensively treated;
- The proportion of surface water ≥Grade III water bodies will reach 81.9% while Grade V will be eliminated;
- The water quality in the upper & middle reaches of the Yellow (above Huayuankou) has reached Grade II, and the water quality of centralized drinking water sources in cities at and above the country level will be ≥Grade III; and
- The elimination rate of black and odorous water bodies in built- up areas will reach >90%.

Note: For consistency and comparability purposes, all power plant installed capacity data used in this factsheet including national power installed capacity are obtained from the Global Power Plant Database managed by the World Resources Institute. This database however, does not reflect the entire national power installed capacity and differs from actual government statistics – discrepancies can range from 2% in Vietnam to 59% in Afghanistan. The analysis in this factsheet while not 100% accurate will suffice in providing insights into the tight water-energy-climate nexus of the HKH 16 countries. For more please see "Global Power Plant Database vs. HKH 16 country statistics" in the CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023.

Source: CWR, CWR's report "No Water, No Growth – Does Asia have enough water to develop?" 2018, Global Power Plant Database.

Read more on this topic from CWR's 2018 Report ***"No Water, No Growth – Does Asia have enough water to develop?"***



This factsheet is part of CWR's 2023 Report, please read this with ***"No River, No Power – Can Asia's rivers power growth in a changing climate?"***

This factsheet is part of CWR's Report "No River, No Power – Can Asia's rivers power growth in a changing climate?" 2023 and should be read in conjunction with this report.

Abbreviations

ADB	Asian Development Bank
APAC	Asia & Pacific region
ASEAN	Association of Southeast Asian Nations
bn	billion
CAS-IGSNRR	Chinese Academy of Science – Institute of Geographic Sciences and Natural Resources Research
CCS	Carbon capture storage
CEC	China Electricity Council
CO2	Carbon dioxide
COP26	26th Conference of the Parties of the UNFCCC held in Glasgow
COP27	27th Conference of the Parties of the UNFCCC held in Egypt
CREA	Centre for Research on Energy and Clean Air
CWR	China Water Risk
CWR APACCT 20 Index	CWR APAC 20 Cities Coastal Threat Index
EDF	Électricité de France
EIA	U.S. Energy Information Administration
ESG	Environmental, Social, and Corporate Governance
EU	European Union
FAO	Food and Agriculture Organization
FYP	Five Year Plan (China)
11FYP	11th Five Year Plan (2006—2010)
12FYP	12th Five Year Plan (2011—2015)
13FYP	13th Five Year Plan (2016—2020)
14FYP	14th Five Year Plan (2011—2025)
GBA	Greater Bay Area
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GLOF	Glacial lake outburst flood
$GtCO_2e$	Gigatonnes of equivalent carbon dioxide
G7	The international Group of Seven
GW	Gigawatt
GWh	Gigawatt hours
HKH	Hindu Kush Himalayas
10 HKH Rivers	Collectively the 10 major rivers that flow from the HKH: they are the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze & Yellow
10 HKH River Basins	The entire basin areas of the 10 HKH Rivers
HKH 16	Collectively the 16 countries that the 10 HKH Rivers flow through: they are Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Kyrgyzstan, Laos, Myanmar, Nepal, Pakistan, Tajikistan, Thailand, Turkmenistan, Uzbekistan & Vietnam.
ICCI	International Cryosphere Climate Initiative
IEA	International Energy Agency

IPCC	Intergovernmental Panel on Climate Change
IPCC AR6 WG1	IPCC Sixth Assessment Report Working Group 1 – Climate Change 2021: The Physical Science Basis
IPCC AR6 WG2	IPCC Sixth Assessment Report Working Group 2 – Climate Change 2022: Impacts, Adaptation and Vulnerability
IPCC AR6 WG3	IPCC Sixth Assessment Report Working Group 3 – Climate Change 2022: Mitigation of Climate Change
IRENA	International Renewable Energy Agency
km^2	Square kilometre
kW	Kilowatt
kWh	Kilowatt hour
LiFE	Lifestyle for Environment
LMC	Lancang-Mekong Cooperation
L/MWh	Litre per megawatt hour
LTLCDS	Long-Term Low-Carbon Development Strategy
mn	million
MRC	Mekong River Commission
MtCO2	Mega tonnes of carbon dioxide = 1 million metric tonnes
mu	Chinese unit of land measurement which is equivalent to $666.67m^2$
MW	Megawatt
MWh	Megawatt hour
NAPCC	National Action Plan on Climate Change
NDC	Nationally Determined Contributions
NDMA	National Disaster Management of Authority (Pakistani Government)
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NGFS	The Network for Greening the Financial System
NWNG	No Water, No Growth Report, CWR 2018
NWP	National Water Policy
ppm	Parts per million
PRC	People's Republic of China
PV	Photovoltaic
RBOs	River Basin Organisations
RCP	Representative Concentration Pathway
REITS	Real estate investment trust
SLR	Sea level rise
SSP	Shared Socioeconomic Pathways
TLG	The Lantau Group
trn	trillion
TW	Terawatt
TWh	Terawatt hour
UHV	Ultra High Voltage
UN	United Nations
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WRI	World Resources Institute
YREB	Yangtze River Economic Belt

References

[1] NGFS website. Membership. https://www.ngfs.net/en/about-us/membership. Accessed 30 Sep 2022

[2] UNEP (2022) Emissions Gap Report 2022: The Closing Window – Climate crisis calls for rapid transformation of societies. October 2022. https://www.unep.org/resources/emissions-gap-report-2022?gclid=CjwKCAjw5pShBhB_EiwAvmnNVxT99AAWQ9afKTXBZcyNCONaI9wtnIUNzoVXbk14Ik555a5yyphGgxoCkfEQAvD_BwE

[3] UN News. Countries' climate promises still not enough to avoid catastrophic global warming: UN Report. 26 October 2022. https://news.un.org/en/story/2022/10/1129892

[4] Vaidyanathan, G. (2022) Scientists welcome 'enormous' US climate bill-but call for stronger action. Nature.

[5] U.S. Energy Information Administration. U.S. crude oil production will increase to new records in 2023 and 2024. 25 January 2023.

[6] The Guardian article "UK offers new North Sea oil and gas licences despite climate concerns" by Alex Lawson, 7 October 2022. https://www.theguardian.com/business/2022/oct/07/uk-offers-new-north-sea-oil-and-gas-licences-despite-climate-concerns

[7] Energy article "Norwegian authorities expect up to 40 exploration wells this year" by Melisa Cavcic, 22 July 2022. https://www.offshore-energy.biz/norwegian-authorities-expect-up-to-40-exploration-wells-this-year/

[8] The Guardian article "'Monster profits' for energy giants reveal a self-destructive fossil fuel resurgence " by Oliver Milman. 9 February 2023. https://www.theguardian.com/environment/2023/feb/09/profits-energy-fossil-fuel-resurgence-climate-crisis-shell-exxon-bp-chevron-totalenergies?CMP=Share_iOSApp_Other

[9] CWR (2018) No Water, No Growth – Does Asia have enough water to develop?. https://www.chinawaterrisk.org/wp-content/uploads/2018/09/CWR-Report-No-Water-No-Growth.pdf

[10] International Cryosphere Climate Initiative (2021) State of Cryosphere 2021 – A Needed Decade of Urgent Action. https://iccinet.org/statecryo21/

[11] HKTDC (2021). RCEP: Asia as the Global Manufacturing Centre (Shutterstock.com). 02 December 2021. https://research.hktdc.com/en/article/OTE4NzMxNTMw

[12] Our World in Data. Primary energy consumption by world region. 2020. https://ourworldindata.org/grapher/primary-energyconsumption-by-region

[13] United Nations (2018). 68% of the world population projected to live in urban areas by 2050, says UN. 16 May 2018. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

[14] United Nations article "Around 2.5 billion more people will be living in cities by 2050, projects new UN report." https://www.un.org/en/desa/around-25-billion-more-people-will-be-living-cities-2050-projects-new-un-report

[15] Asian Development Bank. Energy Policy Review. https://www.adb.org/who-we-are/about/energy-policy-review

[16] WMO (2022). WMO update: 50:50 chance of global temperature temporarily reaching 1.5°C threshold in next five years. https://public.wmo.int/en/media/press-release/wmo-update-5050-chance-of-global-temperature-temporarily-reaching-15%C2%B0c-threshold. Published 9 May 2022.

[17] The World Bank website. GDP. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

[18] IEA (2022). Renewables 2022. Analysis and forecast to 2027. https://iea.blob.core.windows.net/assets/ada7af90-e280-46c4-a577-df2e4fb44254/Renewables2022.pdf

[19] Central Government of the People's Republic of China (www.gov.cn). "My country's renewable energy power generation installed capacity exceeds 1 billion kilowatts" (In Chinese) http://www.gov.cn/xinwen/2021-11/29/content_5653908.htm

[20] Statistica. Renewable energy in India - statistics & facts https://www.statista.com/topics/9608/renewable-energy-inindia/#topicOverview

[21] Carbon Brief article "Analysis: China's CO2 emissions fall by record 8% in second quarter of 2022" by Lauri Myllyvirta. 1 September 2022. https://www.carbonbrief.org/analysis-chinas-co2-emissions-fall-by-record-8-in-second-quarter-of-2022/#:~:text=China's%20carbon%20dioxide%20(CO2)%20emissions,in%20at%20least%20a%20decade

22 National Bureau of Statistics of China. Statistical Communiqué of the People's Republic of China on the 2022 National Economic and Social Development. http://www.stats.gov.cn/english/PressRelease/202302/t20230227_1918979.html

23 ADB (2020) Incorporating a Disaster Risk Financing and Insurance Framework into Country Management and Development Strategies. https://think-asia.org/bitstream/handle/11540/12694/adbi-pb2020-5.pdf?sequence=1

24 ADB (2020) Asian Water Development Outlook 2020: Advancing Water Security across Asia and the Pacific. https://www.adb.org/sites/default/files/publication/663931/awdo-2020.pdf

25 McKinsey Sustainability (2020) Climate risk and response in Asia. https://www.mckinsey.com/capabilities/sustainability/our-insights/climate-risk-and-response-in-asia#/

26 WMO (2020) State of the Climate in Asia 2020. https://public.wmo.int/en/media/press-release/weather-and-climate-extremes-asia-killed-thousands-displaced-millions-and-cost

27 Ocean Policy Research Institute. Ocean Newsletter. No.34. January 5 2002. https://www.spf.org/en/opri/newsletter/34_2.html?full=34_2%20

28 Jin, Y., Behrens, P., Tukker, A., & Scherer, L. (2019). Water use of electricity technologies: A global meta-analysis. Renewable and Sustainable Energy Reviews, 115, 109391.

29 Demeke, T. A., Marence, M., & Mynett, A. E. (2013). Evaporation from reservoirs and the hydropower water footprint. proceedings from Africa, 16-18.

30 Liu, J., Zhao, D., Gerbens-Leenes, P. W., & Guan, D. (2015). China's rising hydropower demand challenges water sector. *Scientific reports, 5*(1), 1-14.

31 Fthenakis, V., & Kim, H. C. (2010). Life-cycle uses of water in US electricity generation. *Renewable and Sustainable Energy Reviews, 14*(7), 2039-2048.

32 Meldrum, J., Nettles-Anderson, S., Heath, G., & Macknick, J. (2013). Life cycle water use for electricity generation: a review and harmonization of literature estimates. *Environmental Research Letters, 8*(1), 015031.

33 Peer, R. A., & Sanders, K. T. (2016). Characterizing cooling water source and usage patterns across US thermoelectric power plants: a comprehensive assessment of self-reported cooling water data. *Environmental Research Letters, 11*(12), 124030.

34 Gao, J., Zhao, P., Zhang, H., Mao, G., & Wang, Y. (2018). Operational water withdrawal and consumption factors for electricity generation technology in China - A literature review. Sustainability, 10(4), 1181.

35 CWR article "Rivers are Running Dry Today" by Debra Tan & Sophie Lam, 24 October 2022. https://www.chinawaterrisk.org/resources/analysis-reviews/rivers-are-running-dry-today/

36 CWR & IRENA (2016) Water Use in China's Power Sector: Impact of Renewables and Cooling Technologies to 2030. https://chinawaterrisk.org/wp-content/uploads/2016/02/CWR-IRENA-Water-Use-in-China-Power-Sector.pdf

37 CWR (2016) Rare Earths: Shades Of Grey – Can China Continue To Fuel Our Global Clean & Smart Future?. https://www.chinawaterrisk.org/notices/cwr-rare-earths-shades-of-grey/

38 The Guardian article "As drought shrivels Lake Powell, millions face power crisis" by Peter Yeung, 13 July 2022. https://www.theguardian.com/us-news/2022/jul/13/lake-powell-drought-electricity

39 The People's Government of Sichuan Province article "Why is there a power shortage in Sichuan, a major hydropower province?" (In Chinese) 18 August, 2022. https://www.sc.gov.cn/10462/10464/13722/2022/8/18/a041da76a6cd45b79b9f39d89b06187d.shtml

40 The Guardian article "Quiet flows the Po: the life and slow death of Italy's longest river" by Tobias Jones. 10 July 2022. https://www.theguardian.com/environment/2022/jul/10/po-river-italy-drought-climate

41 CNBC article "Europe's evaporating rivers wreak havoc for food and energy production ahead of winter" by Sam Meredith. 1 September 2022. https://www.cnbc.com/2022/09/01/europes-evaporating-rivers-wreak-havoc-for-food-and-energy-production.html

42 STCN article "The drought in the Yangtze River Basin has caused the water level of many rivers to drop, and 66 rivers in Chongqing have stopped flowing" (In Chinese) by Cheng Dafa. 19 August 2022. https://news.stcn.com/news/202208/t20220819_4808916.html

CWR

[43] The Guardian article "EDF cuts output at nuclear power plants as French rivers get too warm" by Julia Kollewe. 3 August 2022. https://www.electropages.com/blog/2022/08/edf-restricts-nuclear-power-france-rivers-are-too-darnhot#:~:text=If%20the%20collected%20water%20becomes,in%20France%20due%20to%20heatwaves

[44] Gulf Time article "After Goni, Philippines braces for storm Astani", 3 November 2020. https://www.pressreader.com/qatar/gulf-times/20201103/281891595787013

[45] National Development and Reform Commission, National Energy Administration of the People's Republic of China (2022) 14th Five Year Plan on Modern Energy System Planning. https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202203/P020220322582066837126.pdf

[46] Ministry of Natural Resources of the People's Republic of China (2022) China Sea Level Bulletin 2021. https://www.nmdis.org.cn/hygb/zghpmgb/2021nzghpmgb/

[47] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001.

[48] Bartos, M. D., & Chester, M. V. (2015). Impacts of climate change on electric power supply in the Western United States. Nature Climate Change, 5(8), 748-752

[49] Liu, L., Hejazi, M., Li, H., Forman, B., & Zhang, X. (2017). Vulnerability of US thermoelectric power generation to climate change when incorporating state-level environmental regulations. Nature Energy, 2(8), 1-5.

[50] Van Vliet, M. T., Yearsley, J. R., Ludwig, F., Vögele, S., Lettenmaier, D. P., & Kabat, P. (2012). Vulnerability of US and European electricity supply to climate change. Nature Climate Change, 2(9), 676-681.

[51] Van Vliet, M. T., Wiberg, D., Leduc, S., & Riahi, K. (2016). Power-generation system vulnerability and adaptation to changes in climate and water resources. Nature Climate Change, 6(4), 375-380.

[52] Wang, Y., Byers, E., Parkinson, S., Wanders, N., Wada, Y., Mao, J., & Bielicki, J. M. (2019). Vulnerability of existing and planned coal-fired power plants in Developing Asia to changes in climate and water resources. Energy & Environmental Science, 12(10), 3164-3181.

[53] CWR article "Will Energy Bases Drain the Yellow River" by Prof. Shaofeng Jia. 10 February 2015. https://www.chinawaterrisk.org/opinions/will-energy-bases-drain-the-yellow-river/

[54] Su, F., Zhang, L., Ou, T., Chen, D., Yao, T., Tong, K., & Qi, Y. (2016). Hydrological response to future climate changes for the major upstream river basins in the Tibetan Plateau. Global and Planetary Change, 136, 82-95.

[55] National Development and Reform Commission of the People's Republic of China (2004). Requirements on the planning and construction of coal power plants (In Chinese).

[56] Zhang, C., Anadon, L. D., Mo, H., Zhao, Z., & Liu, Z. (2014). Water−carbon trade-off in China's coal power industry. Environmental science & technology, 48(19), 11082-11089.

[57] IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

[58] Reuters. Europe's driest summer in 500 years threatens crops, energy production. By Aman Bhargava & Samuel Granados. 22 August 2022. https://www.reuters.com/graphics/EUROPE-WEATHER/DROUGHT/jnvwenznyvw/

[59] Reuters article "UPDATE 1-French nuclear supply 1 GW lower as Garonne river temperature surpasses maximum" by Forrest Grellin. 4 August 2022. https://www.reuters.com/article/france-nuclear-idUKL8N2ZG5HK

[60] People's Daily Online article "Yangtze River basin faces severe drought after experiencing lowest rainfall for six decades", 18 August 2022. http://en.people.cn/n3/2022/0818/c90000-10136568.html

[61] UNHCR article "UNHCR: Humanitarian needs remain acute for displaced in flood-hit areas of Pakistan". 29 August 2022. https://news.un.org/en/story/2022/08/1125632

[62] UN News. "Pakistan: WFP working to expand food aid as deadly flooding continues" Reuters article "Pakistan races to keep floodwaters out of power station that supplies millions" by Syed Raza Hassan. 14 September 2022. https://www.reuters.com/world/asia-pacific/pakistan-races-keep-floodwaters-out-power-station-that-supplies-millions-2022-09-12/

[63] The Guardian article "Pakistani PM says he should not have to beg for help after catastrophic floods" by Hannah EllisPetersen & Shah Meer Baloch. 6 October 2022. https://www.theguardian.com/world/2022/oct/06/pakistani-pm-says-he-should-not-have-to-beg-for-help-after-catastrophic-floods

[64] BBC article "US East Coast blanketed by 'bombogenesis' snowstorm". 30 January 2022. https://www.bbc.com/news/world-us-canada-60177979

[65] The Guardian article "Storm-ravaged California scrambles as fresh atmospheric river rolls in" by Dani Anguiano and agencies. 11 January 2023. https://www.theguardian.com/us-news/2023/jan/11/california-storms-latest-atmospheric-river

[66] Rosa, L., Reimer, J. A., Went, M. S., & D'Odorico, P. (2020). Hydrological limits to carbon capture and storage. Nature Sustainability, 3(8), 658-666.

[67] Mallapaty, S. (2022). Why are Pakistan's floods so extreme this year?. Nature.

[68] CWR Big Picture "Mountain-to-Ocean – Risks along the Indus from climate, water, people to GDP." https://www.chinawaterrisk.org/the-big-picture/mountain-to-ocean/

[69] Government of Pakistan. Updated Nationally Determined Contributions 2021. https://unfccc.int/sites/default/files/NDC/2022-06/Pakistan%20Updated%20NDC%202021.pdf

[70] UN article "Secretary-General's remarks to High-Level opening of COP27". 7 November 2022. António Guterres. https://www.un.org/sg/en/content/sg/speeches/2022-11-07/secretary-generals-remarks-high-level-opening-of-cop27#:~:text=Ant%C3%B3nio%20Guterres,crucial%20decade%20%E2%80%93%20on%20our%20watch

[71] Climate Action Tracker (2022). Warming Projections Global Update. November 2022. https://climateactiontracker.org/documents/1094/CAT_2022-11-10_GlobalUpdate_COP27.pdf

[72] Our World in Data. Who emits the most CO2 today?. Hannah Ritchie. 3 October 2019. https://ourworldindata.org/annual-co2-emissions

[73] CWR (2019). Yangtze Water Risks, Hotspots & Growth – Avoiding regulatory shocks from the march to a Beautiful China. https://www.chinawaterrisk.org/wp-content/uploads/2019/09/CWR-Yangtze-Water-Risks-Hotspots-Growth.pdf

[74] The guardian article "Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows" by Patrick Greenfield. 18 January 2023. https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe

[75] Tan, D. (2021). Using Waternomics to Develop and Avoid Systemic Shocks to the Economy. In Water Security Under Climate Change (pp. 277-311). Singapore: Springer Singapore.

[76] Mekong River Commission. Basin Development Strategy for the Mekong River Basin 2021-2030 https://www.mrcmekong.org/interactive-publications/basin-development-strategy-2021-2030/

[77] Insurance Business article "Gabrielle and Auckland floods to erode profits of NZ property insurers" by Kenneth Araullo, 23, Feb 2023

[78] UNFCCC. Nationally determined contribution under the Paris Agreement. Syntehsis report by the secretariat. 26 October 2022. https://unfccc.int/sites/default/files/resource/cma2022_04.pdf

[79] The Guardian article "BP scales back climate goals as profits more than double to £23bn" by Alex Lawson. 7 Feb 2023. https://www.theguardian.com/business/2023/feb/07/bp-profits-windfall-tax-gas-prices-ukraine-war

[80] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi:10.1017/9781009157896.

[81] International Cryosphere Climate Initiative (2022) State of the Cryosphere 2022 – Growing Losses, Global Impacts. https://iccinet.org/statecryo22/

[82] CWR article "IPCC AR6: High Hopes For Oil & The US + China & The Rest Of Us" by Debra Tan and Chien Tat Low. 24 April 2022. https://www.chinawaterrisk.org/resources/analysis-reviews/ipcc-ar6-high-hopes-for-oil-the-us-china-the-rest-of-us/

83 UNFCCC (2022). India's Long-term Low-carbon Development Strategy. Submitted by Ministry of Environment, Forest and Climate Change Government of India. https://unfccc.int/sites/default/files/resource/India_LTLEDS.pdf

84 IPCC website. "The evidence is clear: the time for action is now. We can halve emissions by 2030.". https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/

85 CWR (2022). Together We Can: 8 Habit changes for below 2°C. https://www.chinawaterrisk.org/wpcontent/uploads/2022/03/CWR-Report-Together-We-Can-8-Habits-for-below-2C.pdf

86 Press Information Bureau, Government of India. Coal Demand Likely to Peak Between 2030-2035. 21 December 2022. https://pib.gov.in/PressReleseDetail.aspx?PRID=1885381

87 Outlook article "How Modi Govt Is Taking On West's Criticism Against Its Coal-Powered Energy Sector" by Abdul Haleem Sherif. 17 November 2022. https://www.outlookindia.com/business/how-modi-govt-is-taking-on-west-s-criticism-against-its-coalpowered-energy-sector-news-238166

88 The Times of India article "National water policy and action plan for India 2020 – Part 1" by Dr. Prashant Prabhakar Deshpande. 8 November 2021. https://timesofindia.indiatimes.com/blogs/truth-lies-and-politics/national-water-policy-and-action-plan-for-india-2020-part-1/

89 Ideas For India article "India's new National Water Policy: A paradigm shift" by Ashwini Kulkarni & Mihir Shah. 20 January 2022. https://www.ideasforindia.in/topics/governance/india-s-new-national-water-policy-a-paradigm-shift.html

90 Srinivasan, V. 2019. Climate Adaptation in the Water Sector in India. In India in a Warming World: Integrating Climate Change and Development, edited by Navroz K Dubash, 498–518. Oxford University Press India. https://academic.oup.com/book/35227/chapter/299755629

91 Krishnan, R., J. Sanjay, Gnanaseelan, C., Mujumdar, M., Kulkarni, A. and Chakraborty, S. (2020). Assessment of Climate Change over the Indian Region, A Report of the Ministry of Earth Sciences (MoES), Government of India. Springer Singapore. https://doi.org/10.1007/978-981-15-4327-2

92 National Mission for Clean Ganga (n.d) Namami Gange Programme. https://nmcg.nic.in/NamamiGanga.aspx

93 State Council (2010) The General Office of the State Council Forwards the Notice of the Ministry of Environmental Protection and Other Departments on Promoting the Joint Prevention and Control of Air Pollution and Improving Regional Air Quality (Guiding Opinions). (In Chinese) http://www.gov.cn/xxgk/pub/govpublic/mrlm/201005/t20100513_56516.html

94 National Development and Reform Commission of the People's Republic of China (2012) "The 12th Five-Year Plan" for Coal Industry Development. (In Chinese). http://zfxxgk.nea.gov.cn/auto85/201203/W020120322368710161760.pdf

95 National Development and Reform Commission, National Energy Administration of the People's Republic of China (2016) The 13th Five-Year Plan for Energy Development. (In Chinese). https://www.ndrc.gov.cn/xxgk/zcfb/tz/201701/t20170117_962873.html?code=&state=123

96 IEA (2021). Coal 2021. https://iea.blob.core.windows.net/assets/f1d724d4-a753-4336-9f6e-64679fa23bbf/Coal2021.pdf

97 CWR article "GPC: Smart Subsidies For Renewables" by Yuanchao Xu, 18 September 2017. https://www.chinawaterrisk.org/resources/analysis-reviews/gpc-smart-subsidies-for-renewables/

98 CWR article "China's Renewable Energy Quotas" by Yuanchao Xu, 18 August 2018. https://www.chinawaterrisk.org/resources/analysis-reviews/chinas-renewable-energy-quotas/

99 CWR article "China Still Going Green Despite Coal Moves" by Yuanchao Xu, 18 June 2020. https://www.chinawaterrisk.org/resources/analysis-reviews/china-still-going-green-despite-coal-moves/

100 National Energy Administration of the People's Republic of China (2020) 2019 National Renewable Energy Power Development Monitoring and Evaluation Report. (In Chinese). http://www.gov.cn/zhengce/zhengceku/2020-05/16/content_5512148.htm

101 EIA (n.d.) International. Electricity. https://www.eia.gov/international/data/world/electricity/electricitygeneration?pd=2&p=00000000000000000000000000008&u=0&f=A&v=mapbubble&a=-&i=none&vo=value&t=C&g=none&l=249-ruvvvvvfvtvnvv1vrvvvvfvvvvvv-fvvvou20evvvvvvvvvvnvuvs0008&s=315532800000&e=1577836800000&vb=146&ev=true

102 China Electricity Council (2019). 2019 National Power Industry Statistical Express List (In Chinese) https://www.cec.org.cn/upload/1/editor/1611623781566.pdf

103 Eurostat (n.d.) Statistics Explained. Electricity production, consumption and market overview. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_production,_consumption_and_market_overview

[104] Bloomberg website (n.d.) Renewable Investment - $69.9B Renewable capacity investment, Q2 2022. https://www.bloomberg.com/graphics/climate-change-data-green/investment.html?leadSource=uverify%20wall

[105] Peter G. Peterson Foundation article "The United States spends more on defense than the next 9 countries combined", 1 June 2022. https://www.pgpf.org/blog/2022/06/the-united-states-spends-more-on-defense-than-the-next-9-countries-combined

[106] IEA (2021). An Energy Sector Roadmap to carbon neutrality in China. https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china

[107] IEA (2022). CO2 Emissions in 2022. https://iea.blob.core.windows.net/assets/3c8fa115-35c4-4474-b237-1b00424c8844/CO2Emissionsin2022.pdf#11

[108] National Development and Reform Commission, National Energy Administration of the People's Republic of China (2022) 14th Five Year Plan on Renewable Energy Development Plan. https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202206/P020220602315308557623.pdf

[109] The State Council of The People's Republic of China article "Tianjin Port reveals world's first zero carbon terminal" by Yang Cheng. 24 November 2021. http://english.www.gov.cn/news/topnews/202111/24/content_WS619d9831c6d0df57f98e571e.html

[110] State Administration for Market Regulation (SAMR), Standardization Administration of China (SAC) (2021) Norm of water intake – Part 1: Thermal power production. http://openstd.samr.gov.cn/bzgk/gb/newGbInfo?hcno=9B2661B3CA0EB2A4A08284160C1B44E4

[111] The Guardian article "China drought causes Yangtze to dry up, sparking shortage of hydropower" by helen Davidson, 22 August 2022. https://www.theguardian.com/world/2022/aug/22/china-drought-causes-yangtze-river-to-dry-up-sparking-shortage-of-hydropower

[112] Sixth Tone article "Officials 'Deliberately' Hid Deaths During Henan Floods, Report Finds" by Yuan Ye, 22 Jan 2022. https://www.sixthtone.com/news/1009524/officials-deliberately-hid-deaths-during-henan-floods%2C-reportfinds#:~:text=The%20floods%20killed%20398%20people,July%2C%20according%20to%20the%20report

[113] The State Council of the People's Republic of China (2022) Investigation Report on "7.20" Extraordinary Rainstorm Disaster in Zhengzhou, Henan (In Chinese) https://www.mem.gov.cn/gk/sgcc/tbzdsgdcbg/202201/P020220121639049697767.pdf

[114] BBC article "Floods in Henan: Dozens of people died due to heavy rain. What happened in the first 24 hours?" (In Chinese), 21 July 2021. https://www.bbc.com/zhongwen/trad/chinese-news-57912990

[115] SCMP article "China floods: economic damage to livestock industry tops US$348 million, 6.4 million chickens dead" by Ji Siqi, 30 July 2021.

[116] The Lantau Group (2022) When the Water Runs Out: China's Latest Power Crunch. https://www.lantaugroup.com/file/brief_hydro_aug22.pdf

[117] CWR, Foreign Economic Cooperation Office of the Ministry of Environmental Protection of the People's Republic of China (2016) Water-nomics of the Yangtze River Economic Belt – Strategies & recomeendations for green development along the river. https://chinawaterrisk.org/wp-content/uploads/2016/06/Water-nomics-Of-The-Yangtze-River-Econoic-Belt-CWR-MEP-FECO-Joint-Report-ENG-June-2016.pdf

[118] CWR article "What Lessons Do The Chinese Hydropower Shortages In Summer 2022 Hold For The World? by David Fishman & Mike Thomas, May 2023. https://www.chinawaterrisk.org/opinions/what-lessons-do-the-chinese-hydropower-shortages-insummer-2022-hold-for-the-world

[119] CREA (2023). China permits two new coal power plants per week in 2022. https://energyandcleanair.org/wp/wp-content/uploads/2023/02/CREA_GEM_China-permits-two-new-coal-power-plants-per-week-in-2022.pdf

Notes

Notes

Disclaimer

CWR

WATER MATTERS

DECISIONS TODAY FOR WATER TOMORROW

chinawaterrisk.org

Suite 2405, 24/F, 9 Queens Road Central, Hong Kong