

NO WATER NO GROWTH

Does Asia
have enough water
to develop?

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*In collaboration with Center for Water Resources Research, Institute of Geographic Sciences
and Natural Resources Research, Chinese Academy of Sciences*

NO WATER, NO GROWTH

Does Asia have enough water to develop?

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About China Water Risk & Water-nomics

China Water Risk (CWR) aims to catalyse a better understanding of the complex web of water risks to unlock innovations. We strive to be the “go-to” resource on water risks and collaborate with experts, research & scientific institutes as well as IGOs and NGOs to provide the latest views on water & climate risks in the region so that we can make sound decisions today for a water secure tomorrow.

Water is essential for economic development. For a country with limited water resources, how to balance trade-offs between economic development, water resource availability and quality is key. Policy decisions should thus be made to wed economic planning to water resources and pollution management; we have called this concept ‘water-nomics’.



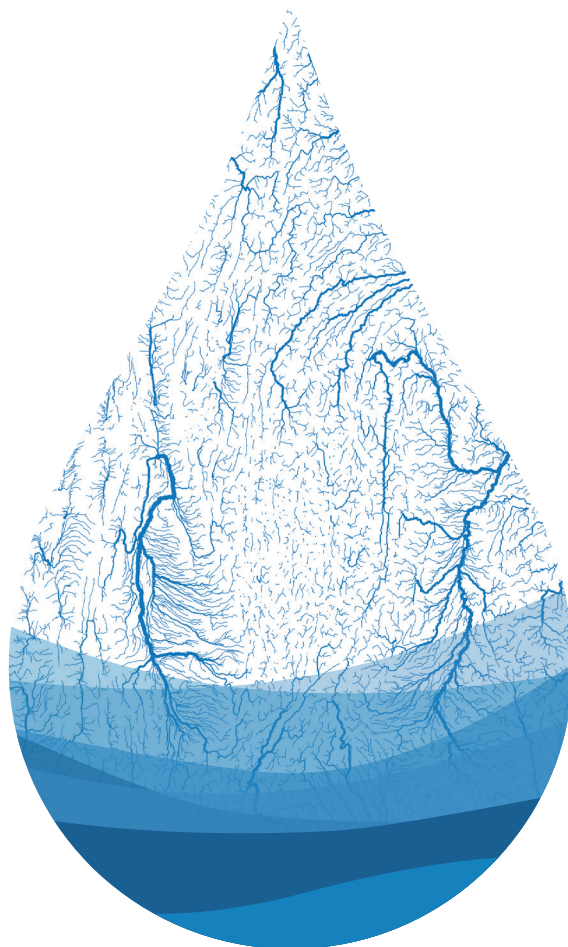
CWR first explored ‘water-nomics’ in a 2015 report commissioned by HSBC, titled ‘No Water More Trade-offs – Can China manage its growth with limited water?’. Since then, we have worked with the Foreign Economic Cooperation Office of the Ministry of Environmental Protection of China (MEPFECO) to examine the water-nomics of the Yangtze River Economic Belt (YREB). This belt is of strategic importance to China: not only in ensuring food and energy security but also in terms of the economy, contributing over 42% of the national GDP. Together with MEPFECO, we have collaborated on policy briefs exploring strategies and recommendations for green development along the river. Beyond China, we catalyse the water-nomics conversation through platforms such as the G20.

Such policy decisions will likely impact multiple industries and disrupt global trade. In this regard, we work to facilitate the transition of polluting and water-intensive Made-in-China industries and supply chain towards a clean and circular future. We also conduct research to encourage cross-sectoral stewardship at a basin level with the Alliance for Water Stewardship (AWS). Ultimately, these water risks, be they economic, physical, reputational or regulatory, will impact the valuation of companies. Here, we are pleased to be a part of the China Green Finance Working Group on Environmental Risk Assessment with a long term view to embed environmental risks in credit lending policy.

Thus, on a macro-level CWR works toward by wedding provincial/national water resource management to economic planning and at a micro-level embedding water risks into the financial valuation of a company thereby influencing capital flow to responsible users. In addition to proprietary research, CWR also has been commissioned by financial institutions to conduct research analysing the impact of water risks on the Power, Mining, Agricultural, Textiles and the Food & Beverage sectors. These briefs and reports have been considered ground-breaking and instrumental in understanding our water challenges.

Join the conversation at www.chinawaterrisk.org

WATER IS LIFE



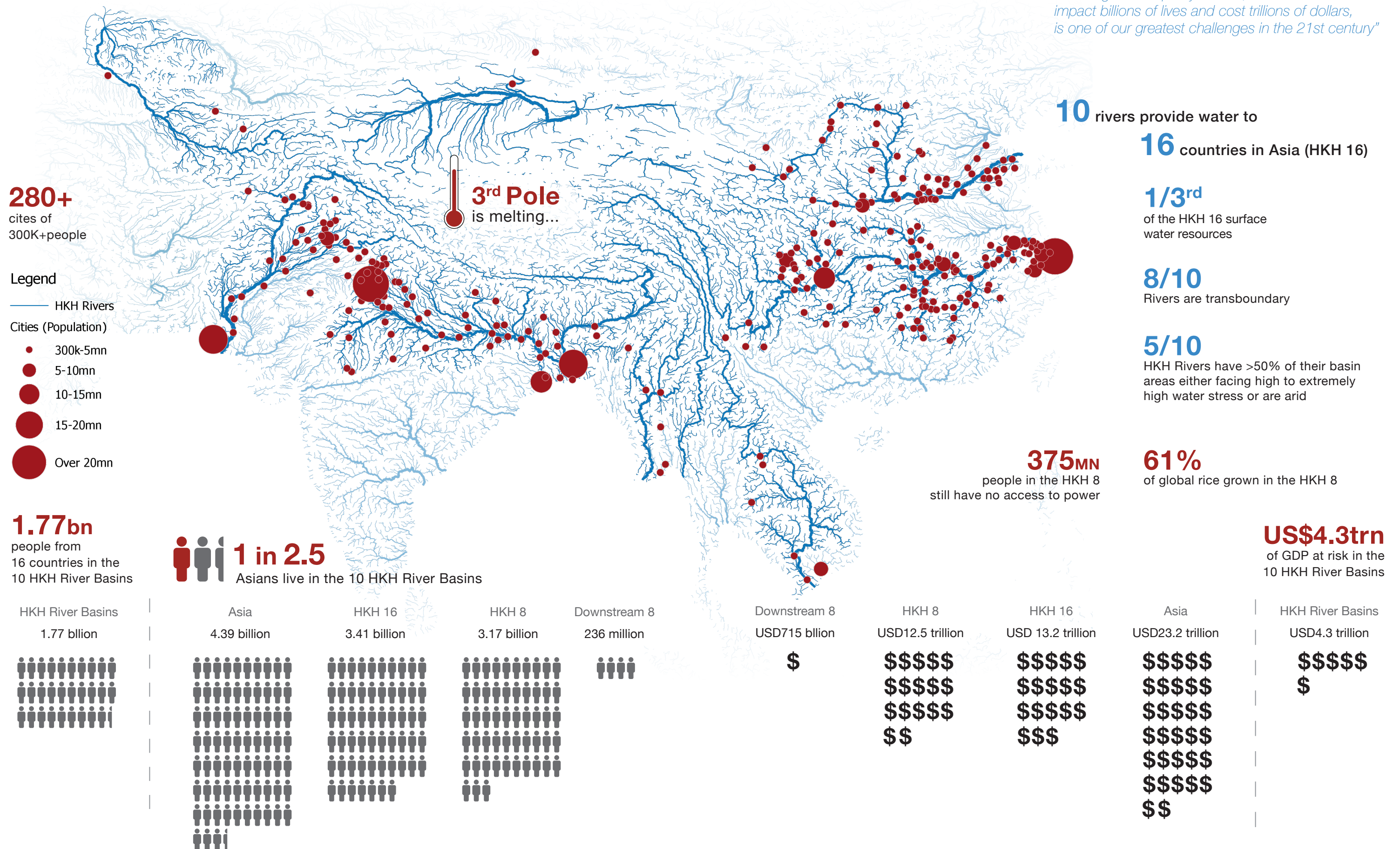
Rivers are important to Asia. The Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze and Yellow are the continent's cradles of civilization. Much of Asia's population and economy are clustered there. Yet, climate change, evident in their common source region, the Hindu Kush Himalayas (HKH), threatens their upper watershed. The flow of these 10 mighty rivers that provide water to 16 countries could be affected. One in every 2.5 Asians live along these rivers and over USD4 trillion 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 catalyse such conversations, this report seeks to provide an overview of the challenges that are extremely critical to Asia. Since our economy runs on water, no water means no growth. So does Asia have enough water to develop? What about water for food and energy security? Will adding the wrong types of power accelerate climate change and how will this impact the water resources of the ten rivers? To what extent do the economies and water resources of the 16 countries in Asia depend on these ten river basins?

The results from our analyses are 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. Building on China Water Risk's body of work on water-nomics, the report urges policy makers, businesses and investors to seriously start assessing water and climate risks for assets located along these rivers and to move development thinking beyond access to clean water toward rethinking development by wedding economic planning with water management.

ASIA'S WATER CHALLENGE

"Avoiding a real liquidity crunch, one that could impact billions of lives and cost trillions of dollars, is one of our greatest challenges in the 21st century"



EXPERT VOICES

Professor Asit Biswas, Distinguished Visiting Professor at the Lee Kuan Yew School for Public Policy

“ Confucius said “Essence of knowledge is having it to apply it.” Rivers originating from Hindu Kush Himalayas affect the livelihoods of hundreds of millions of people in Asia. China Water Risk has produced an excellent report on the water potential for social and economic development of the region. What is exciting and laudable is China Water Risk having produced this report is going to the extra mile to see how this potential can be successfully realized. ”

Mr. Jeremy Bird, former Director General of International Water Management Institute (IWMI)

“ Through their analysis, China Water Risk makes a powerful case for policy makers, water managers, businesses and project financiers to address interdependencies surrounding water. In particular, changing the way we view investments in agriculture, energy, industry and trade to ensure that water crises do not compromise growth and business opportunities, undermine social wellbeing and harm the ecosystems that we depend upon. Apart from cross-sectoral interdependency, the HKH region is characterized by transboundary linkages that require a response beyond that of sharing a water resource, to one of embracing the wider regional economic benefits of cooperation. Business as usual is already changing; and as pointed out in this book, ‘water risks have seeped into the mainstream’. ”



Professor Shaofeng Jia, Deputy Director of Center for Water Resources Research, CASIGSNRR

“ For such an important area, we still lack enough response and action. The change of glaciers, frozen soil and water resources caused by climate change, as well as their impact on human society and mitigating measures, can not stay in a local case study, but also requires integrated multi-disciplinary and transnational assessment. More resources need to be mobilized to meet the challenges of the region. ”

Dr. David Molden, Director General of the International Centre for Integrated Mountain Development (ICIMOD)

“ The report brings into the spotlight the importance of the Hindu Kush Himalaya as the water towers of Asia, and their importance for the future of the economy of Asia. The mountain environment as we know it, is under threat from climate change and numerous other socio-economic changes. We must act now for sustainable mountain development for the people of the mountains, for Asia and the world. ”

Dr Cecilia Tortajada, Senior Research Fellow, Institute of Water Management, Lee Kuan Yew School of Public Policy

“ The report presents a very comprehensive analysis of the role water resources play in the Hindu Kush Himalaya, its 10 rivers and its 16 countries. It discusses crucial water-related risks that are affecting, and that are likely to further affect, the region and its billions of people. By debating gaps, blind spots, changing prospects and new paradigms, among other many topics, it addresses a critical topic the world should pay attention to: why water matters. ”



PREFACE



Debra Tan
Director, China Water Risk

This report holds a special place in my heart. I remembered feeling shocked when it dawned on me that the Third Pole, like the North and South Poles, is melting due to climate change. But unlike the meltwaters from the Arctic and Antarctica that cause sea level rise, glacier and snow melt from the Hindu Kush Himalayas feeds into 10 major rivers which sustain 1.77 billion lives across 16 countries.

That mountains are the source regions for our rivers is obvious, yet I did not make the link. I was taken aback that I was more concerned about penguins and polar bears than the billions of lives at risk. That “a-ha moment” back in 2010 prompted the start of my journey into the water space, culminating with the founding and launch of CWR in 2011.

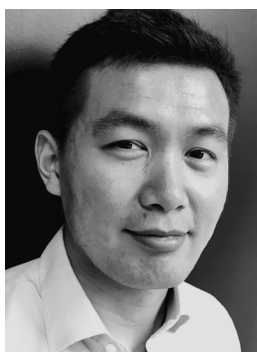
Water and climate risks are recognised as top global risks by world leaders and business elites. They are here to stay; yet despite the gravity, actions and finance to build resilience severely lag. Critical issues continue to be hidden in plain sight today. Over the last three years, I have spent time in the mountains visiting glaciers. There is no doubt they are vanishing and that mountain communities are already feeling the impact. What I see up there breaks my heart, yet we sit downstream oblivious to the “destruction” atop. Far away in remote mountains, many glaciers are no longer white but covered with debris, parts of the mountain brought down with glacier melt as seen in the picture below. The black scar in front of Mount Shivaling is the Gangotri Glacier, the largest glacier in India; to the far right in the distance, is the start of the Ganges.

Decisions made across Asia and the world, be they in economic, industrial, agricultural and power expansion will not only put pressure on already limited water resources, they could accelerate climate change which in turn exacerbates scarcity. Rampant water pollution from decades of rapid development only further intensifies the problem. Water and climate challenges therefore need to be managed comprehensively to ensure socio-economic and water security.

We cannot solve what we do not understand. This report is our attempt to highlight these complex issues in a simple manner; linking water challenges we face from the mountains to the oceans so that we can make sound decisions today for a water secure tomorrow. These risks are complex and interlinked and compounded by the clustering of people, cities and assets along these arterial rivers while the trans-boundary nature of the rivers lends complications. Yet navigating these complex risks is becoming a must.

It's time to reframe the conversation from one on access to safe water to one on water-nomics. There is much to do. To waterproof our assets we must start assessing basin risks. Gaps in research and climate finance must also be plugged. Ultimately, it falls to all of us to create a new paradigm of ‘business unusual’ and circular economies in Asia. These actions need to be applied across multiple sectors; they also need to be concurrent, cohesive and urgent. We cannot fail, for water is the only resource we cannot survive without.





Feng Hu
Water-nomics Lead

I grew up in a small coastal town in the Yangtze River Delta. The sea fed my people generously. Numerous rivers shaped the streets and houses, weaving into every aspect of our daily life. Like many other parts of Asia, our rivers and coastal water suffered from pollution as the economy grew. Some were so polluted that they were eventually filled with concrete to make roads. The widened paths led us further, but part of us, both memories and our way of life, got lost.

Through travels, I started to see the relationship between water and humans in a grander scale. Water that wet my feet on my hometown's muddy beaches could have flown all the way from the pristine ices and snows on top of the "Third Pole". In a sense, I share one source of water with billions of other people in Asia.

However, the rising temperature in the HKH has led to a faster melting rate of ice and snow which has resulted in changes in the hydrological cycle. Many scientific research findings project a greater degree of warming and a more volatile outlook of extreme weather across the region. This 'silent' but massive ongoing change will affect how we, as Asians, live in the future.

The urgency of the issue inspired me to initiate this report. Data and information that we can gather are often broad-brush and scarce. However, even with limited data, we were able to demonstrate a clear and strong linkage between a resilient HKH and the water and economic security of Asia. Going forward, improving basin-level monitoring and data collection must be one of the priorities.

We also need broader collaboration across sectors, regions and stakeholders. Despite natural linkages between water and climate, people in these two fields often work in silos and relevant policies are usually set separately. Methods and efforts based on one-sided views ignore a large part of these natural links. Multi-stakeholder and multi-disciplinary research efforts to improve understanding of hydrological cycles in a changing climate are thus key.

A way forward is more holistic basin-level strategies to manage water and economies in a changing climate. China has started to pilot this in the Yangtze River where we work with the Foreign Economic Cooperation Office of the Ministry of Environmental Protection of China to explore new "green" growth pathways. In this report, we expanded this work beyond the Yangtze to 9 other major river basins in Asia.

By providing a clear picture of what is at stake, we hope to kickstart dialogue to brainstorm concrete solutions and inspire innovative actions. Investing in resilient infrastructure and taking action in adaptation and mitigation are not just costs; they can create business opportunities and jobs. We must all work together and embark on this journey in order to ensure Asia's water and economic security in a changing climate.



CONTEXT

We are writing this report because we feel it is time to move the conversation on water beyond access to clean water to one on water-nomics – managing water in tandem with economic development – so as to ensure long term social, economic and water security in Asia. We believe this is Asia's greatest challenge. The fact that climate change is evident in the Third Pole through temperature rise, melting glaciers and reduced snowfall only lends urgency.

Despite the gravity, it is not easy for stakeholders to grasp the implications of the climate change impacts on water in the HKH region and what this means for Asia's future. This lack of understanding is reflected by the limited financing towards climate change mitigation and adaptation, and the protection of water resources. The amount of finance required for our planet to stay within the 2-degree limit is staggering: globally, the World Bank estimated an annual investment of US\$4.1 trillion² by 2030, whereas the OECD estimates an annual investment of up to US\$6.9 trillion³ – at least 14% of this will be spent on water & sanitation projects.

One stumbling block in understanding and resolving these issues is the multi-disciplinary nature of the action required from scientists, policy makers, businesses, 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 the relative long-term nature of climate change compared to other short-term problems. The report thus seeks to provide an overview of what's at stake across continental Asia so that all stakeholders can get to a base understanding of our common threat and prioritise actions accordingly. The importance of the ten major rivers and their contribution to water resources of the 16 countries they flow through as well as the socio-economy they carry are therefore explored along with the impact of climate change on water flow for each river basin.

One of the biggest challenges we encountered in writing this report was data availability. There is limited comparable data across countries and rivers. The fact that many indicators related to social-economic development are constantly changing, also didn't help. We tried our best to collate and present analysis with the latest available data but gaps still exist; more granular data is needed to give a truer picture of the studied rivers. Moreover, given the limitations in data and uncertainties in climate modelling, the results of climate projections contained in this report should be treated as an indication of trends rather than definite future scenarios.

However, despite these challenges, we feel the importance of the topic warrants the writing of this report. Data gaps aside, we are still able to demonstrate that a resilient HKH is necessary to ensure the water and economic security of Asia. We hope the analyses and discussions contained in this report will initiate more efforts (including financial support) to plug the data gaps with increased monitoring and research across the region as well as follow-up studies and collaboration across different organisations and countries.

It is important to note here that although we have benefited from much existing research by scientists, researchers and organizations that are promoting better understanding of climate and water issues in the HKH, the report is not exhaustive in synthesizing all relevant research carried out in recent decades. We have endeavoured to include information we consider most important and/or relevant to inspire action on the issues covered. In this regard, we have included recommended readings for each of the various issues covered in this report.

Finally, to stick to an overview of the water-nomic challenges faced by Asia, in-depth country-level or even city-level analysis or discussion of challenges was not included. Nevertheless, we sought to present a comprehensive introduction of water and economic risks of the whole region. To this extent, we see this report as a catalyst, rather than a definite guide for Asian leaders be they government, corporate, financial institution, entrepreneur, investor, NGO to academia/scientist to (1) promote the understanding of linkages between economic decisions and water security across continental Asia; (2) see and act to plan Asia's future development through a water-nomic lens; (3) make better policy, business and investment decisions in terms of power/industry/crop mix and trade given limited water resources; (4) facilitate further dialogue and action to mitigate and adapt to climate change in order to build resilience in the HKH countries and rivers, (5) mobilise private financing to protect people and assets in these ten river basins and (6) identify gaps in data/analysis so as to plug them with multi-disciplinary research and financial support.

We envisage this report to be the start of a series of conversations on the 'water-nomics' of the HKH River Basins. This basin-level, country-agnostic approach asks us to think beyond borders and reach across disciplines to resolve our common interests. We invite you to join us on this journey; please contact us if you would like to work with us at info@chinawaterrisk.org.

SPECIAL THANKS

Over the past two years, CWR has collaborated with the Center for Water Resources Research, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (CAS-IGSNRR) to synthesize 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.

The technical support we received from CAS-IGSNRR, in data collection, basin-level data calculation/estimation and climate scenario modelling, provided the basis for our further analysis at country and basin levels. This collaboration has been invaluable to the writing of this report and we would like to express our deep gratitude to the following who made this possible: Professor Shaofeng Jia, Dr. Jiabao Yan and Dr. Wenhua Liu.



We have also drawn on the existing research and publications of multiple scientists, hydrologists, researchers and organisations to write this report. Their important works can be found in the Recommend Readings or References sections of this report. We have also been fortunate to be able to compare the baseline information included in this report to the final results from the Hindu Kush Himalayan Monitoring and Assessment Programme (HIMAP) coordinated by ICIMOD which at the time of writing is expected to be finalised and published in June 2018. To ensure the rigorousness of facts and research findings used, we also sought technical review by leading experts in related fields and would like to thank the following experts for their time and comments on this report:

- **Mr. Jeremy Bird**, former General Director of International Water Management Institute (IWMI);
- **Professor Asit Biswas**, Distinguished Visiting Professor at the Lee Kuan Yew School for Public Policy.
- **Professor Shaofeng Jia**, Deputy Director of Center for Water Resources Research, CAS-IGSNRR;
- **Dr. David Molden**, Director General of the International Centre for Integrated Mountain Development (ICIMOD);
- **Dr. Cecilia Tortajada**, Senior Research Fellow, Institute of Water Management, Lee Kuan Yew School of Public Policy; and

Last but not least, we are grateful to our sponsor the ADM Capital Foundation as well as our core funders, the Rockefeller Brothers Fund and the RS Group. CWR's entire body of work in water-nomics would not exist without their support.



EXECUTIVE SUMMARY

Asia faces serious and urgent water challenges ahead. Already today, two of its most populous countries, India and China, are water stressed and rampant water pollution from decades of rapid development has only further exacerbated water scarcity. Meanwhile, across the continent, water infrastructure, albeit improving, is still lacking leaving hundreds of millions with no access to clean water.

While it is important to ensure adequate access to water, we believe it is time to move the conversation on water in Asia beyond access to clean water to one on water-nomics – managing water in tandem with economic development. We must do this to ensure long term social, economic and water security in Asia. The fact that climate change is evident in the Hindu Kush Himalayas (HKH), also known as the Third Pole, the source region of many of Asia's arterial rivers only lends urgency to start this conversation. The report thus focuses on 10 HKH Rivers, namely the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze and Yellow, that flow through 16 countries (the HKH 16). These 10 HKH Rivers emanate from Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan (the HKH 8) and flow through Cambodia, Kyrgyzstan, Laos, Tajikistan, Thailand, Turkmenistan, Uzbekistan and Vietnam (Downstream 8).

The water-nomic performance of the HKH 16 countries was compared to that of the G20, with more attention paid towards the HKH 8 countries as upper riparians. Analysis of the water-nomic performance as well as climate change impact on river flows of each of the 10 HKH River Basins were also carried out. The results are sobering:

- **Not enough water to develop:** Our analyses finds that of the HKH 8, China, India and Pakistan simply do not have sufficient water to ensure food and energy security plus develop under the current export-led economic growth model. To achieve a per capita GDP of over USD50,000, the US uses at least 1,543m³ of water/pax which is only 16% of its total renewable water resources of 9,538 m³/pax. Unfortunately, China and India are only endowed with total renewable water resources of 2,018m³/pax and 1,458m³/pax respectively; Pakistan has even less. This leaves their governments no choice but to chart a roadmap to more GDP on less water and less pollution. This includes transitioning from agri-to services-led economies, controlling total water use, revamping polluting and water-intensive industries, optimising crop mix and improving efficiencies. Experiences from developed G20 countries show that trade can also be used. Europe uses less water than the US as it is largely reliant on water-intensive imports, essentially using other people's water, whereas the US is largely food and energy secure. Regulating for water scarcity will clearly bring transitional and disruptive risks.
- **Material river basin exposure – people & economy:** The 10 HKH Rivers only account for a third of the HKH 16's surface water resources but one in two people from the 16 countries live along these rivers. Moreover, USD4.3trn, or a third of the HKH 16's GDP is generated in the 10 basins. Such clustering of people and the economy 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, it beggars belief that business and investment communities have yet to start assessing the exposure of their assets to basin water risk, let alone climate risks.
- **Climate change impacts river flow:** The 10 HKH Rivers are vulnerable to climate change; their flow components from glacier melt, snowfall to rainfall are changing, even monsoon patterns will shift. Glacier and snow melt can form a significant component of runoff mix eg. 62-79% for the Upper Indus and 25% for the Upper Yellow but despite a material water source, there is no comprehensive glacier database for Asia. We estimate total ice reserves supplying the HKH River Basins to be 7,574km³. This largest accumulation of ice outside the two poles is often called Asia's Water Tower. When melted, it will provide almost 7trn m³ of freshwater, enough to fill two Great Lakes (Michigan and Erie) plus almost 40 Three Gorges Dams. Already, China has lost glaciated areas greater than the land area of Thailand between 1970s and 2000s. Thus, we must invest in finding our baseline; a first step would be to plug the gaps in data, monitoring and multi-disciplinary research.
- **Rising clustered risks due to urbanisation:** Rising urbanisation adds further pressure on basin water resources as people flock to the 280+ major cities (including capitals) located in the 10 HKH River Basins. Such "clustering" also increases exposure to climate change in the form of 1) changes in river flows as well as 2) extreme weather events such as floods and droughts. Already 1.77bn people live in the 10 HKH River Basins; 1.7bn are in the HKH 8. By 2050, six of the HKH 8 countries will have an urbanisation rate above 50%. Short of moving billions of people, we must start building resilience to adapt. Rising systemic exposure at the basin-level also means that banks will eventually have to rethink credit policy to factor in environmental risks from a basin perspective.

- **Future climate trends for basins not encouraging:** Aside from glaciers, historical (1955-2005) and future (2006-2055) trends in temperature, snowfall, rainfall and runoff under RCP 4.5 were made by our report partner, the Chinese Academy of Sciences, using five climate models. Results were not encouraging. 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 impact with four rivers seeing shrinkages in flow. These projections assume we stay within +2°C.
- **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 USD3.8trn, 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.
- **What’s at stake - shocking perspectives:** For perspective, the annual flow of the Ganges will not even fill up Lake Erie, the smallest of the Great Lakes, but yet an estimated population of 614mn (almost twice that of the US) lives there, generating a third of India’s GDP. The annual flow of the Indus will not even fill half a Lake Erie, but it houses 88% of Pakistan’s population and generates 92% of the country’s GDP. Meanwhile, annual flows from the Yellow are less than that of the Indus. Although the flow from the Yangtze can fill more than two Lake Eries, China has started looking at holistic water-nomic management and green development along the Yangtze.

It is clear that challenges ahead are monumental and daunting. The fact that eight out of 10 HKH Rivers are transboundary lends further complexity. The current arrangements of people, resources and economies shaped by previous physical conditions will thus likely change; we have to adapt. This will require trillions of dollars of financing but despite what’s at stake, adaptation plans and financing lag. Currently, the majority of climate finance raised goes towards mitigation, not adaptation. Closing this finance gap is the minimum, as clustered exposure along rivers together with limited national water resources means that Asia does not have the luxury to continue with business as usual.

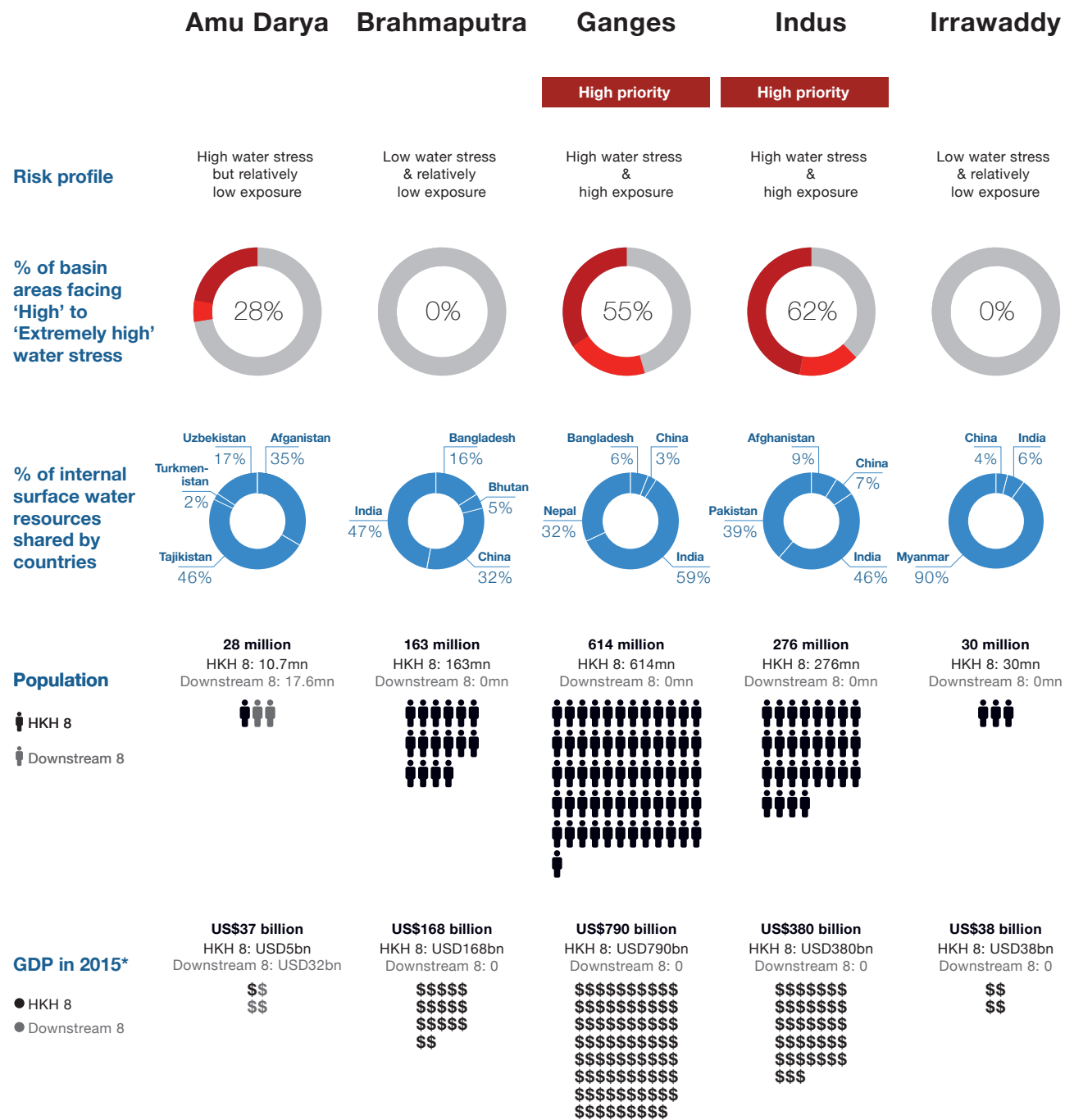
India and China, as upper riparians, must look beyond national interests to protect their common waters and lead the way in both transboundary and regional economic cooperation. They must create a new paradigm of ‘business unusual’ and circular economies to ensure the continent’s water security. Multiple actions will have to be taken, some of which are fundamental: A change in mind-set, governance, the way we do business and how we spend. We have identified eight broad action areas in this report. At the core is de-emphasizing economic growth and prioritising the environment. China has started: entrenching “eco-civilisation” into its constitution and de-prioritising GDP targets under the vision of a Beautiful China, Made in China 2025, plus redefining trade via the Belt & Road Initiative are key to this paradigm shift. India has also recognised its liquidity constraints. Earlier this year, NITI Aayog, a government think tank, released a report titled “Composite Water Management Index” to better manage its water resources.

These are positive steps but the road ahead is long. Asia is still hungry for thirsty power and energy choices matter as coal-fired power generation can be water-intensive and accelerate climate change, which in turn exacerbates scarcity. Tough trade-offs lie ahead as 375 million people in the HKH 8 still have no access to power. Smart energy choices must be made today, to protect water tomorrow. With abundant hydropower resources, dams are thus likely here to stay and stronger hydro/transboundary governance will be required. As the largest employer, water user and generally the largest polluter, the agricultural sector will need to be rehailed and there will be trade-offs such as food security. Trade will also be impacted as countries with limited water move away from exporting water-intensive goods.

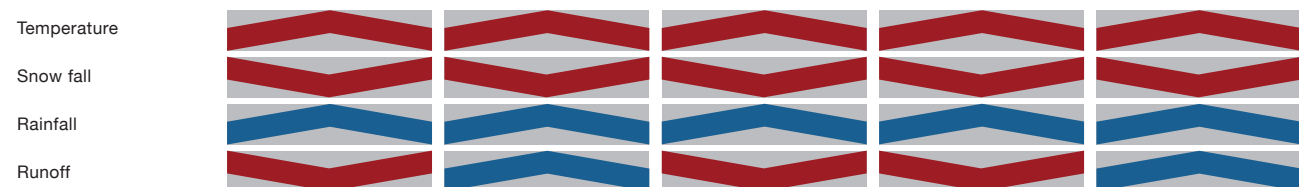
There is no doubt that these policy shifts when implemented will reshape the development landscape for Asia and disrupt multiple industries in Asia and beyond. Transitional and regulatory risks plus climate change will impact businesses, investment portfolios and loan books exposed to these 10 HKH River Basins. Business and investment communities also must start to create a new paradigm of ‘business unusual’ so that they can continue to flourish.

The future of Asia is at stake. We have to start linking these complex issues. We must understand our real liquidity constraints so that we make better policy, investment and business decisions today for a water and economic secure tomorrow. Avoiding a real liquidity crunch, one that could impact billions of lives and cost trillions of dollars is one of Asia’s greatest challenges in the 21st century. We all have a part to play. Asian leaders, businesses, financiers, entrepreneurs and scientists have the opportunity to pave the way toward a future with water.

ASIA WATER-NOMICS - 10 HKH RIVERS FOR 16 COUNTRIES

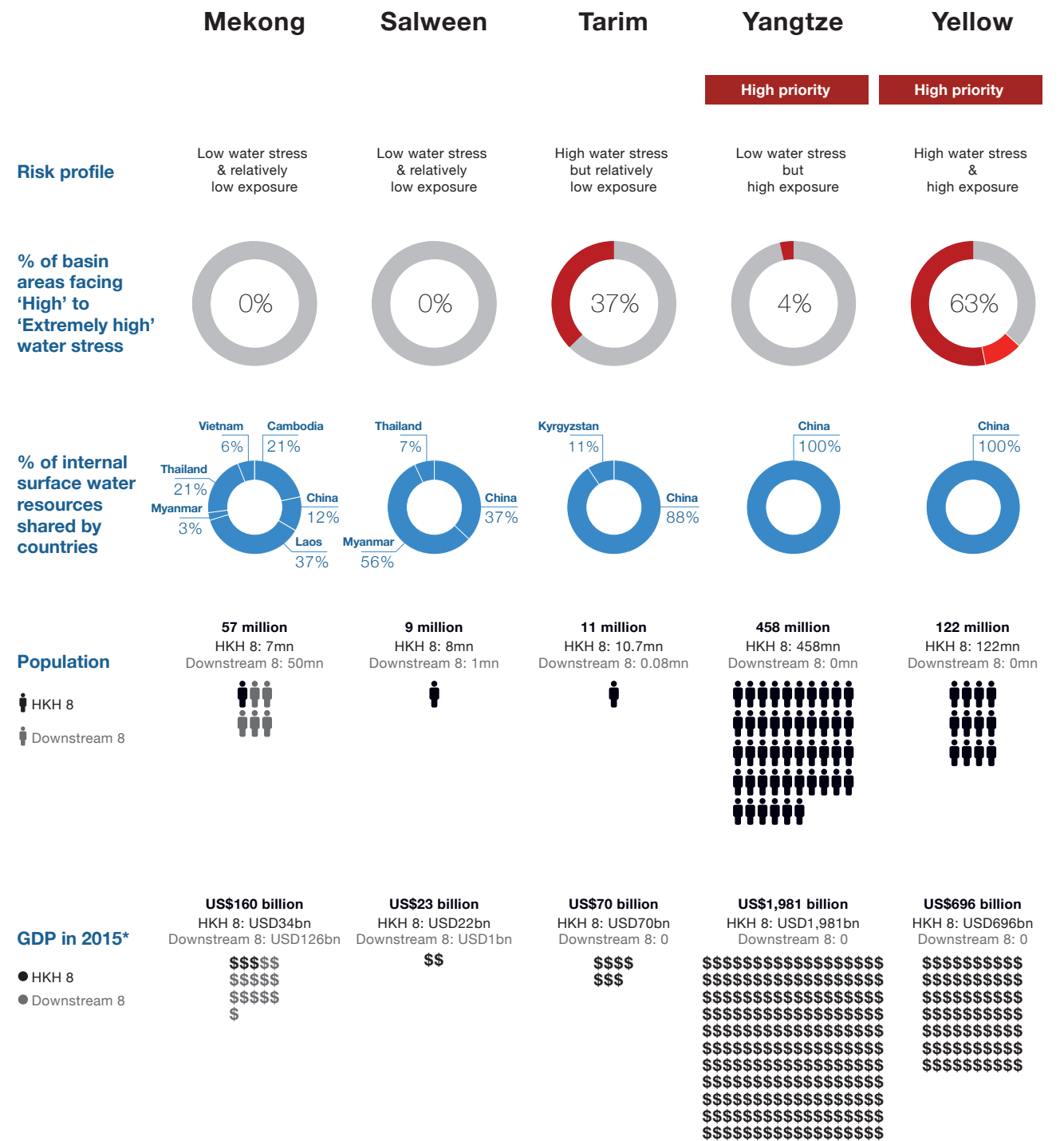


Climate projections under RCP4.5**



Sources: China Water Risk report "No Water, No Growth - Does Asia have enough water to develop?" 2018

* Constant 2010 price ** Climate projections show annual average change during 2006-2055 based on five ensemble models (BCC-CSM1.1, CanESM2, CCSM4, MIROC5, MPI-ESM-LR) in IPCC AR5. The result does not reflect reasonable variability nor differences within a river basin.



Climate projections under RCP4.5**

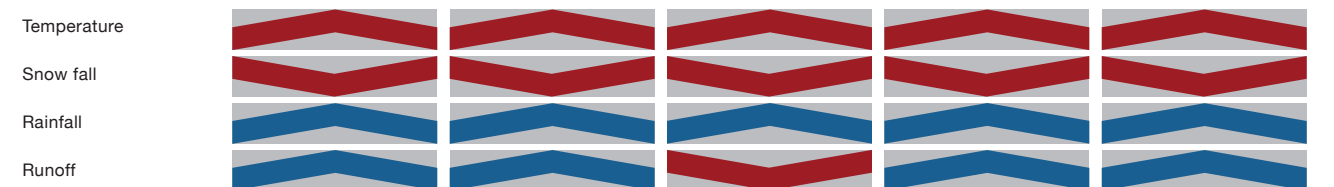


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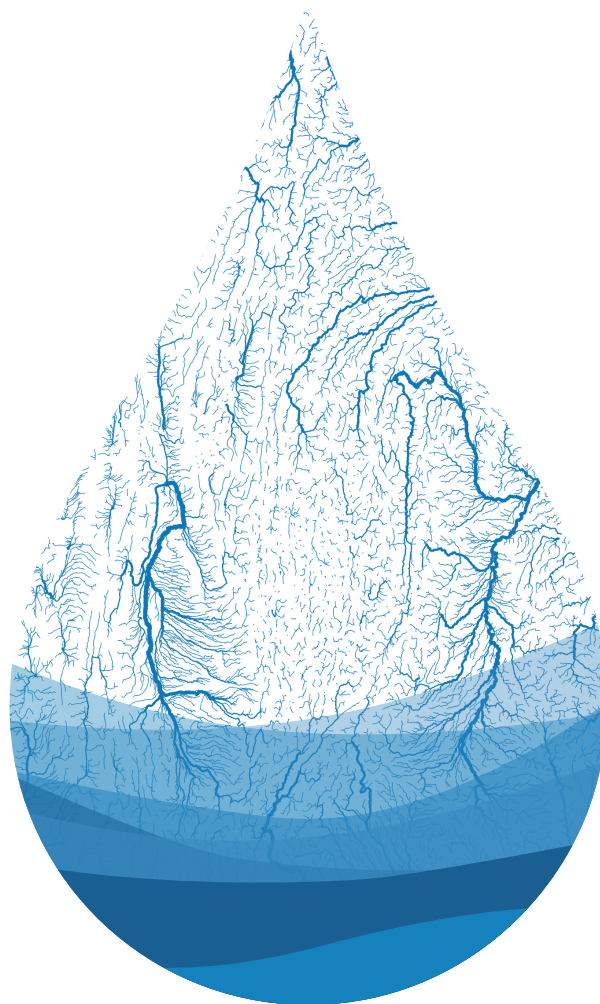
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THE CHALLENGE

10 RIVERS FOR 16 COUNTRIES



THE CHALLENGE : 10 RIVERS FOR 16 COUNTRIES

- Asia's bright future could be dampened by water. By 2050, as demand for water rises by 30-40% across Asia Pacific, an estimated 3.4bn people will likely live in water stressed areas according to the ADB. Already today, two of the world's most populous countries, India and China are water stressed and rampant water pollution from decades of rapid development has only further exacerbated water scarcity.
- Water is vital to our survival. Beyond quenching thirst, water is used to grow food, make our clothes, electronics and other consumables as well as to mine and generate power. Literally our economy runs on water. Where water is limited, ensuring that water is managed well so that there is enough water for all these competing needs becomes a priority.
- Asian leaders need to face these inconvenient but basic truths and rethink development. The current water-intensive export-led growth model is likely not sustainable and Asian countries may have no choice but to develop with business unusual practices and build circular economies.
- China has already started to wed economic planning with the management of water resources; we have called this "water-nomics". The national water caps imposed back in 2011 signaled a limit to China's GDP growth of 5.7% between 2020 and 2030. More recently, beyond water, China has moved to entrench "ecological civilisation" into its constitution and deprioritise GDP to rebalance its economy and environment.
- Increasing competition for water needs multi-pronged strategies to ensure security. Managing water allocation across sectors, controlling total water use and promoting water use efficiency are all important, but so is optimising future crop, industrial and economic mixes in favour of more crop or GDP generated on less water and less pollution. Exporting less water-intensive goods or importing more water-intensive goods can also be considered.
- China has started looking at the holistic management of such trade-offs along the Yangtze. This is not surprising since the Yangtze River Economic Belt generates around 42% of China's GDP, provides around a third of national rice production, 73% of hydroelectricity and is home to over 500mn people. Other countries with limited water resources could follow suit and seek new growth pathways along their key rivers.

"One in every 2.5 Asians, or 1.77 billion people live in these 10 river basins. We must reframe the conversation on water beyond access to clean water to one on water-nomics..."

- There are ten major rivers in Asia, all of which flow from the Hindu Kush Himalayas (HKH). They are the Amu Darya, Brahmaputra, Ganges, Indus, Irrawady, Mekong, Salween, Tarim, Yangtze and Yellow rivers (collectively the 10 HKH Rivers). Many of the continent's major cities and important economic hubs lie in their basins.
- These 10 HKH Rivers emanate from 8 countries (HKH 8) and flow through 16 countries (HKH 16), namely Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Kyrgyzstan, Laos, Myanmar, Nepal, Pakistan, Tajikistan, Thailand, Turkmenistan, Uzbekistan and Vietnam. These 10 river basins provide the 16 countries with a third of their surface water resources and are home to 1.77bn people, or one in 2.5 Asians.
- Eight of the 10 HKH Rivers are transboundary. Decisions made by the upper riparian will affect the others but bilateral/ multilateral agreements to ensure equitable use of shared water resources are still lacking. What's worse is that the HKH 8 has 3.3x the water resources of the 8 countries downstream (Downstream 8) but 13.4x the population.
- Clearly, actions taken by the HKH 8 matter. Yet rivers that are more important to some countries may not for others. For example the Indus is key to Afghanistan and Pakistan providing them with around a quarter of their water resources, compared to China (0.4%) and India (4%), but yet China and India are both upstream of Pakistan and Afghanistan. In fact, nine out of 10 HKH Rivers have source points in China.
- However, all these 10 river basins and 16 countries share a common threat: climate change in the HKH, also known as the Third Pole. Rising temperatures, glacial melt and reduced snowfall can all affect river flow as well as monsoon and climate patterns beyond the HKH. It is imperative that the HKH 8 work together to build resilience, but this is easier said than done as national interests are the natural go-to.
- It is time to reframe the conversation on water beyond access to clean water to one on water-economics. This requires a shift in mindset across many stakeholders. Despite difficulties, China and India (with control of most of the HKH) must take the lead. The future of Asia is at stake, we must understand our real liquidity constraint so that we make better policy, investment and business decisions today for a water and economic secure tomorrow.

... Avoiding a real liquidity crunch, one that could impact billions of lives and cost trillions of dollars is one of our greatest challenges in the 21st century"

Asia will need more water for its people & economy

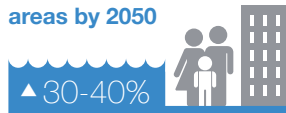
Asia is an important driver to the global economy & key to global supply chains ...

Since the second half of the last century, Asian countries have become important drivers of the global economy and play key roles in the global supply chain⁸. Despite various financial crises, China and India, have become two of the most vibrant and fastest-growing economies in the world. An expanding middle class also forms a strong base for a promising future. Huge strides have been made in poverty alleviation and public health including improved access to safe drinking water and sanitation.

... but bright future could be dampened by water

However, limited water resources could cloud Asia's bright future. Water is an essential ingredient for economic development; globally, it is estimated that threats to water security would lead to an annual cost of USD500 billion or around 1% of the world's GDP⁹. But if we include the impacts of water availability on the business continuity and long-term sustainability, the figure could be much higher. For Asia, the impacts of water risks can be significant; not only is it the most populous continent, the economy is at stake as power generation, food production and manufacturing all require water.

As water demand rises 30-40%, 3.4bn people will live in water stressed areas by 2050



The ADB says that by 2050, up to 3.4 billion people in the Asia and the Pacific (APAC) will be living in water stressed regions⁴. It also warns that water is likely to constrain economic growth in a number of Asian countries. Its latest 'Water Development Outlook' estimates water demand for the APAC to rise 30-40% by 2050⁴. The projection also notes that despite the dominance of agricultural usage, industrial and municipal water use will grow rapidly as the region continues to industrialise, urbanise and produce the world's goods.

China has capped water use...this could limit China's 2020-2030 GDP growth to 5.7%

In China, affirmative steps have been taken to manage its limited water resources through a series of actions involving water use caps and efficiency targets linked to GDP. As a result, we estimated China's GDP growth to be capped at 5.7% between 2020-2030, unless these targets are surpassed⁵.

With an additional 290 million over Chinese gaining access to clean water between 2011-2015¹⁰, the Chinese government is moving towards linking water management with economic planning. This shift towards a water-nomics mindset in planning is in line with the nation's vision to deliver an ecological civilisation, a "Beautiful China" where the economy and the environment are given equal weighting. Other water stressed countries in Asia should consider following suit.

Moving beyond access to water to balancing competing needs

Future competition for water needs strategies beyond efficiency gains ...

Increasing pressure on governments in Asia to manage water resources to balance all competing needs, will push the respective governments and business leaders to look beyond traditional methods of irrigation and industrial water savings and into the management of its water resources by deciding the nation's economy, energy and crop mix.

... new development & circular economy models will be 'the norm'

New development models, 'Business Unusual' and circular economy will have to also be explored, not only for efficient and effective management of water resources today, but to ensure water security and sustained growth in the future.

This new way of linking economic and water management, or water-nomics was highlighted in our research for HSBC. The 2015 report "*No Water, More Trade-offs – Managing China's growth with limited water*", points out the importance of economic mix. By balancing its tradeoffs with water, it can help countries with limited water availability manage water stress⁵.

We first explored the 'water-nomics' concept with HSBC

“

...a country with limited water resources should consider how to manage its domestic water use in terms of economic mix and the goods it produces, as this may have an effect on whether the country is able to move towards higher levels of income.

”

"No Water More Tradeoffs: Managing China's growth with limited water",
HSBC, August 2015

Already, Asia's two largest economies, India and China are water stressed¹¹. HSBC in its report in 2013 identified them as the #1 and #2 most water stressed countries in the world, stating clear concerns that *"increasing water stress is the biggest risk factor because of the implications for economic activity and societal tensions"*¹².

Our analyses with HSBC in 2015 and later with the Foreign Cooperation Office of the Ministry of Environmental Protection of the People's Republic of China (MEPFECO) show that both India and China will have to adopt business unusual growth models. It is clear from the comparison of the per capita GDP and water use of these countries, set out in the **"Basic Water-nomics"** spread in the following two-page insert, that they are far from their G20 peers. According to HSBC's 2015 report *"No Water, More Trade-offs: Managing China's growth with limited water"* which China Water Risk was commissioned to research and analysed for, they expressed *"in our view, a country with limited water resources should consider how to manage its national water use in terms of economic mix and the goods it produces, as this may have an effect on whether the country is able to move towards higher levels of income"*⁵.

This means that countries with limited water availability will have to rethink development.

In addition, the analyses set out in the following two-page insert regarding trade clearly reveal that water stressed countries like India and China are exporting their precious water through goods to Europe and the US, enabling those countries to grow their economies with less water. This current water-intensive export-led growth model will clearly not work for Asia in the long run; it is simply not sustainable.

The bottom line is that India and China and other water stressed Asian countries do not have enough water to run the economy, feed the people, generate power, grow our economy and ensure prosperity for their own population, let alone produce goods for export. Lax environmental laws have also meant that rampant pollution is left in the waterways of Asia, further exacerbating scarcity. Asian leaders need to deal with these inconvenient but basic truths.

Asia needs to find a new way forward. It's time to work together to ensure water, food, energy and economic security for the continent. China has started exploring its liquidity constraint and its implications – please see the box below on **"China Water-nomics"**. Asian leaders be they government, business, NGOs or academia need to follow suit.

CHINA WATER-NOMICS

China has already started exploring the management its "water-nomics" by taking preliminary steps to wed economic planning to management of its rivers and lakes. In 2016, President Xi Jinping stressed the importance of ecological protection in developing the Yangtze River Economic Belt and called for a stop to large-scale development along the river for a rather long period to come¹³.

Although, there are many big rivers in China, choosing the Yangtze to pilot the holistic water-nomics approach does not surprise. Not only is the river basin home to over 500 million people, it also supplies the nation with 65% of its rice, 73% of hydroelectricity and 81% of chemical fibers, and generates over 42% of China's GDP⁶.

In our joint brief with the Foreign Economic Cooperation Office of Ministry of Environmental Protection of P.R. China in 2016, which is titled *"Water-nomics of the Yangtze River Economic Belt: strategies for green development along the river"*, we proposed that *"given the economic and pollution disparities along the Yangtze River, holistic solutions are needed to avoid pollution risks spreading from mountaintop to the sea and even threatening food safety and security"*⁶.

Our call for holistic water management along the Yangtze was echoed in the new YREB Development Plan. Issued in October 2016, the plan set the overall strategy as *"prioritizing ecological protection, river basin coordination and integrated development"*. One key target is *"to fully establish unified and highly efficient river basin management system on the Yangtze"* by 2020¹⁴. By 2030, the socio-economic development of the Upper Reaches, Middle Reaches and the Yangtze River Delta should be fully integrated and well-coordinated whilst ensuring the overall importance of the water quality and ecological environment of the river.

India & China are the #1 & #2 most water stressed countries in the world...

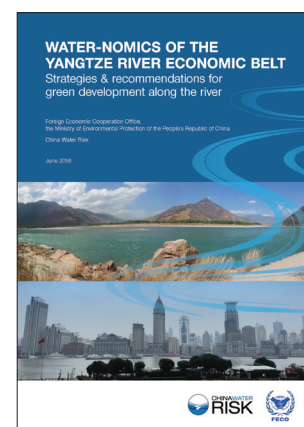
... India & China will have to adopt business unusual growth models

Water-intensive export-led growth will not work; it is not sustainable

Asian leaders need to deal with these inconvenient but basic truths...

... Asia needs to find a new way to develop

China started to look into managing trade-offs between water & economy along the Yangtze...



...government plan prioritises ecological protection, river basin coordination & integrated development by 2030

BASIC WATER-NOMICS

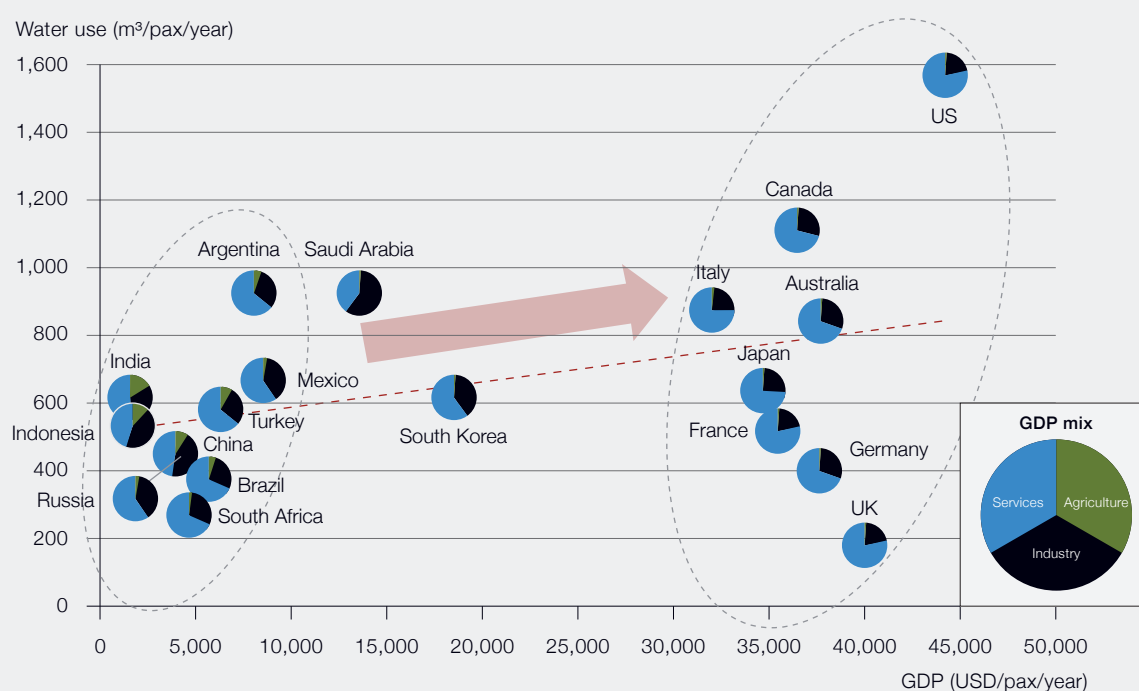
We first explored the concept of 'water-nomics' in a 2015 report commissioned by HSBC, titled '*No Water More Tradeoffs*'¹⁵. Since then, we applied the discussion to the Yangtze River Economic Belt (YREB) – a river basin that is of strategic importance to China – together with the Foreign Economic Cooperation Office of the Ministry of Environmental Protection of China.

It is evident that water is important for development. As China develops, the demand for water will likely rise, adding pressure to its already limited water resources. These challenges are explored by looking at the relationships between water and development across the G20 countries below.

G20 water-nomics

Water is essential for economic development. Analyses of per capita GDP and water use as well as GDP contribution across the G20 countries are set out in Chart 1 below. Generally, agri-heavy economies fall in the lower left quadrant, while more services-heavy economies use more water and have higher GDP.

**Chart 1: Water use corresponds to economic development - changing GDP mix matters
(G20 Per Capita Water Use vs. GDP)**



Source: China Water Risk based on FAO Aquastat, World Bank, NBSC

Note: For each country, the latest available data for water use is considered (ranging from 2000 to 2014). GDP at that year is expressed in Constant 2005\$

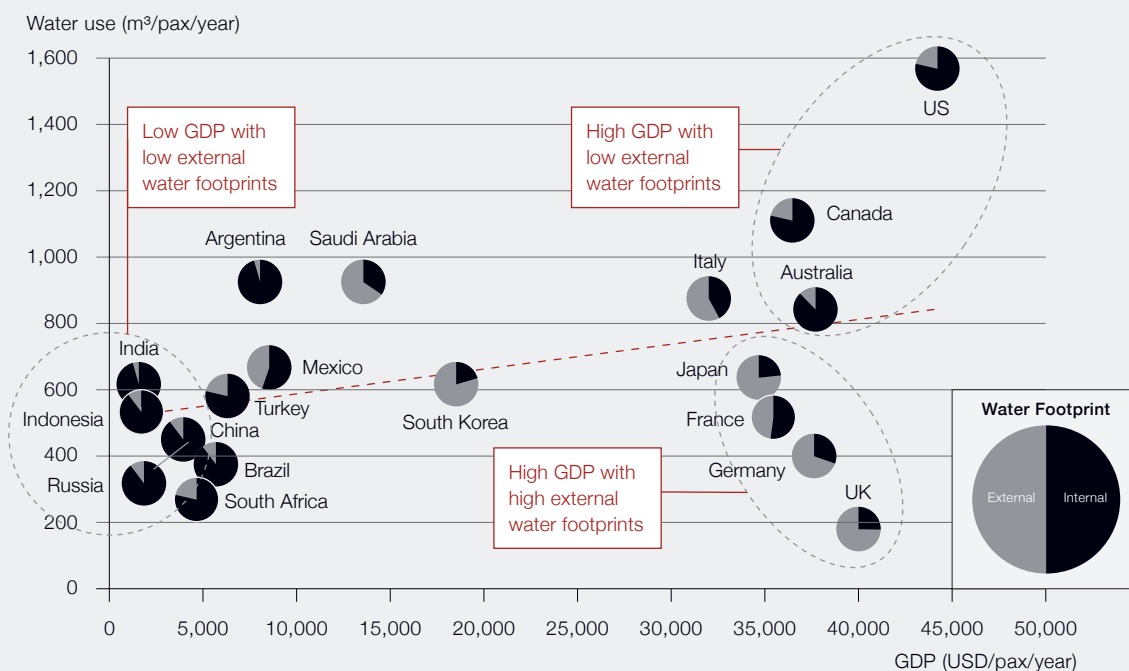
Economic mix matters and can help countries with limited water manage water stress. China aims to double the 2010 GDP and per capita personal income by 2020¹⁵, but can it achieve this with limited water resources?

In theory, higher GDP with less water can be achieved with a shift away from agriculture towards more services. However, in practice, the agriculture sector in China employs 314 million people¹⁶; moreover, it is imperative for China to maintain food security. Have any G20 country managed to grow their service industries with less water, while maintaining food security?

Virtual water trade profile of a country matters for national water use

Some developed countries such as Japan, France, Germany and the UK have succeeded to develop with limited water resources. A closer look shows that this has been made possible by outsourcing part of their water use through higher external water footprints facilitated by the import of water-intensive goods.

**Chart 2: Outsourcing water - imports can help reduce domestic water use
(G20 Per Capita Water Use vs. GDP)**



Source: China Water Risk based on FAO Aquastat, World Bank, NBSC, Water Footprint Network

Note: For each country, the latest available data for water use is considered (ranging from 2000 to 2014). GDP at that year is expressed in Constant 2005\$

Key takeaways from the above Chart 2 are:

- **High GDP with high external water footprints:** Japan, France, Germany and the UK have managed to achieve a high GDP with low national water use by having a larger external water footprint. This cluster is using the water resources of other countries by importing water intensive goods.
- **High GDP with low external water footprints:** US, Canada and Australia on the other hand are primarily self-sufficient with internal water footprints of 80%, 79% and 88% respectively.
- **Low GDP with low external water footprints:** China and India with low per capita GDP are primarily self-sufficient with internal water footprints of 90% to 97% respectively. In fact, many of the developing economies in Asia not only have low external water footprints, they are in many cases even exporting water – like China with ‘Made in China’.

The path of self-sufficiency, like the US, Canada and Australia, points to more water use. However, given limited water resources and the Three Red Lines, China needs to look beyond water saving efficiencies to manage its limited water resources. This includes:

1. Optimizing economic mix;
2. Optimizing industrial and crop mix;
3. Importing more water-intensive goods and exporting less water-intensive goods; and
4. Shifting output & recycling within China to match local water resource availability.

Solutions to achieve national water security need to be cohesive and comprehensive. Policy decisions across all aspects of the economy matter for water and development.

Source: based on excerpts from “**WATER-NOMICS OF THE YANGTZE RIVER ECONOMIC BELT: Strategies & recommendations for green development along the river**”, jointly published by China Water Risk and the Foreign Economic Cooperation Office of the Ministry of Environmental Protection of the People’s Republic of China (MEP FECO). A Chinese journal article based on this joint brief was published in the national academic journal “Environmental Protection” (Issue 15, 2016).

Rivers lie at the heart of the economy

Rivers are vital civilisation & development hubs

That rivers are important sources of water is obvious. What's less obvious is that they provide water to run and power the economy. They also provide alternative routes for trade and navigation. It is thus not surprising that early civilisations all started along rivers¹⁷. Cities sprout along these waterways with tales and myths of these mighty rivers passed down generation after generation. Until today, many of Asia's major cities and important economic hubs still lie along these rivers.

There are 10 major rivers basins in Asia

There are ten such mighty rivers in Asia. They are the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze and Yellow. They flow through 16 countries, playing important roles in their history and development. For instance:

They are...

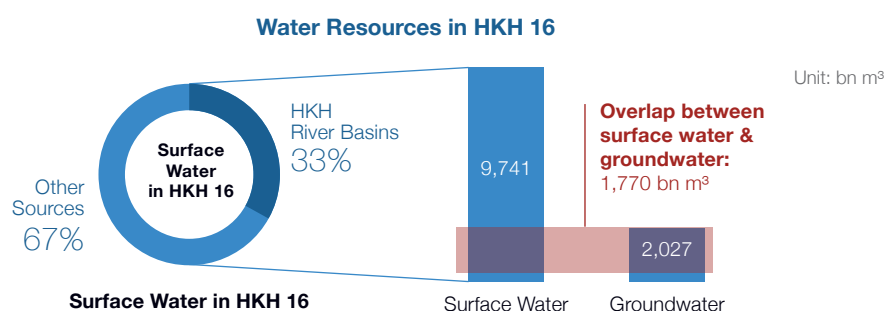
...the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze & Yellow

- Pakistan's administrative capital, Islamabad, and two of its most populous cities, Karachi and Lahore, lie in the Indus River Basin. In fact, all cities in Pakistan with a population over 300,000 are located in the Indus River Basin¹⁸;
- In China, the Yangtze River Basin is estimated to hold 21% of China's GDP whereas the broader Yangtze River Economic Belt (YREB), comprising 11 provinces and municipalities, 42% of China's GDP. This belt is also China's rice bowl accounting for around two-thirds of the nation's rice production⁶. The Yellow River, the cradle of Chinese civilisation, continues to power the nation as important energy bases and agricultural land lie along this river. Provinces along the Yellow account for around 57% of the country's wheat production¹⁹;
- The Mekong River flowing through 6 countries inspired a rich array of musical and artistic expressions in each of the countries and continue to sustain the livelihoods of around 57 million who live in the entire basin¹; and
- The Ganges River Basin, with over 614 million people¹, is not only the most populous amongst the ten rivers, but also steeped in myths. Considered the 'mother river' of India, it is embedded in the nation's psyche. At its source is the Gangotri glacier²⁰, one of India's largest glaciers and the home of the Hindu god Shiva. The glacier and the Ganges were granted legal status as human beings briefly in 2017²¹.

These 10 rivers are an important source of water for Asia ...

These ten rivers are an important source of water for Asia. Together, they provide the 16 countries they flow through with a third of their surface water resources as shown in the chart below. It is important to note that although the report focuses on rivers, groundwater is just as important and closely linked through the water cycle for ecosystem services, water supply and pollution impacts.

... they flow through 16 countries, providing a third of their surface water resources



Source: China Water Risk based on FAO AQUASTAT, and river-specific annual average date of surface water resource for 1998-2015 estimated by multiplying annual precipitation and runoff coefficient

Managing these rivers will be important for a water secure future in Asia

Evidently, these ten river basins form a significant part of the HKH 16's water resources. Managing these rivers will be important for a water secure future in Asia. When facing water stress, the allocation of water resources between industries, which crop to grow, or which cities to expand must be considered. These considerations are not just for the generally more prosperous river deltas, but also the middle reaches and further upstream in the source regions.

The water-nomics of the 10 HKH River Basins together with the water-nomics of the HKH 16 are explored in more detail in Chapter "Asia Water-nomics: The Real Liquidity Crunch".

The HKH: Source of 10 rivers for 16 countries

Often called ‘the Third Pole’, 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. As Asia’s ‘Water Tower’, the HKH is the source of ten major rivers, namely the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtze and Yellow (collectively the “**HKH Rivers**”).

Collectively, these 10 river basins cover an area of nearly 9 million km² (collectively the “**HKH River Basins**”)^{22,23}. These basins house rich indigenous cultures and diverse landscapes, as well as some of the most vibrant economies in the world.

Not only do the HKH Rivers provide water for 211 million people²⁴ living within the HKH Region as defined by ICIMOD, they also flow beyond the HKH Region into 16 countries before emptying into respective seas or ending in desert in the case of Tarim. For the purposes of this report, we have classified these 16 countries into two groups:

- **HKH 8:** The 10 HKH Rivers emanate from eight countries: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan, hereafter defined as “HKH 8”. Note here that the HKH is located within the country boundaries of HKH 8; and
- **Downstream 8:** The 10 HKH Rivers span beyond the HKH 8 into another 8 countries. These are Cambodia, Kyrgyzstan, Laos, Tajikistan, Thailand, Turkmenistan, Uzbekistan and Vietnam, hereafter defined as “Downstream 8”.

The HKH 8 and Downstream 8 are collectively defined as the “**HKH 16**”.

The entire basin area of the 10 HKH River Basins lie within the HKH 16. This means that the total number of people who rely on these basins for water could reach over 1.77 billion*. This is more than a fifth of the world’s population. In other words, they provide water to at least one in five people on this planet. For Asia, the ratio tightens; one in two and a half Asians rely on water from these 10 HKH River Basins.

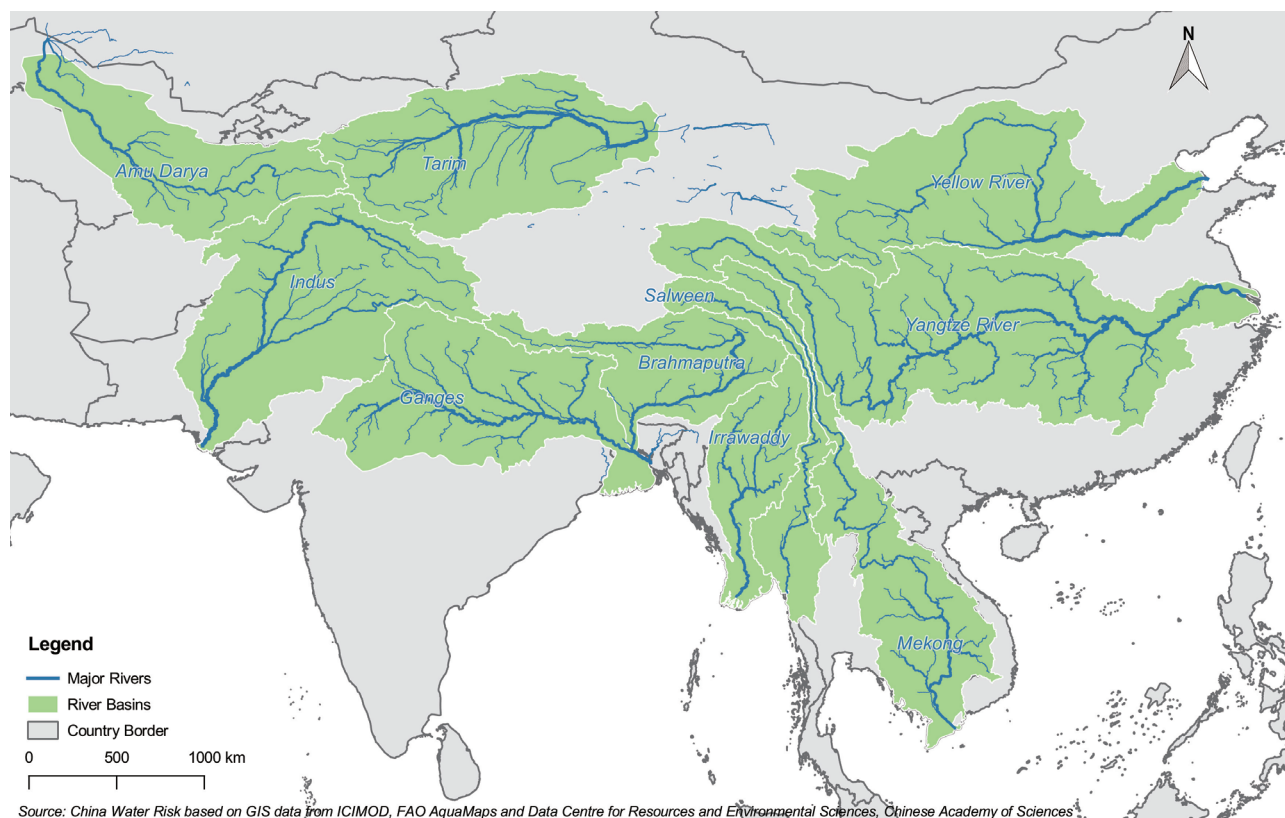
The Third Pole/HKH is the source region of Asia’s ten major rivers ...

These 10 HKH Rivers emanate from 8 countries (HKH8) ...

...and flow to a further 8 eight countries (Downstream 8)

1.77 billion people live in the 10 river basins...

At least 1/5 people on this planet ... or 1/2.5 Asians rely on water from these 10 rivers



* According to ICIMOD, the population living in the strictly speaking HKH region is estimated to be around 210 million; if we consider the entire HKH River Basins, it increases to 1.3 billion people. However, ICIMOD’s data sources range from 1995 to 2005²⁵; while our research partner CAS-IGSNRR modelled the population within the HKH River Basins based on WorldPop’s 2015 data sets.

Transboundary nature of the rivers lends complexity

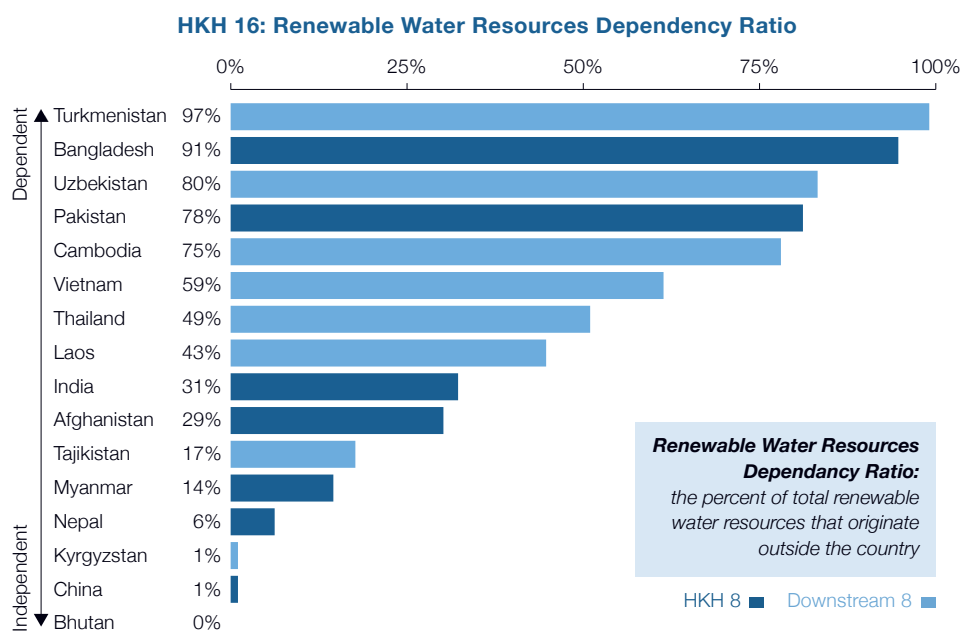
8 of the 10 HKH Rivers are transboundary

Eight out of the 10 HKH Rivers are transboundary. Decisions made by one country will affect the others be they about agriculture, energy mix, economic/infrastructure development or water resource management.

The FAO defines the renewable water resources dependency ratio as “the percent of total renewable water resources originating outside the country”⁷. The results for the HKH 8 are shown in the chart below:

Turkmenistan receives 97% of its water from external sources...

...whereas Bhutan has full control of its water resources



Source: China Water Risk based on FAO AQUASTAT data

High dependency ratios mean countries need to agree on how to share water...

It is clear from the chart above that amongst the HKH 16, except for Bhutan, all the other countries receive water that flows from other countries. Indeed, aside from Bhutan, China, Kyrgyzstan and maybe Nepal, all the other HKH 16 have considerable shares of their water resources originating from neighbouring countries. Within the HKH 8, Bangladesh and Pakistan have the highest ratios, which are 91% and 78% respectively⁷. The two receive more than three quarters of their water from neighbours, mainly India²⁵. For the Downstream 8, Cambodia and Vietnam also have considerable reliance on external water inflow, whose shares stand at 75% and 59% respectively⁷.

...transboundary water agreements are needed to avoid potential conflicts

This means that managing water resources for many countries in the HKH 16 is difficult; they may not have strong influence over their upper riparians. Allocating water to competing needs within and across countries can be a fine balancing act. The actions of the upper riparian countries, regarding how they utilise water of transboundary rivers matter to the downstream countries. The HKH 8's policies regarding these rivers therefore have clear impact on not just themselves, but also the Downstream 8.

Such agreements are lacking...

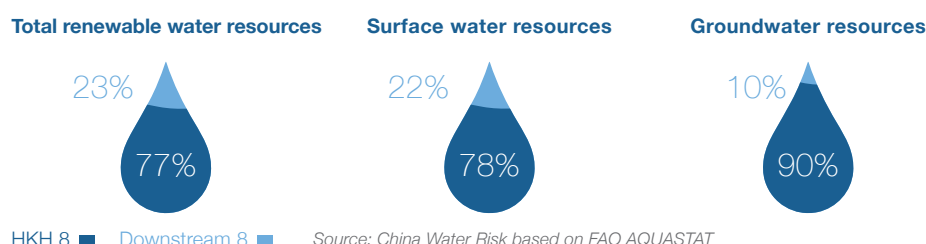
For transboundary rivers, bilateral/multilateral transboundary agreements are thus important. They can provide formal legal frameworks and mechanisms for dialogue and negotiation to avoid potential conflicts and to deal with water sharing in case of any emergency (be it drought or flood). Regional bodies and programmes have been set up to facilitate these bilateral/multilateral agreements between HKH 8 Countries to ensure equitable utilisation of shared water resources. Please see “**A New Era of Regional Cooperation along the Mekong**” for examples of such cooperation.

... plus none of the HKH 8 ratified the UN Watercourses Convention

None of the HKH 8 has ratified the UN Watercourses Convention, which entered into force on 17 August 2014²⁶. It should be noted here that of all the HKH 16 countries, only Vietnam has done so. With a dependency ratio of 59%⁷ and concerns over upstream hydropower development²⁷, it is not hard to see why.

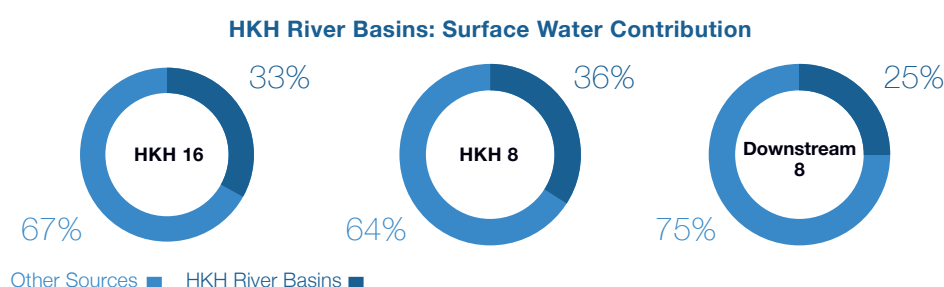
Upstream vs downstream: what the HKH 8 does matters

Although the total renewable water resources of HKH 16 amounts to over a fifth of the world's total fresh water resources⁷ at around 9,998 billion m³, over three quarters of this amount lies upstream within the HKH 8. A closer look into the share of surface and ground water reveals that while surface water is split: 78% in favour of the HKH 8 and 22% for the Downstream 8, for groundwater, the volume held within the HKH 8 is even greater than for the Downstream 8 at 90% vs. 10%⁷ as shown in the charts below:



The HKH 8 has **3.3x** the water resources of the Downstream 8

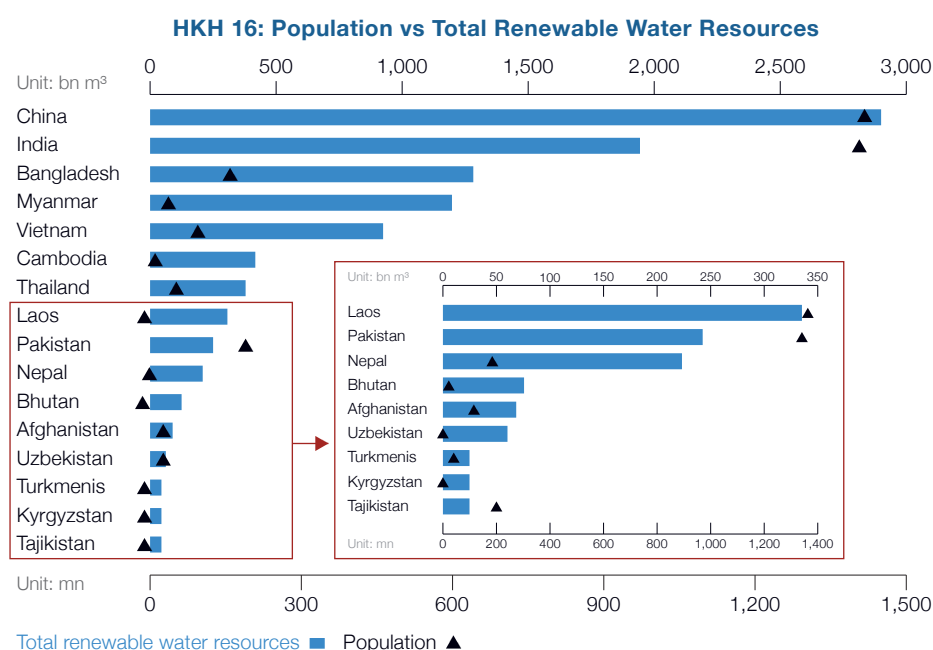
It is also worth noting that while the HKH Rivers account for 36% of the total surface water resources of the HKH 8, they only form 25% of the Downstream 81. In short, the Downstream 8 is less reliant on the 10 HKH River Basins for their surface water as shown in the charts below:



Downstream 8 are less reliant on the 10 HKH River Basins ...

... they provide only 25% of Downstream 8's surface water resources; compare to 36% for HKH 8

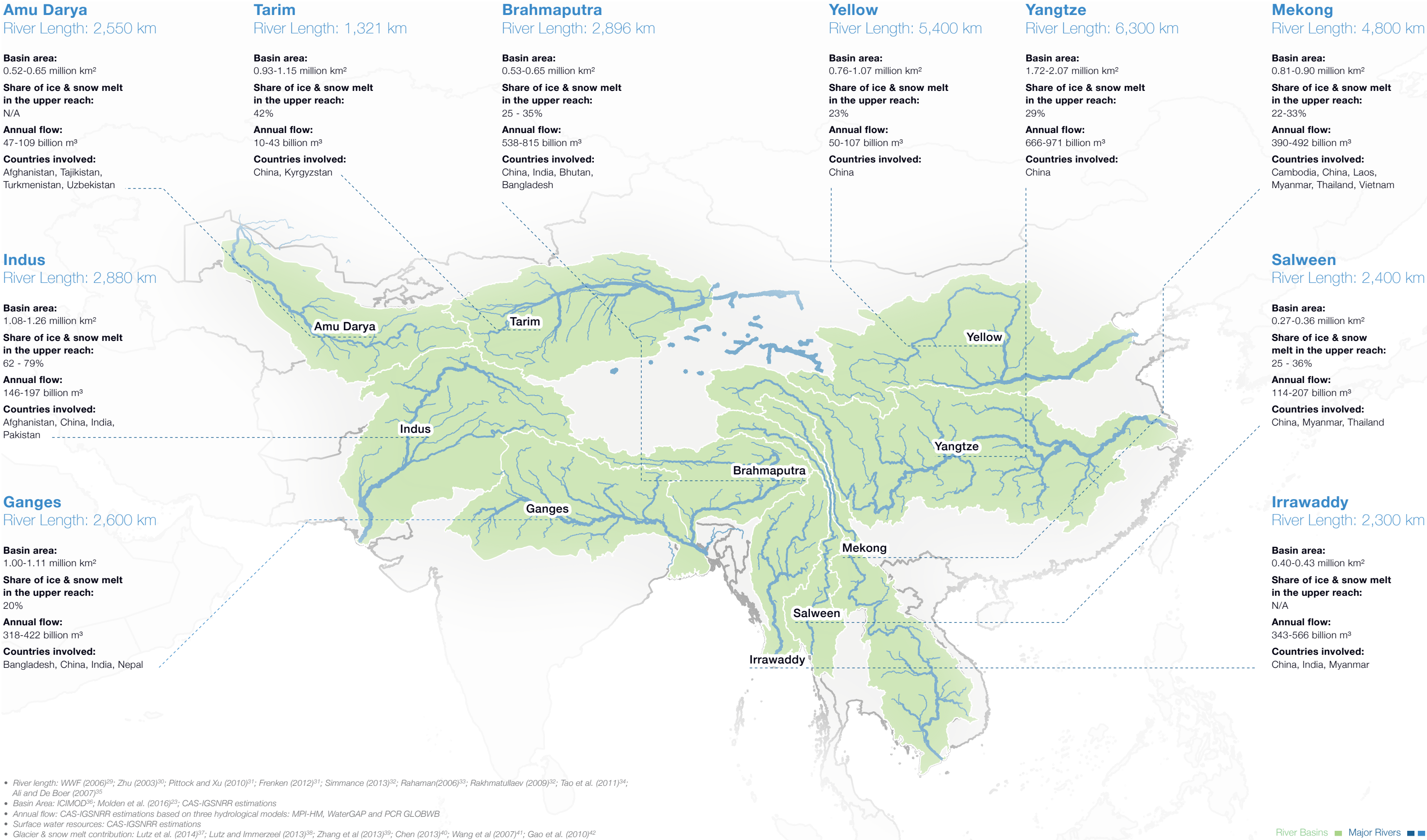
The HKH 8 is not only important for the HKH 16 in terms of water but also population. The HKH 8 accounts for 93% of the population of the HKH 16²⁸. Is 7,746 billion m³ of water⁷ enough for 3,176 million people in the HKH 8²⁸? A glance at the chart below showing the per capita water resources across the HKH 16 indicates that China, India, Pakistan, Uzbekistan and Afghanistan may struggle with ensuring their water availability for future growth. It is worth noting here that China and India are the upper riparians of multiple transboundary rivers.



But 93% of the population of the HKH 16 lives in the HKH 8 ...

Is 7.8 trillion m³ of water enough for 3.2 bn people in the HKH 8?

THE 10 HKH RIVER BASINS



Source: China Water Risk report “No Water, No Growth - Does Asia have enough water to develop?” 2018

Rivers that are important to some countries, are not for others

Some rivers provide more water than others ...

...the HKH Rivers share of surface water resources ranges: from 9% in Bangladesh to 59% in Nepal

Except the Yellow & Yangtze, 8 of the 10 HKH Rivers are transboundary

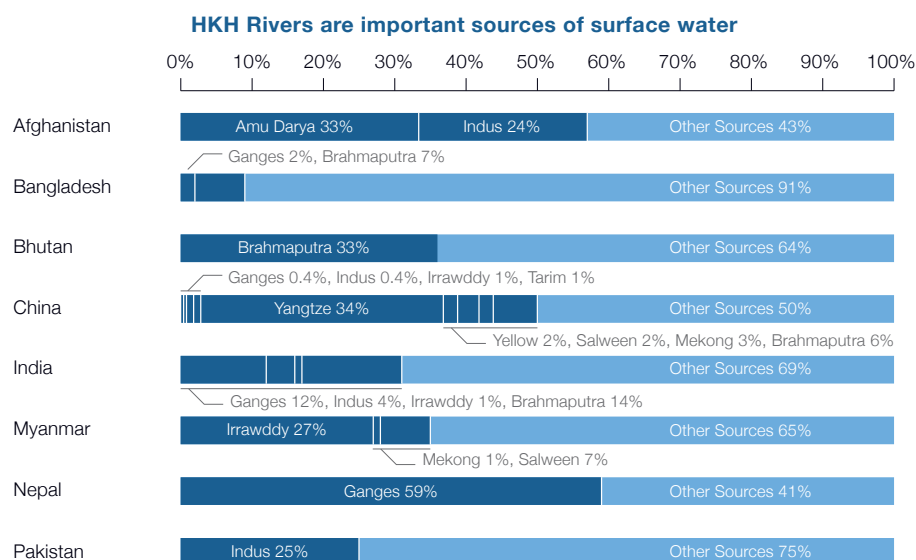
The Indus is more key to Afghanistan (24%) & Pakistan (25%) than China (0.4%) & India (4%) ...but China & India are upstream

9 of the 10 HKH Rivers have source points in China

Where people live matter...

...the Brahmaputra may only provide 7% of Bangladesh's surface water, but houses 67% of its population and 64% its GDP

It is important to note here that some of these rivers provide more water than the others. As shown in the chart below, the shares of internal surface water resources produced within the 10 HKH River Basins range from 9% to 59% across the HKH 8^{1,7}. Note that sources beyond the national border are not included.



Source: China Water Risk based on national figures from FAO AQUASTAT, and annual average data on river-specific annual surface water resources for 1998-2015 estimated by multiplying annual precipitation and runoff coefficient.

Note: that the dark blue bars represent the long-term average annual volume of surface water generated by direct runoff from the HKH 8.

Key points from the chart above in terms of internal surface water resources of each river are:

- Some rivers are more important to some countries but not others. For example, 0.4% of China's and 4% of India's surface water^{1,7} is generated within their individual part of the Indus River Basin. Meanwhile, for both Afghanistan and Pakistan, the in-country section of Indus accounts for around a quarter of each of their surface water resources;
- The Brahmaputra and the Ganges together account for over a quarter of India's surface water^{1,7} and are also clearly important to Nepal and Bhutan.
- At a glance, it can be seen that China benefits from almost all the ten rivers. Except for the Amu Darya, nine out of the 10 HKH Rivers have source points in China. The Yangtze alone holds over a third of China's surface water resources; and
- Aside from the Yangtze and the Yellow, the other eight rivers are all transboundary and provide water sources to multiple countries within and beyond the HKH 8.

Although the Ganges and Brahmaputra within Bangladesh only account for 2% and 7% of the country's surface water respectively^{1,7}, both rivers supply a significant part of external surface water resources flowing into the country and are thus vital to Bangladesh. These two rivers, along with the Meghna, forms the flood plains where most of Bangladesh is located⁴³. As shown in the two-page spread "HKH Rivers: What's at Stake" in the next chapter, 18% and 67% of Bangladesh's population live within the Ganges and Brahmaputra river basins¹. The two basins also hold 12% and 64% of the country's GDP respectively^{1,44}. Despite the proximity to the rivers, the lack of water infrastructure for transfer and storage means that 80% of the country's current water demand is actually met by groundwater; This leads to unsustainable abstraction, especially in dry seasons as groundwater only makes up only 2% of the Bangladesh's total renewable water resources⁴⁵. Inter-linkages between surface and groundwater differ within a basin; as such, any decision-making with regards to water management should be tailored and take both surface and groundwater into account. With as much as 1.3 trillion m³ of inflows and river runoff within the country not consumed and discharged to the sea⁴⁵, there is a clear need to invest in infrastructure for storage. This becomes especially urgent with climate change which will likely impact future monsoon patterns, bringing uncertainty around future water availability⁴⁵.

A common threat: climate change in the Third Pole

There is no doubt that the transboundary nature of the 10 HKH Rivers lends complexity in managing water resources. However, these rivers face a common threat – they are all suffering from the impact of climate change in the HKH. The Third Pole is experiencing rising temperatures, glacial melt and reduced snowfall, all of which can affect river flow as well as the monsoon and climate patterns.

“

The glaciers across the High Mountain regions of Asia have shown measurable signs of recession. However, changes are highly heterogeneous. Available climate change impact assessments have shown an increase of both the risk of flooding and water shortages....

...it is also very likely that the region will face water shortages due...to growing water demand from rapid population and economic growth. Options to cope with water scarcity may include integrated river basin management, adaptive management of old reservoirs, construction of new reservoirs, and techniques for efficient water use such as rainwater harvesting and water reuse.

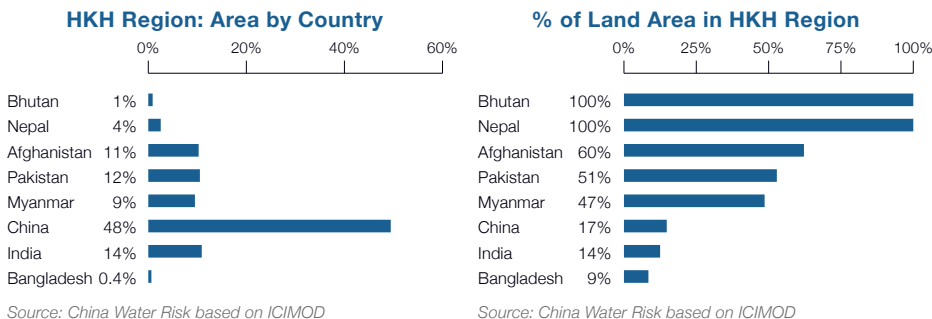
--- ADB, "A Region at Risk: The Human Dimensions of Climate Change in Asia and the Pacific"

”

10 HKH Rivers face a common threat ... climate change

Glacial melt, rising temperatures & reduced snowfall can affect river flow & monsoon patterns

As shown in the next chapters, the implications of climate change and underlying water stress are urgent and pressing for Asia. They can only be resolved if we work together, not separately. The HKH 8 need to act to build resilience in the Third Pole, yet this is easier said than done, largely due to the lay of the land illustrated in the charts below which show the percentage split of the land area of the HKH Region (as defined by ICIMOD) by country and the percentage of the land area of each country represented by the HKH Region.



HKH 8 must work together & build resilience in the 3rd Pole ...but easier said than done

Bhutan & Nepal which are 100% encased in the HKH Region, only has control 5% of the region

With a 100% of the country encased in the HKH Region, both Bhutan and Nepal will naturally feel the impact of climate change; but yet they only control 5% of the HKH Region³⁶. Conversely, HKH 8 countries like China which account for almost half of the HKH Region with the potential to play a greater role, only has 17% of its total land area in the HKH Region³⁶. India controls around 14% of the HKH Region³⁶. India is also the upper riparian of the Indus for Pakistan and both the Ganges and Brahmaputra for Bangladesh.

Indeed, China and India (as the upper riparians of 9 of the 10 rivers for South and Southeast Asia) can lead in reframing the water conversation beyond access to clean water to one of water-nomics. This requires a shift in mindset. While we know how large a sector, say electronics, or telecommunications is and its relative importance to the economy of the country, we do not consider our arterial rivers in this way. Water is not only a necessary input to multiple manufacturing processes, power generation and food production, it is vital to our survival.

China & India must take the lead... water is vital to our survival

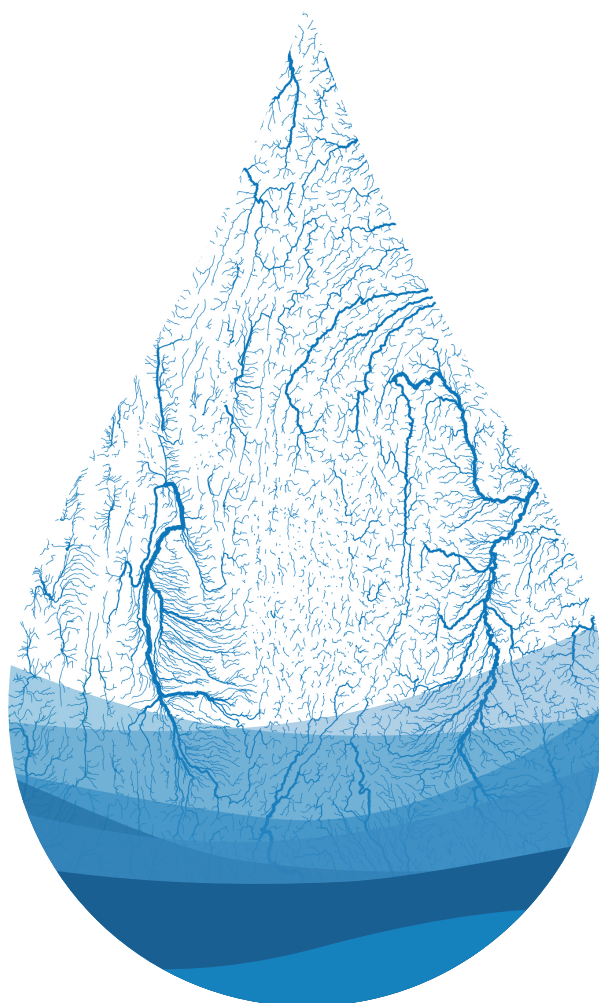
National interests are the natural go-to but the common threat of climate change at the source region cannot be ignored. The future state of Asia's water resources and economic security are at stake. The water-nomics of the HKH 16 and the 10 HKH River Basins and what's at stake are covered detail in **Chapter 2** while the impact of climate change on each of these ten rivers is set out in **Chapter 3**. Understanding of these fundamental constraints and challenges should help us make better policy, business and investment decisions today for a water and economic secure tomorrow.

The future of Asia is at stake... we must make better policy, investment and business decisions today



ASIA WATER-NOMICS

THE REAL LIQUIDITY CRUNCH



ASIA WATER-NOMICS : THE REAL LIQUIDITY CRUNCH

- The HKH 16 is important for Asia. Almost 4 out of 5 Asians live in the HKH 16 countries driving 57% of Asia's GDP with two-thirds of the continent's total renewable water resources. The HKH 8 is a significant contributor: of the 3.41bn people in the HKH 16, over 90% of them reside in the HKH 8. The HKH 8 also drives a lion's share of the HKH 16's GDP and water: 95% of GDP and 77% renewable water resources.
- With a collective GDP of USD13.2trn in 2016, at 78% that of the US, the HKH 16 is fast becoming an economic block to contend with globally. In Asia, HKH 16 GDP is already 2.2x that of Japan in absolute terms, but on a per capita basis, it only represents a mere 8%. The HKH 16 clearly still have long way to go in terms of development but is there enough water?
- Since countries need water to develop, we explored the water-nomic performance of the HKH 16 against that of the G20 countries. Results show that the HKH 16 not only lag the G20 but some countries also face liquidity limitations. To achieve GDP of over USD50,000/pax, the US uses at least 1,543m³ of water/pax but China and India only have total renewable water resources of 2,018m³/pax and 1,458m³/pax respectively.
- The HKH 16, in particular India, China, Pakistan and Afghanistan, will have no choice but to maximise water-nomic performance. This includes revamping agriculture and currently highly polluting and water intensive industries as well as careful planning of energy expansion and future industries so as to build a collective roadmap toward more GDP on less water and less pollution.
- Experiences from developed G20 countries show that trade can be used to manage national water use for the HKH 16. European countries like France, Germany and the UK as well as Japan appear to use less water than the US, Canada and Australia. This is because they are largely reliant on water-intensive imports from other countries whereas the US, Canada and Australia are all relatively more food and energy secure.
- Agriculture and energy play key roles as the two largest water users and improving efficiencies and curbing demand are must-do's. Beyond these, more crop per drop, improved yields and optimised crop mix can be used to ensure food security while shifting from an agri- to service-led economy. Energy choices also matter as coal-fired power generation can be water-intensive and accelerate climate change, which exacerbates scarcity. Toughtrade-offs lie ahead: China's energy/pax is 65% that of Japan's; India's only 18% and Bangladesh's a mere 8%.
- Balancing food and energy security and adopting these actions to shift the HKH 16 away from a largely agri-andexport-led driven growth model will likely cause disruptions with material implications for businesses and trade, not just for Asia, but globally. China has started transitioning their water-intensive and polluting industries toward a circular economy and promoting Made in China 2025 plus trade through the ambitious Belt & Road Initiative.

The HKH 16 countries have a collective GDP of USD13.2trn; a third of this (USD4.3trn) is generated in the 10 HKH River Basins where a population of 1.77bn is also clustered ...

- Within the HKH 16, disparities are amplified. The HKH 8 and Downstream 8 have similar GDP/pax, but HKH 8's water use/pax is half that of the Downstream 8. The Downstream 8 clearly are 'more wasteful' with water but note that none of them are water stressed, whereas four of the HKH 8 face 'high' and 'medium-high' water stress: these are Pakistan, India, Afghanistan and China.
- The HKH 8's water-nomic performance is varied. On a per capita basis, China generates the most GDP using the least water, while Afghanistan and Pakistan clearly fall behind. Given that these two countries along with India have higher WTA Stress ratios than China, there are lessons to be shared amongst the HKH 8. Even for China, there is clear room for improvement, especially in densely populated regions.
- Where people live matters. One in two people in the HKH 16 live in the HKH River Basins. Of the 1.77bn people who live in the HKH River Basins, 1.7 bn are in the HKH 8. By 2050, six of the HKH 8 countries will have an urbanisation rate above 50%. Since this will likely add pressure on the respective river basins, it is imperative to assess the socio-water-economic carrying capacity of each of the 10 HKH River Basins.
- Like population, the economy of the HKH 16 is also clustered in the HKH River Basins. USD4.3trn or a third of the GDP of the HKH 16 is estimated to be generated in the 10 HKH River Basins alone. The bad news is that 30% of these basins already face 'high' or 'extremely high' water stress. 93% of these areas are in the HKH 8 which incidentally also accounts for almost all of the GDP in the HKH River Basins at USD4.2trn.
- Analysing the water-nomic performance of the 10 basins indicate significant variation. The Amu Darya, Brahmaputra & Irrawaddy are the least efficient in water use to generate same amount of GDP. Industry and services drive the economy of the better performers: Tarim, Yellow, Mekong & Yangtze. Together, they account for 30% of China's GDP and house a population of almost 650mn people across seven countries. Meanwhile, the Indus, Ganges & Brahmaputra are key to the GDP of India (42%), Pakistan (92%) & Bangladesh (77%).
- Every river is important to each of the HKH 16. However, our 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 USD3.8trn, they are densely populated with 1.5bn people. Moreover, 4% to 63% of these four basin areas already face 'high' or 'extremely high' water stress lending complexity to water allocation and management.
- Climate change, already evident in the HKH, will make water-nomic management even more difficult. Even if we could meet the 2-degree target, under RCP4.5, the HKH Region's average temperature will likely rise by at least +4°C before the end of this century. This will impact the 10 basins albeit differently (see next chapter). Urgent actions are needed, be they inter-state/provincial policies or basin-wide co-operation across the HKH 16.

... India and China must lead the HKH 8 toward a collaborative development roadmap that ensures socio-economic-security for all 16 countries by focusing on the most at-risk basins: Ganges, Indus, Yangtze & Yellow

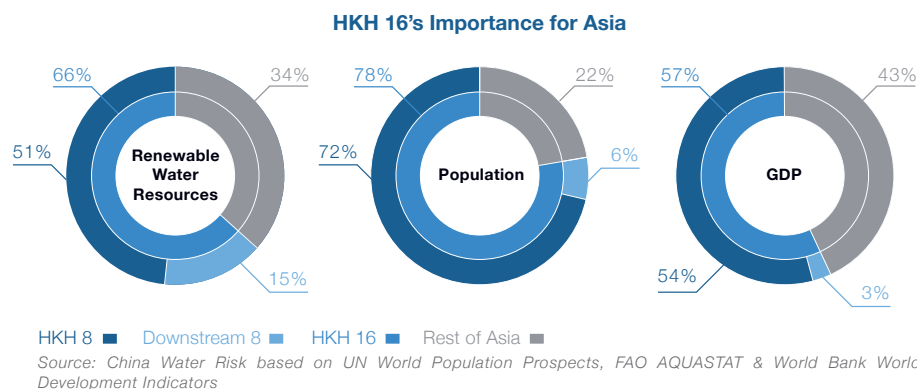
The importance of the HKH 16 for Asia's economy

Almost 4 of 5 Asians live in the HKH16; >90% of these live in the HKH 8

The HKH 16 also accounts for a large share of Asia's water (66%) & GDP (57%) ...

...the HKH8 is a significant contributor

The HKH 16 countries are an integral part of Asia with a significant share of its population, renewable water resources and GDP. With a population of 3.41 billion, the HKH 16 (inner ring) represents 78% of Asia's population, two-thirds of renewable water resources and 57% of Asia's GDP. As can be seen in charts below the HKH 8 (outer ring) accounts for a lion's share at 72% of Asia's population, 51% of renewable water resources and 54% of GDP. Note that Japan and South Korea together account for 4% of Asia's population and 32% of its GDP, so HKH 8, Japan and South Korea deliver about 86% of Asia's GDP. Actions taken by the HKH 8 are therefore key in ensuring Asia's water and socio-economic security.



Cities & economies are clustered along rivers ...

...33% of India's GDP is generated along the Ganges

...92% of Pakistan's GDP from the Indus

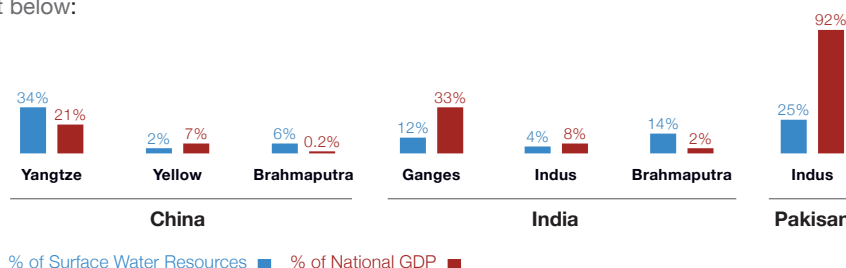
...36% of China's GDP from the Yangtze & Yellow

As discussed in the previous chapter, the ten HKH Rivers provide a third of the HKH 8's internal total surface water resources and as such, are key to its water security. But it is not just water, these 10 river basins also house significant economies.

In India, the Ganges provides 12% of surface water resources, Brahmaputra (14%) and Indus (4%) whereas our analysis based on CAS's estimation shows that 33% of India's GDP is generated along the Ganges, 2% along the Brahmaputra and 8% on the Indus. So although seemingly less important from a water perspective, with less than third of the nation's surface water resources, these three rivers are very important from an economic perspective with 43% of India's GDP. This trend also holds true for Pakistan. While the Indus only accounts for a quarter of surface water resources, it is estimated that 92% of Pakistan's GDP is generated from this river basin.

For China, the trend is reversed for the Yangtze but not for the Yellow River Basin. They provide China with 34% and 2% of their surface water resources respectively, but only house 21% and 7% of the China's GDP respectively¹. The share of surface water and GDP are illustrated in the chart below:

The economy literally runs on water...



Also, 1.63 billion people live in these 5 river basins = imperative to look into water-nomics

It is obvious that economies of these countries are clustered in these HKH River Basins. For China, India and Pakistan, the Yangtze, Ganges and Indus are of particular importance for water and their economy. These shares are clearly too significant to ignore; literally the economy runs on water. Moreover, 1.63 billion people live in these 5 river basins¹. It is therefore imperative that we examine the water-nomics of the HKH 16 to determine whether there is enough water for continued prosperity for the 16 countries spread across Asia. We will dive into the water-nomics of the 10 HKH River Basins later, but first we start by looking at the water-nomics of HKH 16 vs the G20 countries before diving into the water-nomics of the HKH 8 in more detail.

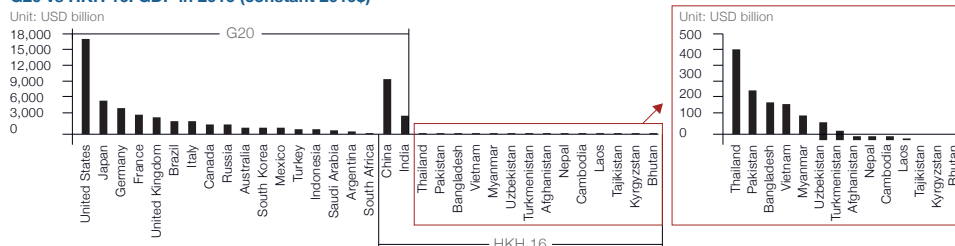
HKH 16: still a long way to develop on little water

The collective economy of the HKH 16 stands at USD13.2 trillion⁴⁴. This is 2.2x that of Japan's GDP and 78% of that of the US as shown in the chart below. However, a large population living within these countries means a much lower GDP per capita compared to the developed countries. Although the region has two of the fastest growing economies, China and India, the average GDP per capita of the HKH 16 was only around USD3,868 in 2016 compared to South Korea's USD25,459 or Japan's USD47,608; only 15% of Korea's and a mere 8% of Japan's⁴⁴.

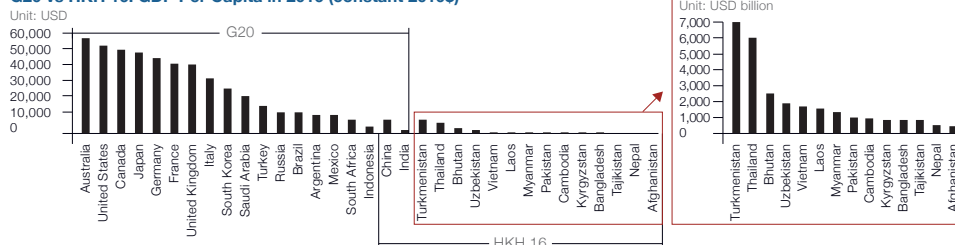
HKH 16's GDP of USD13.2tn is 2.2x that Japan...

...but only 8% on a per capita basis

G20 vs HKH 16: GDP in 2016 (constant 2010\$)



G20 vs HKH 16: GDP Per Capita in 2016 (constant 2010\$)



No doubt that HKH 16 countries need to grow their economy. But, do we have enough water to reach the level of those in G20? The World Bank defines the Water Poverty Mark at 1,000m³ per person per year for a nation or a region's renewable water resources, below which nations or regions are considered water scarce, which means that the lack of water becomes a severe constraint on food production, economic development, and protection of natural systems. Countries that are using over 10% of their available water resources are said to be facing low water stress, over 20% means medium water stress and above 40%, high water stress.

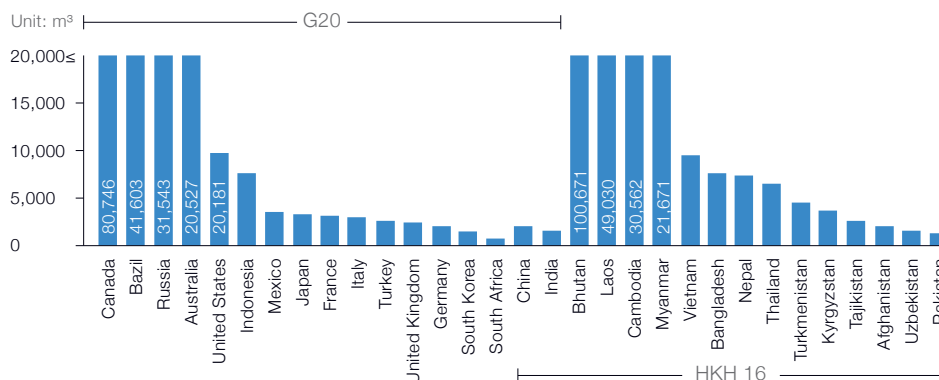
Water Poverty Mark = 1000m³

Using >40% of water resources = facing high water stress

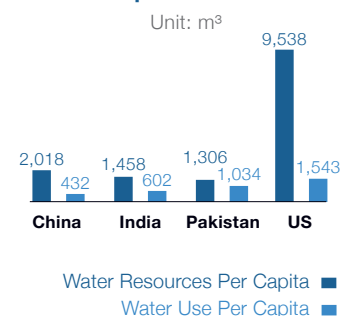
To achieve a per capita GDP of over USD50,000, the US uses at least 1,543m³ of water per capita or around 16% of its water resource per capita⁷. However, it is important to remember at this point that the two largest economies in the HKH 16, China and India, only have total renewable water resources of 2,018m³/pax and 1,458m³/pax respectively⁷. Using around 1,500m³ like the US would mean they are using three-quarters of its water resources of China or all of India's water. Such intense use of water would be unsustainable. The prospects are even dimmer for Pakistan with only 1,306m³/pax. China, India & Pakistan will have no choice but to follow the path of Europe and use other people's water through virtual water trade. Please see "Basic Water-nomics" for more.

Using ~1,500m³ like the US means China will be using 75% of its water resources & India all of its water

G20 vs HKH 16: Water Resources Per Capita



Limited water resources per capita constraint development choices

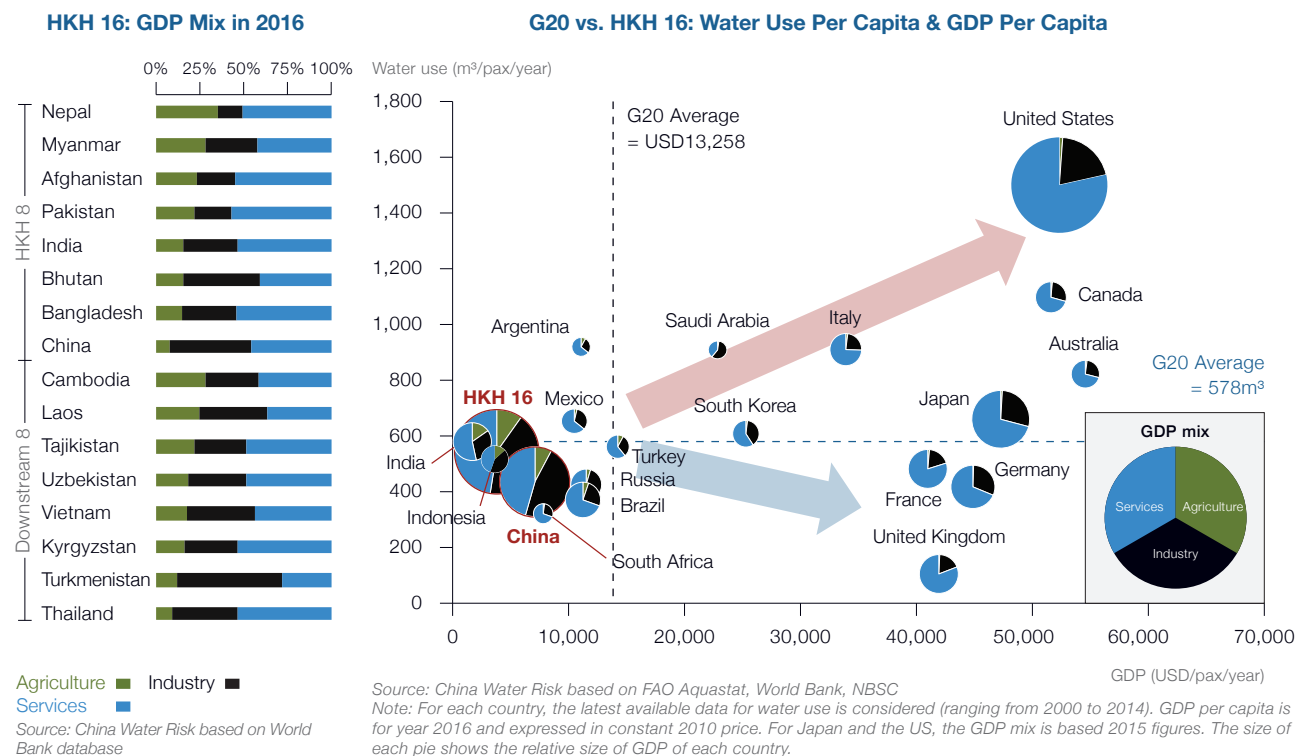


Water-nomics: HKH 16 vs. G20 countries

We compare the per capita water use & GDP of the HKH 16 with each G20 country

Although the GDP of the HKH is 78% that of the US...

Countries need water to develop and grow their economies as discussed in the “Basic water-nomics” in Chapter 1. So where are the HKH 16 in terms of water-nomic performance? Given limited water resources, do the HKH 16 have enough water to “grow” their economies and develop? In this regard, we compared the HKH 16 to the G20 countries. The chart below shows the correlation between GDP and water use per capita for each of the G20 countries as well as the collective GDP and water use per capita of the HKH 16. Note that the size of each pie shows the relative size of GDP of each country.

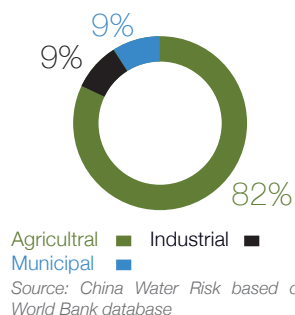


...the water-nomic performance of the HKH 16 lags the G20

For Asia, water use is expected to rise 30-40% by 2050...

...agri water savings are a must-do

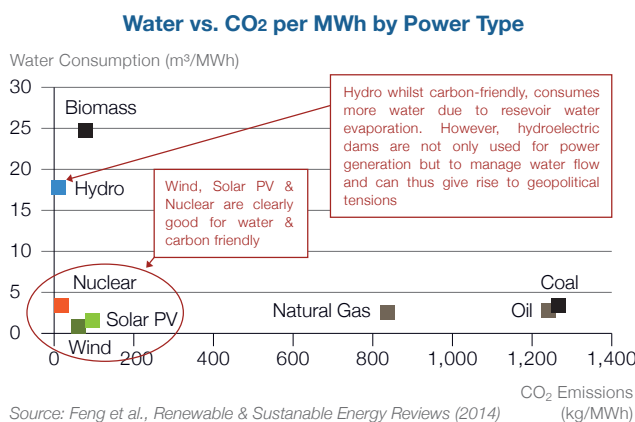
HKH 16: Water Use Mix



Key points of note from the chart above are:

- **The HKH 16 lags the G20:** The HKH 16 falls in the lower left quadrant and has a long way to go in terms of both per capita GDP and water use. It is interesting to note that the three most populous countries in the world (China, India & Indonesia) are relatively close to each other;
- **Water use is expected to rise in the HKH 16:** The average water use per capita of the HKH 16 stands at nearly 558m³/pax. India and China's water use is 602m³/pax and 432m³/pax, respectively. For the broader Asia region, future water demand is expected to increase by 30%-40% by 2050 from the 2010 level⁴. We expect water use in the HKH 16 will likely go up as a result of improving living standards and continued urbanisation. More on urbanisation later in the two-pager insert titled “People & Rivers in Asia”.
- **HKH 16 will need to revamp agriculture for more water & GDP:** Agriculture's share of GDP mix falls as countries become richer, in line with conventional industrial- and services-led growth. Agriculture's share of GDP is thus still visible for countries in the bottom left quadrant, including the HKH 16. Agriculture is typically the sector with the largest water use in developing countries and in the HKH 16, it accounts for 82% of water use – see left chart. Shifting away from agricultural-led economies could be a way to reduce water use and raise GDP. However, this is often easier said than done as countries remain heavily dependent on agriculture and related industries for employment – India and China employ over 480 million people in this sector alone. More feasible solutions for the near term would be optimising crop mix in terms of water use and value added, and improving irrigation efficiencies and yields⁵.

- HKH 16 energy choices also matter for both water & climate:** The per capita energy use of the HKH 16 is only at 15MWh/pax compared to 81MWh/pax for the US or 32MWh/pax for the UK⁴⁴, where power generation rather than the agriculture sector is the largest user of water. Adding the “wrong” type of power, such as coal-fired power, can thus have a direct as well as indirect impact on water use by accelerating climate change, which in turn exacerbates water scarcity. Renewable energy such as wind, solar and hydropower therefore plays an important role in meeting future energy water without adding more pressure on climate and water – see chart below. The HKH Rivers provide natural advantages for HKH 16 to develop hydropower; the HKH 8 alone is home to about a third of global hydropower installed capacity. Hydro also provides other benefits such as flow regulation and flood control and help with irrigation. That said, hydro projects should be planned and developed to ensure the sharing of benefits with affected communities as well as compliance with environmental standards and impact assessments.

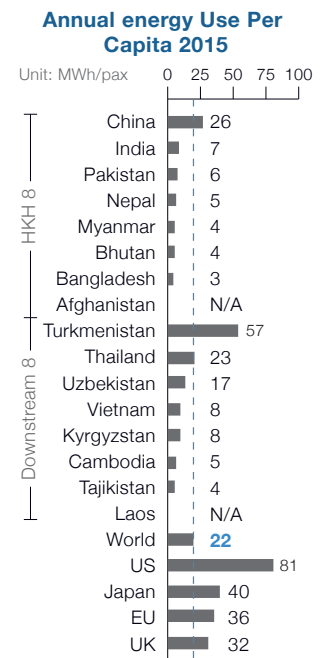


Renewables can bring both carbon & water savings

Our joint brief with the International Renewable Energy Agency (IRENA)⁶⁸ estimates that China's water use intensity in power generation can fall by 42% along with carbon emissions intensity by 37%, if renewable targets are achieved by 2030.

Source: China Water Risk & IRENA, "Water Use in China's Power Sector: Impact of Renewables and Cooling Technologies to 2030", February 2016

Choosing the right type of power is also important



Source: China Water Risk based on World Bank database.

Note: Conversion factor used: 1kg of oil equals 0.01163MWh

- Trade can be used to manage national water use:** European countries like France, Germany and the United Kingdom as well as Japan appear to be using less water than the US, Canada and Australia. This is because they are largely reliant on water-intensive imports from other countries whereas the US, Canada and Australia grow their own food and largely supply their own fuels. For countries like China, where food self-sufficiency and energy security are of high priority, a minimum amount of water will have to be dedicated to agriculture water use and power generation. China will thus likely veer toward the path of the US-Canada-Australia cluster as oppose to that of Japan-Germany-France-UK. This means that China will have to look beyond efficiency gains, industrial and crop mixes towards using trade to alleviate national water use. Such policies, while good for China, could change the face of current global trade and can be extremely disruptive to multiple global industries – please see the following page on “**Blindspots Ahead: Global Trade Disruptions**”.

It is clear from the above that limited per capita water resources constrains future development choices from the economy, energy and food to trade. Asia's two largest economies, China and India may both have no choice but to adopt all the above measures to manage economic growth whilst striving for water, food and energy security.

Indeed, China is already revamping Made-in-China with a new set of strategic emerging industries and transitioning their water-intensive and polluting industries toward a circular economy. China is also aggressively promoting global trade through its One Belt and One Road initiative. All these will have significant implications for natural resources and environment, not only in China, but also across the globe through trade. With the tighter environmental regulation in China, does that mean that polluting industry may shift to countries with lax regulation? As pollution exacerbates scarcity, clearly it would be a zero-sum game for already water-stressed countries.

The actions of China as the upper riparian are important but so are those of the other HKH 8 as they comprise a lion's share of not only the economy, but the water resources of the HKH 16. It therefore pays to take a closer look at the Water-nomics of the HKH 8.

Trade can be used to manage national water use...

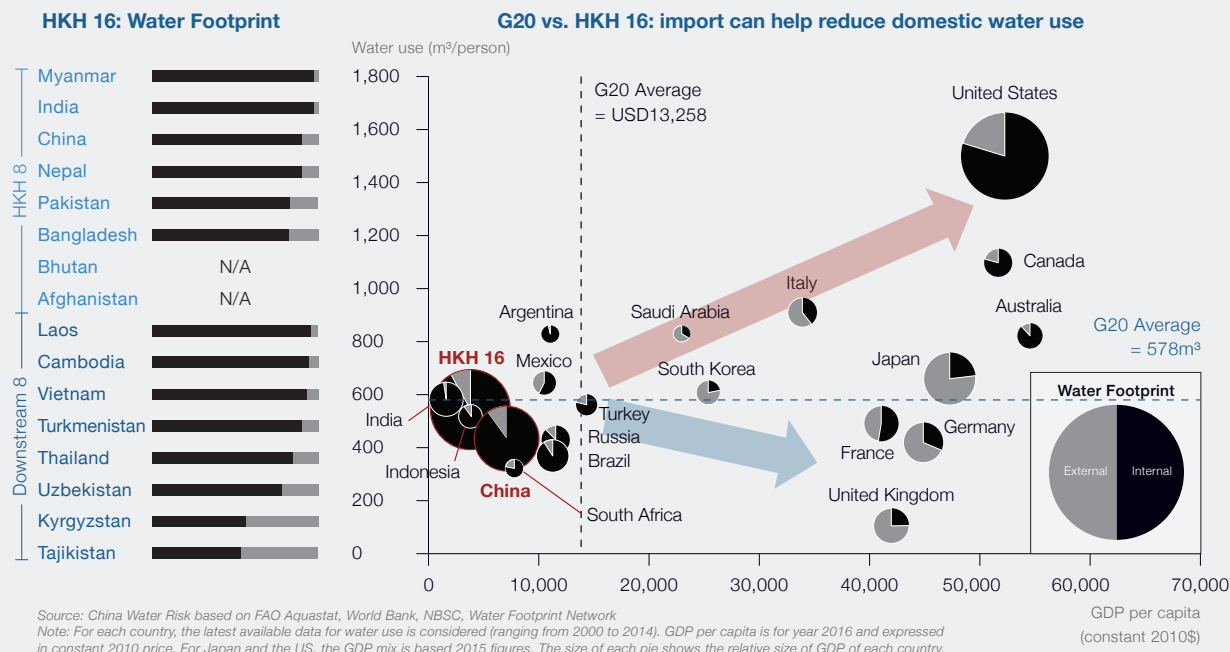
...China's actions may be good for China, but disrupt global trade

China & India have no choice...must save water, maximise energy, industrial & crop mixes plus use trade to achieve growth with limited water

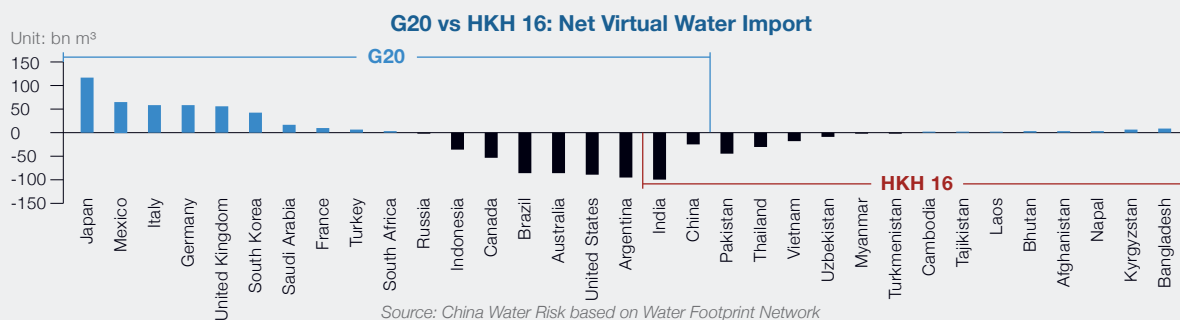
Pollution which exacerbates scarcity must also be considered

BLINDSPOTS AHEAD: GLOBAL TRADE DISRUPTIONS

Trade can play an important role in deciding national and regional water-nomics strategy. The chart below clearly illustrates this. The US-Canada-Australia cluster has a high internal water footprint compared to that of the Japan-Germany-France-UK cluster, which has a relatively higher external water footprint, in short using other people's water. The HKH 16 is largely self-reliant using its own water, both individually and collectively.



For HKH countries facing water stress, trade can also be used to manage national water use. Other factors being equal, choosing to import more water-intensive goods can help better manage available water resources. A closer look at the net virtual water flows of the G20 Countries and the HKH 16, shows that many of the developed countries with lower water use such as Germany and the United Kingdom are net virtual water importers; while countries with relatively higher water use are mostly net virtual water exporters (see chart below).

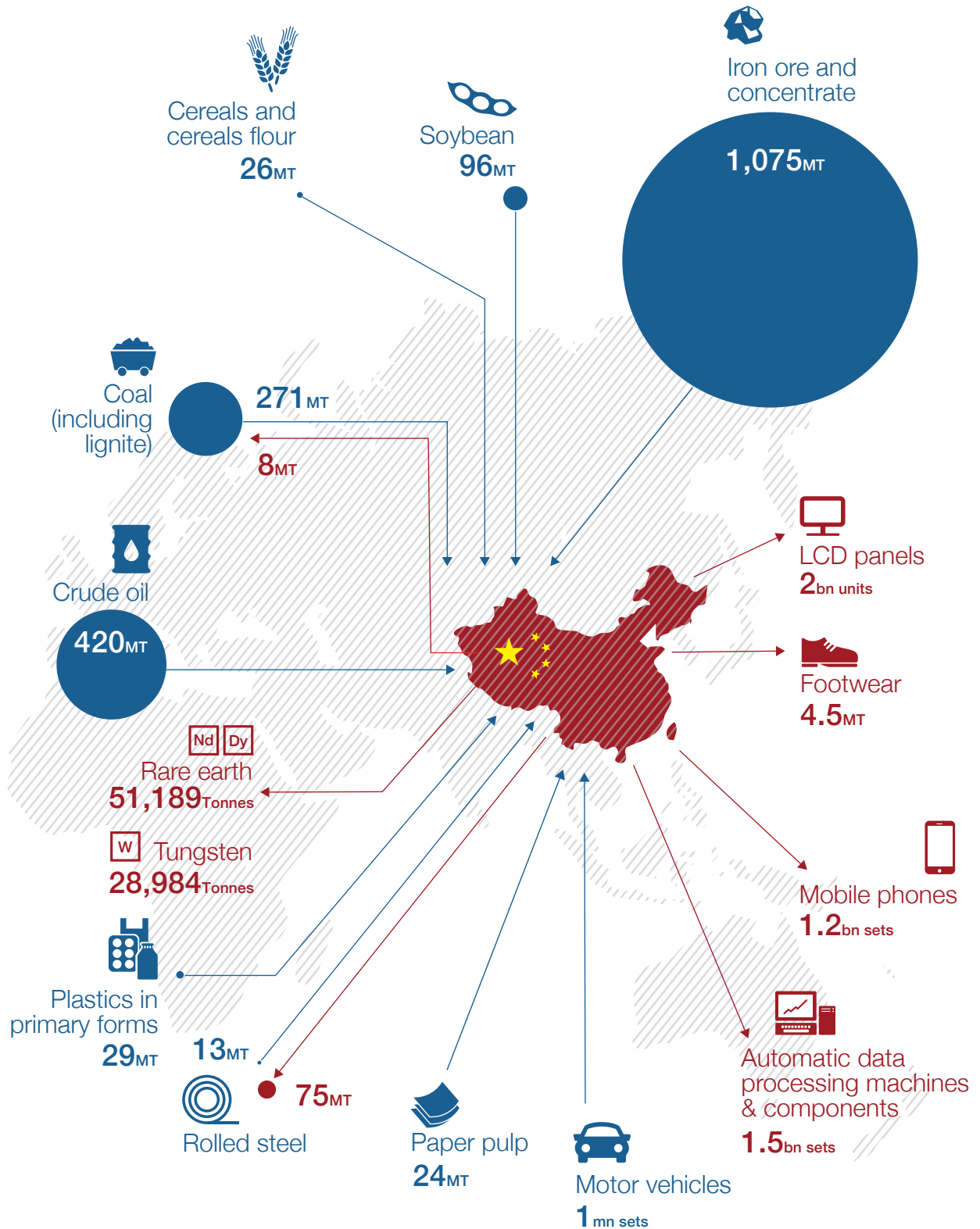


Although the above estimates are based on data during 1996-2005, they show the relative size of virtual water flows embedded in global trade and the magnitude of potential disruptions driven by water-nomic decisions in HKH 16. Currently, the HKH 16 is estimated to export about 209 billion m³ of net virtual water in trade with India as the largest virtual water exporter with 95 billion m³ net outflow⁴⁶. Note that China, while a large exporter of industrial goods is a smaller net virtual water exporter than India; this is due to large agricultural imports, in particular soya beans. It is also worth noting that the option of using other people's water may not be available for some countries due to various factors such as affordability and insufficient logistic infrastructure. Also, water stressed countries may continue to adopt an export-led development model to alleviate poverty and create jobs.

The obvious question here is whether India, China and Pakistan, which do not have sufficient water resources per capita and are already facing water stress, should continue to export water-intensive goods. Is Made-in-India the right way forward? As we mentioned in "Basic Water-nomics", the UK has a high external water footprint. Hoekstra & Mekonnen (2016) found that 49% of UK's global blue water footprints exceed the local sustainable level where Pakistan and India represent 10% and 7%; mainly driven by UK imports of their water intensive goods such as rice⁴⁷. Could such virtual water trade exacerbate their water scarcity? Asia may have no choice but to turn to trade to manage its growth on limited water. There is clearly much upside as evidenced by Japan, the largest net virtual water importer at nearly 117 billion m³ net inflow⁴⁶. Unfortunately, water-nomic policies using virtual water trade to alleviate water stress that are good for the HKH 16, may be black swan risks for the rest of the world.

CHINA MATTERS FOR GLOBAL TRADE

China's Main Import & Export Commodities in 2017



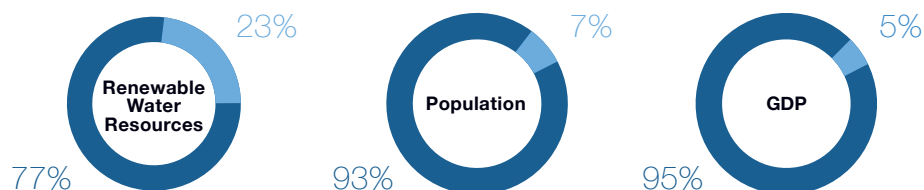
Source: China Water Risk, NBSC
MT=million tonnes

Water & the economy: HKH 8 vs. Downstream 8

The HKH 8 has a large share of HKH 16's water (77%), population (93%) & GDP (95%)

The HKH 8 dwarfs the Downstream 8 in terms of GDP. In 2016, the HKH 8 generated USD12.5 trillion in GDP compared to the Downstream 8's USD715 million (2010 constant price)⁴⁴. The charts below show the HKH 8's dominance in water resources, population as well as GDP:

HKH 8: Important for HKH 16



HKH 8 ■ Downstream 8 ■

Source: China Water Risk based on UN World Population Prospects, FAO AQUASTAT & World Bank World Development Indicators

Downstream 8 and HKH 8 have similar GDP/pax ...

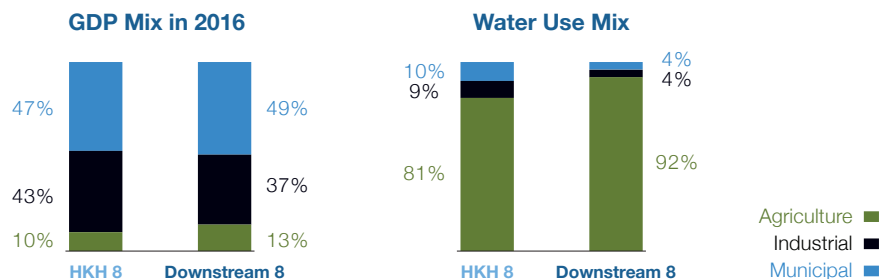
That said, the HKH 8's two most populous countries in the world bring the average GDP per capita of HKH 8 down to USD3,930 compared to the Downstream 8's USD3,026⁴⁴. These represent less than 10% of Japan's GDP per capita or around 15% of South Korea's GDP⁴⁴. The per capita water use however, varies dramatically: the average water use per capita of the HKH 8 is around 521m³/pax whereas that of the Downstream 8 is 2x this at 1,050m³/pax⁷.

...but HKH 8's water use/pax is half that of Downstream 8

This could be explained by the Downstream 8's significant agricultural water use. As can be seen from charts below, although both the HKH 8 and Downstream 8 have similar GDP mixes as a whole (left-below chart), agricultural water use is clearly more dominant in the Downstream 8 (right-below chart). Data also shows that the HKH 8 is more productive: to generate the same amount of agricultural added value, the Downstream 8 use 2.5x water compared to the HKH 8⁷.

For the same amount of agri added value, Downstream 8 water uses is 2.5x that of HKH 8

None of the Downstream 8 are water stressed ...



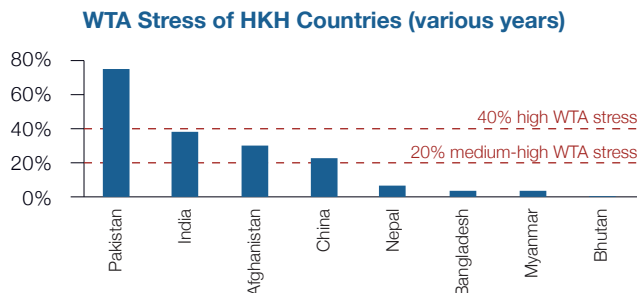
Source: CWR based on World Bank (left chart) and FAO, various years (right-side chart)

Finally, it is worth noting here that while none of the Downstream 8 are water stressed, four of the HKH 8 face 'medium-high' and 'high' water stress.

Four of the HKH 8 are water stressed

Here, we take a closer look at the water use-to availability ratio (WTA), a common indicator for water stress across the HKH 8. The results are shown in the chart below:

... whereas Pakistan, India, Afghanistan & China of the HKH 8 are water stressed



Source: China Water Risk based on FAO AQUASTAT and NBSC.

Note: WTA stress = water withdrawal/total renewable water resources. The data of total renewable water resources data of each country all refer to 2014; however, for water withdrawal, due to limited data in FAO database, the data year ranges from 1998 to 2010. For China's total water withdrawal, the 2014 figure from national statistical yearbook is used.

WTA Stress

Water use-to availability ratio (WTA) is a commonly used indicator for water stress of a certain region. It is calculated as the ratio of water withdrawal over total renewable water resources over the same period (e.g. a year).

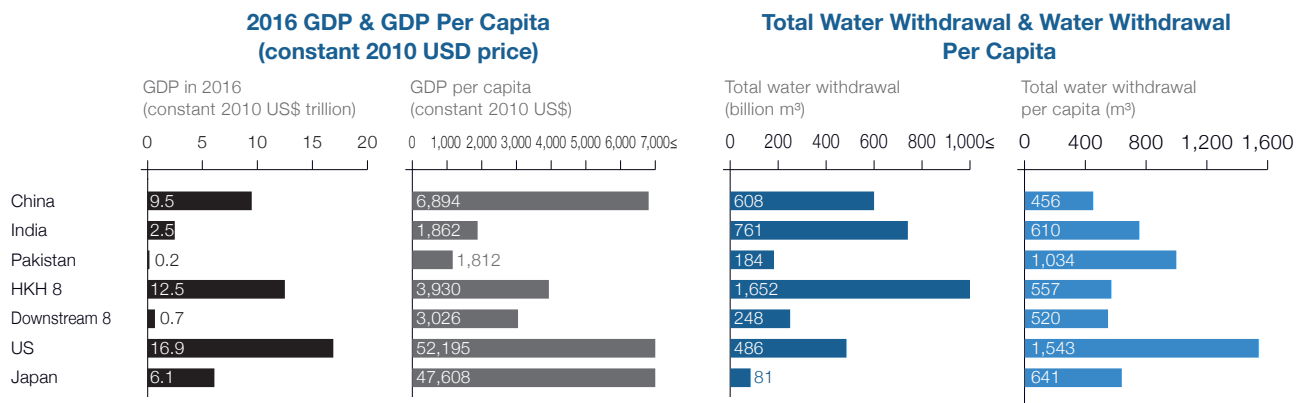
A region with a WTA above 10% suffers from moderate WTA stress, above 20% is medium-high WTA stress, and over 40% is high WTA stress.

At a glance, half of the HKH 8 face water stress: China & Afghanistan face medium-high WTA stress whereas India & Pakistan face high WTA stress. Pakistan, with a WTA of 74%⁷, is close to the 80% threshold defined by World Resource Institute as 'extremely high' water stress. It is not difficult to see why China, India, Pakistan and Afghanistan are water stressed. As discussed previously in Chapter 1: "The Challenge: 10 Rivers for 16 Countries", they are not naturally endowed with much water in the first place. What's worse is climate change experienced in the Third Pole which will only serve to exacerbate underlying scarcity. The impact of climate change will differ across basins, at times accentuating the stress. Climate change's impact on the annual flows of each of the 10 HKH Rivers as well as extreme weather events, are explored in detail in the next chapter.

These four countries are not naturally endowed with much water in the first place ...

... climate change exacerbates this

It should be noted here that infrastructure plays an important role. In mountain regions that face low water stress, may still be water scarce because of poor infrastructure and difficult topography. Also, note that due to limits on data availability on water withdrawal, the 2014 results shown in the chart above are the latest available information. While it may not reflect the current WTA stress status, it gives an indication of the baseline water stress, which will likely only rise with urbanisation and development.

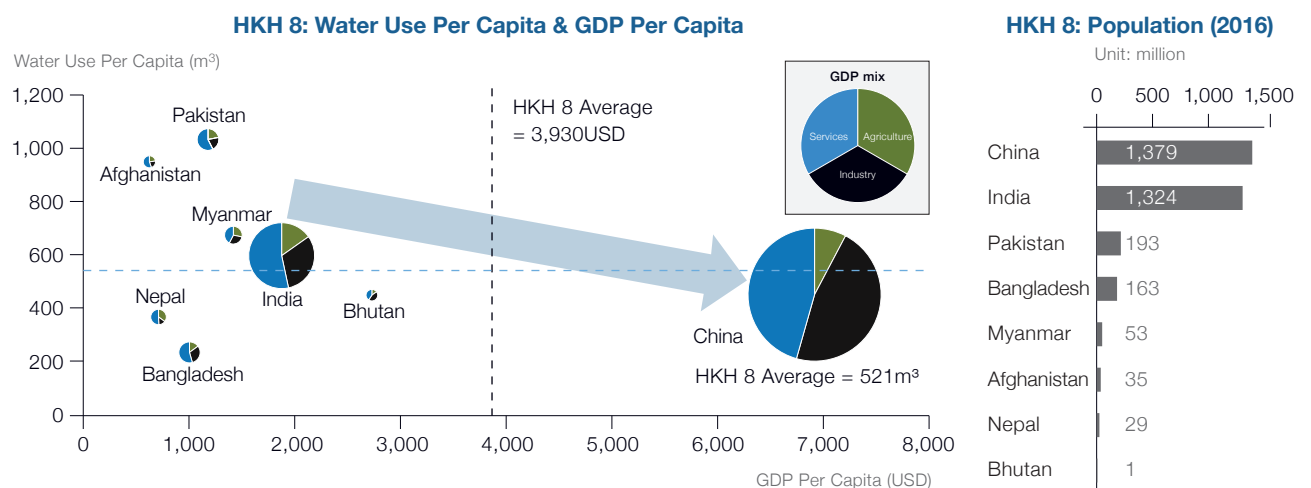


Source: China Water Risk based on World Bank and FAO

Water-nomics of the HKH 8

Some HKH 8 countries perform better than others; disparities in GDP mix and water use are magnified at the country level. The water-nomic performances of the HKH 8 are analysed and set out in the chart below which shows their GDP per capita and the latest available water use per capita:

We compare water-nomics performance across the HKH 8



Source: China Water Risk based on 2016 GDP per capita data (constant 2010 US\$) from World Bank's World Development Indicators, and water withdrawal per capita data from FAO AQUASTAT. The data year for water withdrawal per capita varies across the countries: China (2015), Myanmar (2005), India (2010), Bangladesh (2008), Nepal (2006), Bhutan (2008), Pakistan (2008) and Afghanistan (2005). The HKH 8 Average water use per capita is calculated based on total water withdrawal of HKH 8 divided by the latest total population of HKH 8. The size of each pie reflects the relative size of each country's GDP in 2016 (constant 2010 US\$).

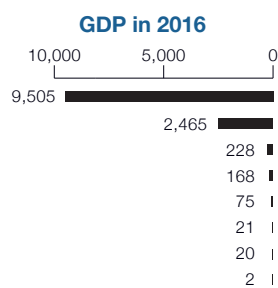
China leads in GDP per capita across the HKH 8...

... and generates more GDP on less water

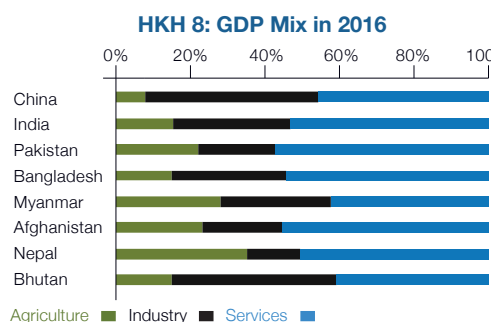
Water stressed countries should improve irrigation & maximise crop mix

It is clear from the above chart that:

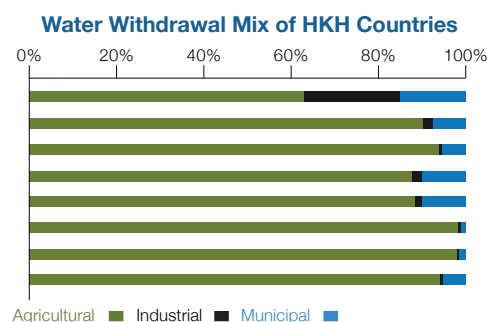
- **China's economic performance drives up the average:** China is a clear leader in the HKH 8 when it comes to GDP. It's the only upper-middle-income economy according to the World Bank's definition. The GDPs per capita of the other countries are all below USD3,000. Afghanistan and Nepal are classified by the World Bank as low-income economies; while, Bangladesh, Myanmar, Pakistan, India and Bhutan are lower-middle-income economies.⁴⁸
- **Wide range of water use per capita:** from a low of 231m³ in Bangladesh to a high of 1,034m³ in Pakistan, nearly 5x that of the former. With the exception of Pakistan and Afghanistan, all the other countries have a water withdrawal per capita that is lower than the OECD average of 812m³ in 2015⁴⁹ or that of the US (1,543m³ as of 2010⁷). Urbanisation is expected to drive up water use. Already in general, countries with higher urbanisation rates also have relatively higher share of municipal water use as shown in the charts below.
- **Reducing agricultural water is imperative:** The high water use per capita generally corresponds to a higher share of agriculture in GDP. For example, Afghanistan and Pakistan where agriculture accounts for 23% and 22% of their respective GDP, agriculture uses over 90% of water withdrawal. There are, however, anomalies such as Myanmar and Nepal, which are demonstrating higher agricultural share of GDP than Afghanistan and Pakistan but lower water use per capita as shown in the charts below. These anomalies are likely due to types of crops grown, the use of irrigation and/or quality of infrastructure.



Unit: US\$ bn
(constant 2010 price)



Source: China Water Risk based on World Bank, World Development Indicators



Source: China Water Risk based on data from FAO AQUASTAT.
Note: Due to limited data in FAO database, the data year ranges from 1998 to 2010. For China's total water withdrawal, the 2015 figure from national statistical yearbook is used.

For Pakistan, India, Afghanistan and even China, which face medium-high to high water stress, it is important to reduce water use in agriculture. This can be done by improving agriculture and irrigation practices and maximizing crop mix. As discussed earlier, managing virtual water trade by importing, instead of exporting, water intensive crops/products may be an option.

Shifting away from low value water intensive & polluting industries makes sense

- **Shifting GDP mix to favour industry & services is also necessary:** GDP mix impacts water use levels. From the charts above, it is obvious that while agricultural share of the economy varies across the HKH 8, it is by far the largest user of water. Agricultural water use ranges from 63% (China) to 98% (Afghanistan), but agricultural share of 2016 GDP ranges from a low of 8% (China) to a high of 35% (Nepal). Shifting away from an agriculture-led economy thus makes sense. Aside from China, industrial water use accounts for a very small share of total water withdrawal in the other HKH 8 countries. Promoting less water-intensive service sectors is another way. But, except for Myanmar and Bhutan, services already account for over half of the GDP of the other six countries.

Clear room for improvement, even for China...

... must find roadmap to more GDP on less water & pollution

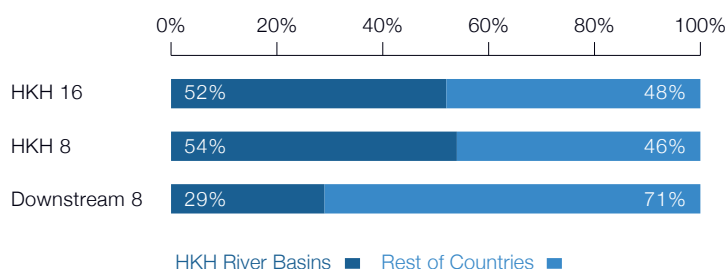
There is clear room for improvement, even for China which leads the HKH 8. For the rest of the HKH 8 to shift into the lower right-quadrant of the above chart will require a fine balancing act for policy makers in these countries. While China is ahead in generating more GDP per drop, its performance should also be benchmarked against its own available water resources, which have also been affected by rampant pollution. China is currently fighting a 'War on Pollution' with a newly updated "Water Pollution Prevention & Control Law", which has come into effect on 1 January 2018 and should help stricter enforcement along with other more stringent environmental regulation and policies. Although there is still a long way to go, this is a good step towards the right direction. The HKH 8 must find a collective and collaborative roadmap forward to generate more GDP on less water and pollution.

So how do the 10 HKH River Basins fit into this national narrative?

Where people are matters: Over half live in HKH River Basins

Where people live matters. Within the HKH 16, more than half (52%) of the population of 3.41 billion live along the HKH River Basins¹. This clearly raises the importance of the river basin regardless of its contributions to surface water flows or the economy. Most of these 1.77 billion living in the HKH River Basins are in the HKH 8: 1.7 billion in the HKH 8 compared to 68.1 million in the Downstream 8, where only 29% of the population live along the river basins¹ (see chart below). The HKH River Basins are therefore much more important to the HKH 8 than the Downstream 8. This is also reflected in the population density map in the following two-page spread on “People & Rivers in Asia”.

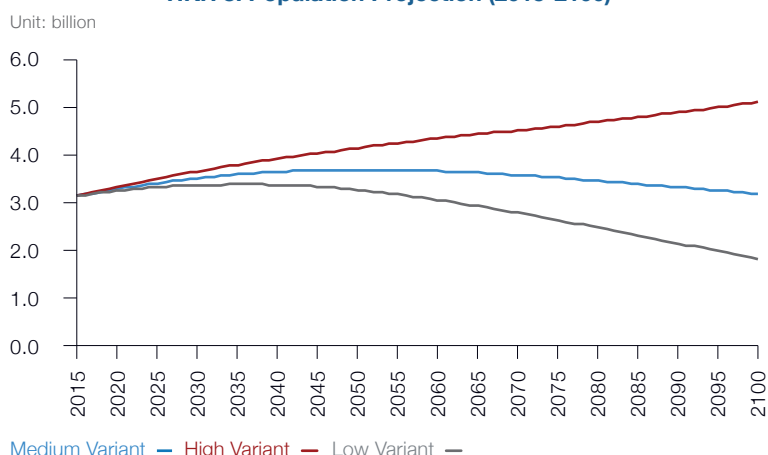
HKH 16: half of population live along HKH Rivers



Source: China Water Risk based on CAS estimates & United Nations Population Division, World Population Prospects: The 2015 Revision

According to population projections from the World Population Prospects: The 2017 Revision²⁸, the total population of the HKH 8 will continue to rise at least through 2035. The UN Population Division projected population of each country by 2100 under three different scenarios. Under the low variant projection, the total population of the HKH 8 will peak at 3.40 billion by 2036 before declining²⁸. Under the medium-variant projection, the total population is expected to peak at 3.69 billion by 2051; while under the high-variant projection, it will not peak within this century²⁸. These scenarios are shown in the chart below:

HKH 8: Population Projection (2015-2100)



Source: China Water Risk based on World Population Prospects: The 2017 Revision

The projection by country under the medium variant scenario shows that, with the exception of China, all the other HKH 8 would maintain a population above the 2015 level by 2100. India's population is expected to surpass that of China by 2024 and continue rising until 2060 to 1.68 billion; China is expected to peak at 1.44 billion by 2029. By 2100, India's population will be 48.6% larger than that of China. If future population growth follows this trend, at least half of the increase may well be in the HKH River Basins within the HKH 8. Since much of the population already lives in urban clusters located along these rivers (see the following two-page insert on “People & Rivers in Asia”), this will add further pressure on managing future water demand in already stressed HKH River Basins – more on this later.

1 in 2 people in the HKH 16 live in the HKH River Basins...

1.77bn people live in the HKH River Basins

1.7bn of these are in the HKH 8...

Only 27% of the Downstream 8 population (57.2mn) lives in the HKH River Basins

The HKH 8's population will continue to rise at least through 2035...

...at best population will peak at 3.4bn by 2036...

...at worse not peak until the next century

Three scenarios for population growth

Three main scenarios based on expected future fertility levels are set: 1) medium variant, 2) high variant and 3) low variant projections. The medium variant projection assumes a fall of global fertility level from 2.5 births per woman during 2010-2015 to 2.2 2045-2050 and then to 2.0 in 2095-2100. The high variant projection assumed a higher fertility level, and the low variant projection assumed an even lower fertility level. The total population projections of the HKH 8 under these three different scenarios are shown in the chart.

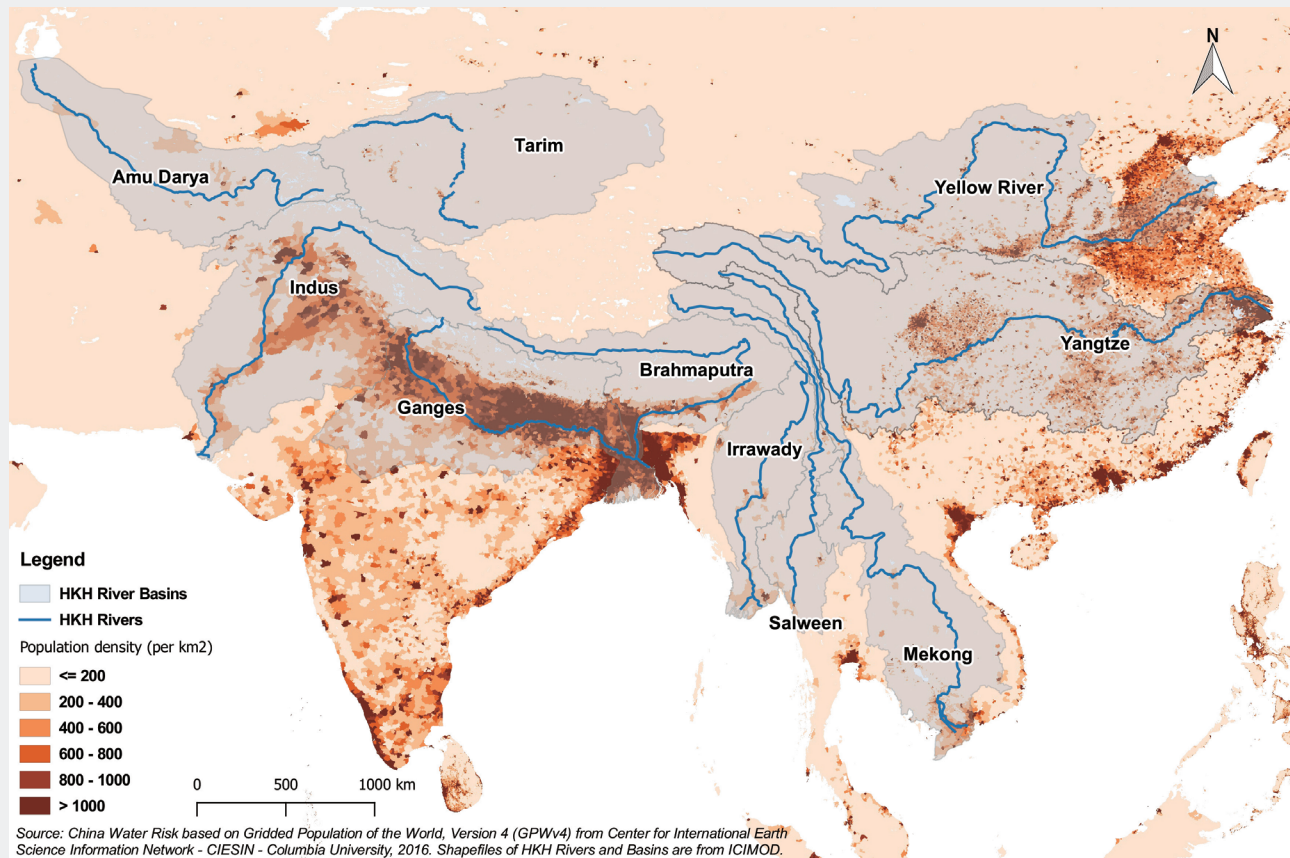
India's population likely 48.6% > China by 2100

>50% of population growth likely to be in the HKH River Basins within the HKH 8

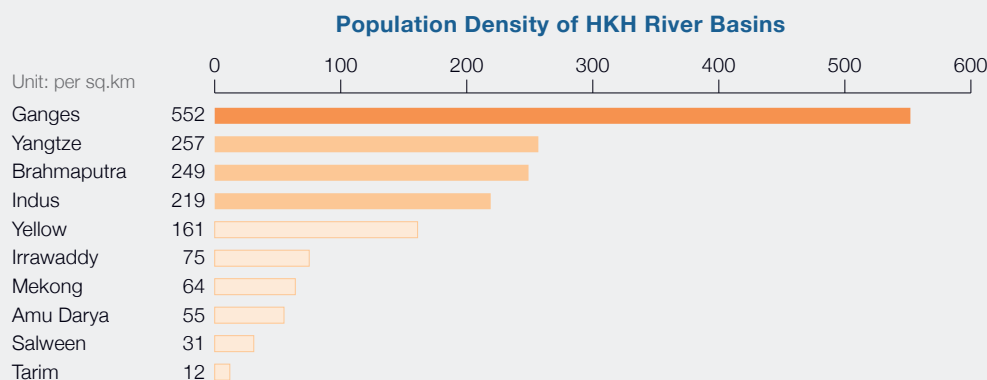
PEOPLE & RIVERS IN ASIA

Along the HKH Rivers ...

Population density is illustrated in the map below. The darker the area, the more populated it is. At a glance, it is clear that while population is clustered around the 10 HKH Rivers Basins, it is not equally distributed across HKH River Basins as well as along each river.



It is evident from the map above that the Ganges River Basin is the most densely populated basin. It houses 552 persons per km² (meaning on average, four people live on an area of the size of a soccer field; in some areas, as seen on the map, it can be a lot more densely populated); more than 2x that of the Yangtze, Indus Brahmaputra and more than 3x that of the Yellow as per the chart below. For perspective, it is twice as crowded than the Rhine River Basin, one of the most urbanized regions in the world, housing only 270 persons per km² ⁵⁰.



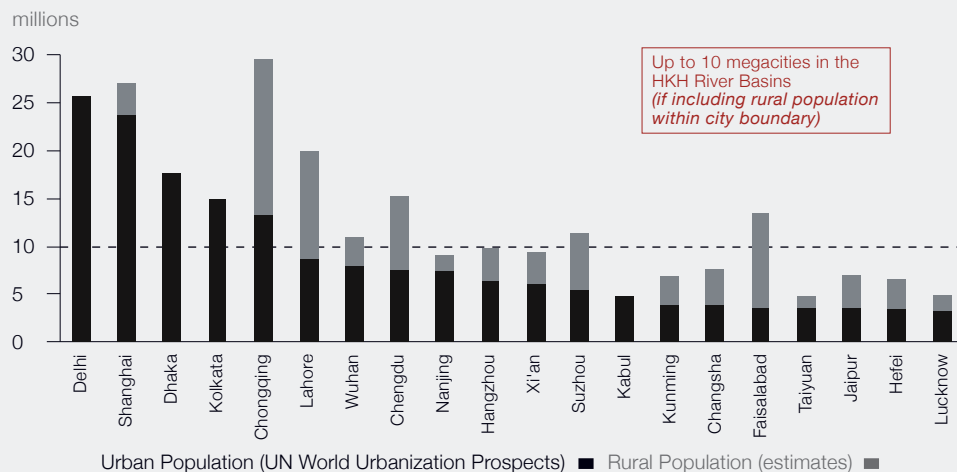
Source: China Water Risk based on calculation done by China Academy of Sciences from WorldPop, 2015 estimates. Uzbekistan and Turkmenistan data are not available.

Aside from having the highest population densities, the Ganges, Yangtze, Brahmaputra, Indus and Yellow are also the five most populated basins in Asia. Large population together with high population density along the rivers only result in increasing stress on natural resources such as water. It is thus not surprising that the Ganges is considered the most vulnerable amongst the six HKH River Basins south of China⁵¹. As if this is not bad enough, many of Asia's mega-cities also lie on these rivers, which mean that population along these rivers will likely rise with urbanisation.

In the cities ...

Now: In 2015, about 56% of China's population lived in urban areas whereas the urbanisation rates of the other HKH 8 remain well below 40%. Nepal has the lowest urbanisation rate at 19%. Many of these HKH 8 cities lie along the banks of the 10 HKH Rivers. Currently, there are up to 10 megacities with total population over 10 million along the HKH River Basins (all in HKH 8). These are listed in the chart below. Five of these are in China, Pakistan (2), India (2) and Bangladesh (1). The two largest cities (including both rural and urban population), Chongqing (29.6 million) and Shanghai (27.1 million), are both located on the Yangtze River. With China promoting the development of five key urban clusters along the Yangtze, we will likely see more HKH megacities, at least along the Yangtze in the future.

Top 20 Most Populated Cities in the HKH River Basin



Urban Population (UN World Urbanization Prospects) ■ Rural Population (estimates) ■

Source: China Water Risk based on urban population from the UN World Urbanisation Prospects: The 2014 Edition. The rural population is calculated as the difference between the total population estimates by the China Academy of Sciences based on WorldPop (2015), and the urban population from the UN World Urbanisation Prospects. The rural population in Delhi, Dhaka, Kolkata and Kabul are not shown in the chart due to difference in geographical boundary in two datasets.

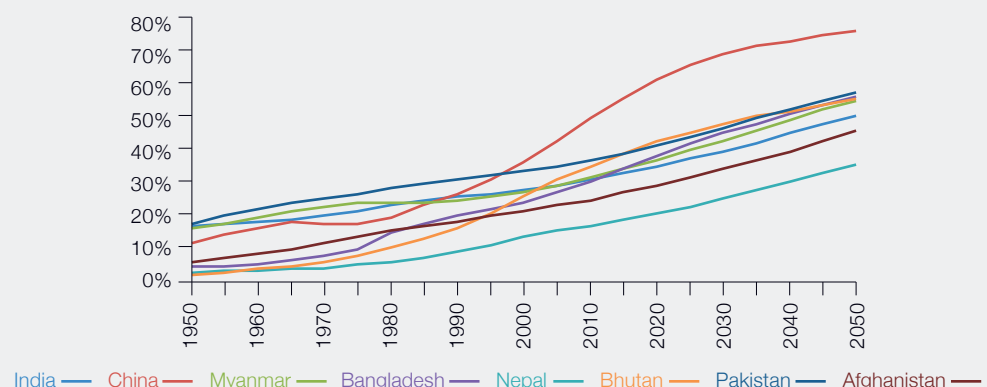
In the future: The past six decades have seen increasing shares of urban population across HKH 8 countries. This trend is expected to continue as shown in the chart below. By 2050, six out of the HKH 8 will have an urbanisation rate above 50%. China's urbanisation rate is projected to rise to 76%. Even the two least urbanised countries, Afghanistan and Nepal, are expected to reach 45% and 36%, respectively by 2050.

HKH 8: Urbanisation rate in 2015



Source: China Water Risk based on UN World Urbanization Prospects

HKH 8: Share of Urban Population (1950-2050)



Source: China Water Risk based on World Population Prospects: The 2017 Revision

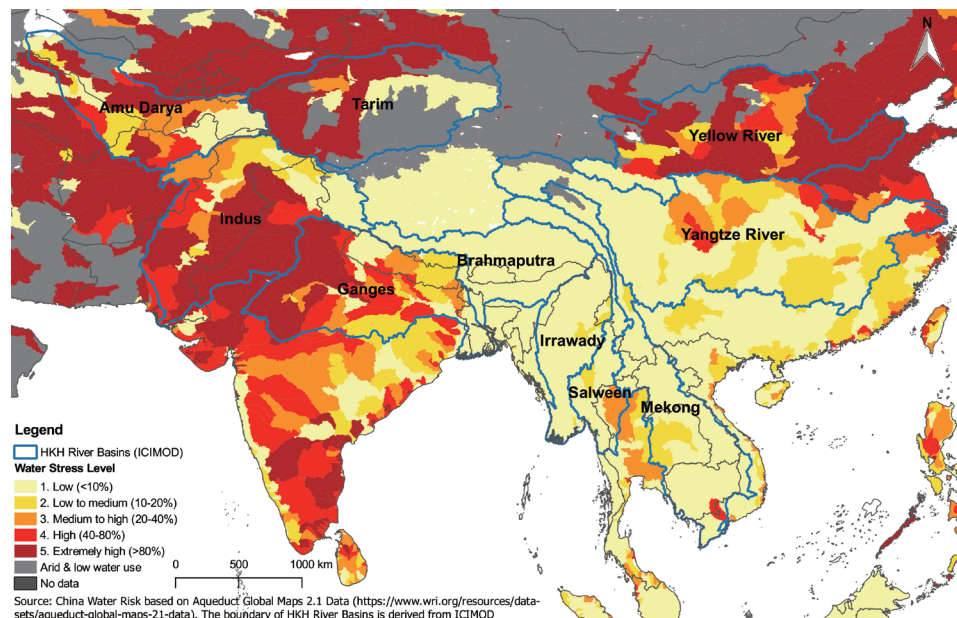
This trend not only holds true for the HKH 8, but for the broader Asia Pacific region, where over 60% of the population is expected to be living in cities by 2050⁴. Rising urbanisation, coupled with projected population increase by the middle of this century, means more concentration in urban areas. On one hand, this will push up demand for resources and services for both national consumption and economic growth, adding pressure on the ecosystems⁵² as well as the systems of water supply and wastewater treatment. On the other hand, it will likely increase the exposure of people and economic assets to extreme weather events such as floods in the HKH River Basins. Such population trends mean that it is imperative to assess the socio-water-economic carrying capacity of each of the 10 HKH River Basins carefully – see “**Water-nomics of HKH River Basins within the HKH 8**”.

30% HKH River Basins face above 'high' water stress

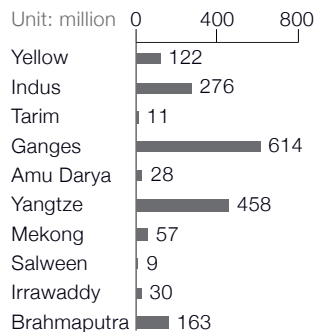
HKH River Basins in Northern China & South Asia are more water stressed ...

...the Yellow, Indus, Tarim, Ganges & Amu Darya all have areas that face 'extremely high' water stress

The below map shows the HKH River Basin overlaid with the Aqueeduct Baseline Water Stress map of World Resource Institute (WRI). At first glance, the HKH River Basins in Northern China and South Asia are more water stressed than those in Southern China and Southeast Asia.

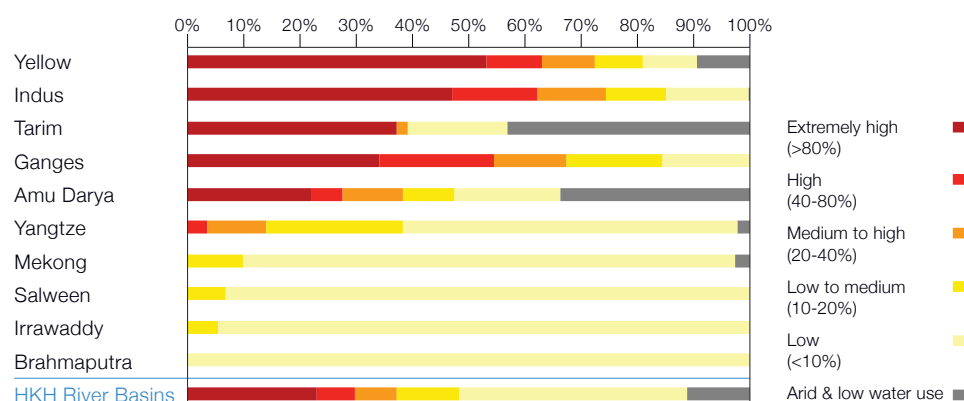


2015 Estimated Population (in HKH 16)



Source: China Water Risk based on calculation done by China Academy of Sciences from WorldPop, 2015 estimates. Uzbekistan and Turkmenistan data are not available.

HKH River Basins: Baseline Water Stress (Current Conditions)



Source: China Water Risk based on World Resources Institute Aqueeduct 2014

Notes: Baseline water stress measures the ratio of total annual water withdrawal to average annual available blue water

30% of the HKH River Basins (in terms of area) face either 'high' or 'extremely high' water stress...

... due to high urbanisation along the river & activities from farming to industry plus energy production

Key takeaways from the map and chart above are as follows⁵³:

- 30% of the HKH River Basins (in terms of area) face either 'high' or 'extremely high' water stress (93% of these areas are in the HKH 8); 23% face 'extremely high' water stress and 7% face 'high' water stress; moreover, 11% lie in 'arid & low water use' areas (dark grey);
- The Yellow, Indus, Tarim, Ganges and Amu Darya river basins all have certain areas falling under the 'extremely high' water stress category, which range from 53%, 47%, 37%, 34% to 22%, respectively. In particular, nearly two thirds of the Yellow, as well as the Indus, face above 'high' water stress; and
- Around 34% of the Amu Darya and 43% of the Tarim are 'arid' or with 'low water use'.

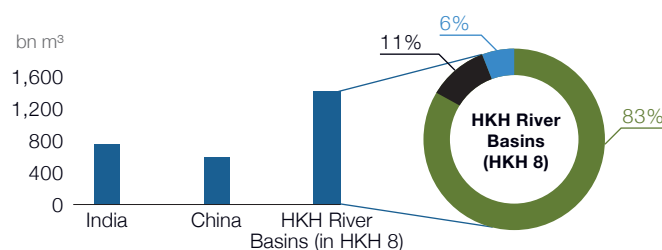
The reasons for 'high' water stress in some of the HKH Basins, can be multi-fold. Two obvious reasons are that 1) many cities and billions of people rely on these rivers for water supply (The Ganges, Yangtze, Indus, Brahmaputra and Yellow represent about 35%, 26%, 16%, 9% and 7% of the total population living in the HKH River Basins); and 2) multiple economic activities, including agricultural, energy generation and industrial production, are also reliant on these water resources. Given this and significant levels of water stress, we conducted deeper analysis on water-nomics of each HKH River Basin within the HKH 8. The picture is not pretty.

Water-nomics of HKH River Basins within the HKH 8

The HKH River Basins are important; collectively these river basins within the boundary of the HKH 8 account for around 36% of the total GDP of the HKH 8. In 2015, the 10 HKH River Basins within the boundary of the HKH 8 generated a total GDP of nearly USD4.2 trillion (2010 constant price)¹. Methodology to estimate GDP generated in each river basin and data used can be found in the “Methodology” section.

The sheer size of the economy in the HKH River Basins means huge demand for water resources. According to our research partner CAS-IGSNRR, the total water use in the HKH River Basins within the HKH 8 is estimated to be around 1,445 billion m³ in 2015¹. This is as much as 2.3x of China's total water use in 2015. Agricultural, industrial and municipal uses account for 83%, 11% and 6% of the total water use¹, respectively as shown in the charts below:

Water Use Comparison: India vs China vs HKH River Basins

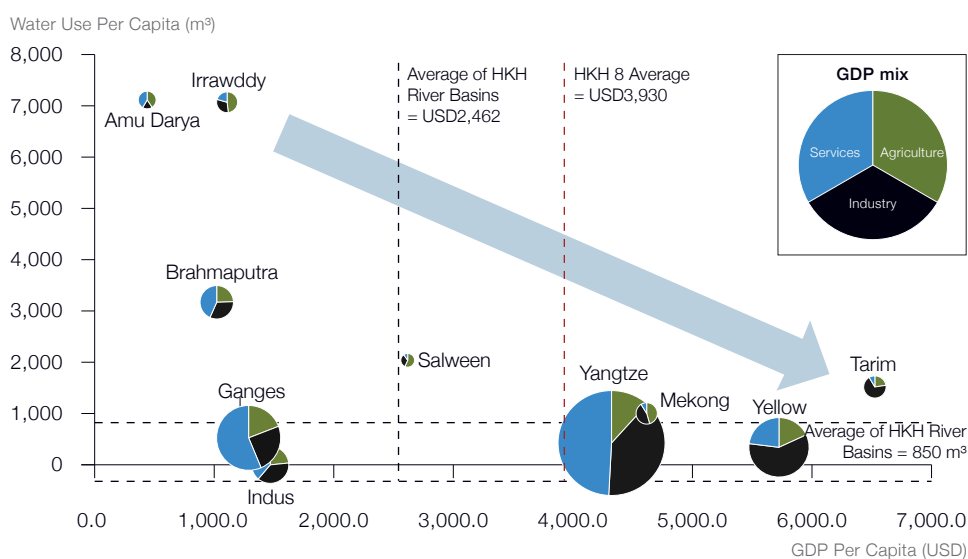


Source: China Water Risk based on 1) basin-level data calculated by CAS-IGSNRR; and 2) country-level data from FAO AQUASTAT. Note: Data of the Yangtze and the Yellow are from year 2014; while the rest are estimates based on irrigation data (2005), population data (2015) and other relevant indicators due to data availability.

Of the 1.77 billion people who live in the HKH River Basins, 96% of the total population living along the HKH River Basins are in the HKH 8¹. Clearly, more research and efforts from NGOs, government and businesses should focus on the upper reaches of these rivers in the HKH 8, in particular the five most populous ones (the Ganges, Indus, Yangtze, Yellow and Brahmaputra).

Prioritisation of these river basins becomes more urgent as inter-linkages between water and economic development are more pronounced at basin level due to water-reliant economic activities are organized along the rivers such as agricultural production and cities. As such, the per capita water use vs. GDP chart below for the HKH River Basins within the HKH 8 shows a different picture to that of the country set out in “Water-nomics of the HKH 8”:

2015 HKH River Basins: Water Use Per Capita & GDP Per Capita



Source: China Water Risk based on results calculated by our research partner at China Academy of Sciences. Note: 1. Population for each river basin is estimated based on WorldPop data. 2. GDP is the sum of estimated agriculture added value, industrial added value and services added value for year 2015. 3. For water use, the data of the Yangtze and the Yellow are from year 2014; while the rest are estimates based on irrigation data (2005), population data (2015) and other relevant indicators due to data availability. 4. The size of each pie reflects the relative size of GDP of each river basin within the HKH 8.

The picture is not pretty...

USD4.2tn of GDP generated in HKH River Basins within the HKH 8 needs ~1.4tn m³ of water...

...this is 2.3x that of China's total water use

Agriculture is the largest user at 83%

River basins within HKH 8 are home to 30x the population along rivers in the Downstream 8 ...

1.7bn (HKH 8) vs. 57mn (Downstream 8)

We compare water-nomics performance across HKH River Basins

Based on the above chart, we can draw the following broad observations:

Per capita GDP & water use vary widely...

- **High variation in both GDP and water use:** Water use per capita differs widely across river basins, ranging from 203m³ in the Indus to 7,203m³ in the Amu Darya - the difference can be as large as nearly 36x! GDP per capita also differs greatly across basins, with the Yangtze, Yellow and Tarim above the HKH 8 Average of USD3,930, whilst the rest all below USD3,000¹;
- **The 10 HKH River Basins within the HKH 8 fall into three cluster groups:** While the average GDP per capita for the 10 basins was USD2,462 and average annual water use per capita was 850m³, the HKH River Basins fall into three broad cluster groups:

The GDP of the Yellow & Tarim are driven by Industry... the Yangtze is more service-led...

...together with the Mekong, these 4 rivers drive 30% of China's GDP & is home to 598mn within the HKH 8

- 1 **High GDP & low water use** – these are the Tarim, Yellow, Yangtze and Mekong. Here, GDP generated by the first three basins only contribute to China's national GDP whereas the Mekong accounts for both China and Myanmar.

There are about 598 million people living in the 4 river basins within the HKH 8, of which over 597 million or 99.9% are in China representing 43% of China's total population^{1,28}. The China portion of these basins also accounts for nearly 30% of China's GDP^{1,44}. Industry is the main driver of GDP for the Yellow and Tarim while the Yangtze enjoys a more service-led economy;

- 2 **Low GDP & low water use** – these are the Salween, Indus, Ganges and Brahmaputra. The GDP mix is varied across these river basins: the economy along the Salween is agri-led; while the Ganges is services-led. Meanwhile, the GDP mix of the Indus and Brahmaputra are fairly evenly spread¹. Whereas the economy of Salween is shared between China and Myanmar, the other three river basins mainly serve India, Pakistan and Bangladesh.

The Indus, Ganges & Brahmaputra ... drives the GDP of India (42%), Bangladesh (77%) & Pakistan (92%) with >1bn people

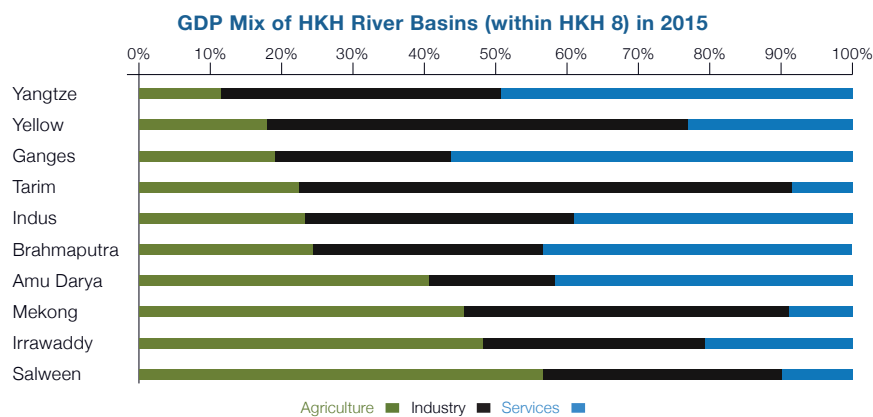
Indeed, based on CAS's estimation, around 53% of India's population, 88% of Pakistan's population and 85% of Bangladesh's population live along the three rivers (Indus, Ganges and Brahmaputra) basins^{1,28}. Beyond population, these three rivers significantly drive the GDP of India (42%), Pakistan (92%) and Bangladesh (77%)^{1,44}. Also, don't forget that 47% of the Indus and 34% of the Ganges face 'extremely high' water stress. Moreover, over one billion people live in these three river basins across the three countries; and

- 3 **Low GDP & high water use** – these are the Irrawaddy and the Amu Darya. Agricultural contribution to GDP is significant in these two basins. Also note here that the Amu Darya is water stressed and yet demonstrates a high per capita water use; while, for Irrawaddy, as shown in the [below water withdrawal mix chart](#), agriculture accounts for nearly half of the water use. Given the low GDP per capita in both river basins, efforts should be directed at increasing water efficiency and productivity in the economy, especially in the agricultural sector. This is especially true to Amu Darya as 22% of its basin areas face 'extremely high' water stress, whilst another 34% being considered 'arid' or with 'low water use'⁵³.

The Irrawaddy & Amu Darya only houses 46mn people but generate significant GDP ... Myanmar (39%); Afghanistan (25%)

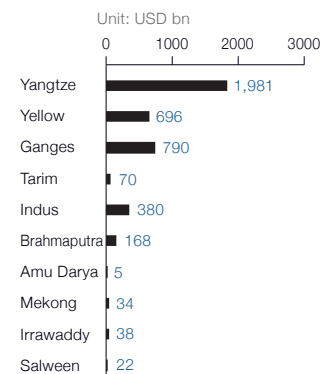
Although less people live in the river basins of the Irrawaddy (30 million) and Amu Darya (11 million) in the HKH 8, they are nevertheless important to Afghanistan and Myanmar^{1,28}. The Amu Darya accounts for a quarter of Afghanistan's GDP and supports nearly a third of its population; the Irrawaddy accounts for 39% of Myanmar's GDP and is home to 48% of its population^{1,28,44}.

- **Economic mix and population affect water use:** We take a closer look at the GDP mix of HKH River Basins as per chart below. The Yangtze has the lowest agriculture share at less than 15%, whilst the Salween has the highest at over 50%¹. That is not to say the Yangtze is not important for food production in China; in fact, provinces along the Yangtze produce about 65% of China's No.1 staple: rice⁶. As for the Salween, it houses the smallest population across the 10 HKH River Basins, which is primarily agriculture-focused.



Source: China Water Risk based on data estimated by the research partner at the Center for Water Resources Research of CAS-IGSNRR.
 Note: For agriculture added value, it is calculated by multiplying the cropland area by basin and country with the agriculture production value per unit area by country. For industrial added value, its relationship with nighttime light was analyzed and country-level industrial production value density was calculated. The industrial added value by basin and country then can be estimated from basin and country nighttime light and country-level industrial production value density. For services added value, it is calculated by multiplying services added value logarithm density in different countries with population in the basin and country.

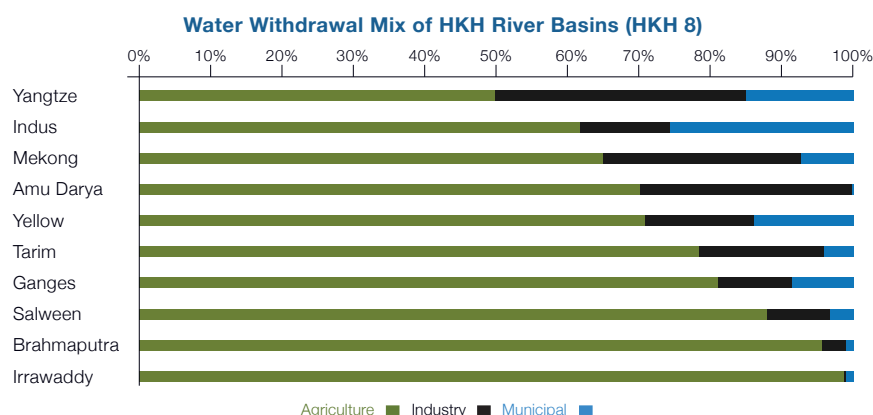
GDP of HKH River Basins (within HKH 8) in 2015



Source: China Water Risk based on data estimated by the research partner at the Center for Water Resources Research of CAS-IGSNRR.

The chart below shows the withdrawal mix of the ten HKH River Basins within the boundary of HKH 8, where the Yangtze has the lowest share of agricultural water withdrawal (50%)¹. However, the rest of the river basins do not necessarily reflect the order of GDP mix. For instance, the Indus has a higher share of agricultural value added in GDP mix than the Yellow, but the former has a lower share of agricultural water use in its water withdrawal mix than the latter. Moreover, although the Salween has the highest share of agricultural value added in GDP mix, the Irrawaddy has the largest share of agricultural water use in its water withdrawal mix.

Differences in efficiency = water withdrawal mix does not necessarily reflect GDP mix



Source: China Water Risk based on results calculated by our research partner at China Academy of Sciences.
 Note: Data of the Yangtze and the Yellow are from year 2014; while the rest are estimates based on irrigation data (2005), population data (2015) and other relevant indicators due to data availability.

The Amu Darya, Brahmaputra & Irrawaddy are the least efficient in using water to generate same amount of GDP

The differences reflect different water usage and efficiency in each sector across the HKH River Basins. Indeed, to generate the same amount of GDP or value added from agriculture or industries, water demand varies across river basins, with Amu Darya, Brahmaputra and Irrawaddy being the least efficient. The main reasons are likely to be the types of crops that farmers grow (i.e. crop mix), the types of industries that are being developed (i.e. industrial mix), the technological levels and management practices of production, and population and urbanisation rates in these river basins. Even for the same crop mix, water use may differ due to differences in precipitation and water availability, irrigation technologies deployed and farming practices.

Tech can help improve efficiencies

... but crop selection, types of industries & circular economies can also be used to manage water use & pollution...

Pollution is another important factor. Pollution exacerbates scarcity and impacts health. In addition to more water on less GDP, transforming and cleaning up industries along the rivers are important; as is favouring non-polluting industries to drive economic growth in the future. This includes transitioning to circular economies with less and/or reuse of waste materials. Please see “**The Yangtze: More GDP on Less Water & Pollution**” for examples of this in China on the following page. Therefore, managing water use at the basin level is really about holistically managing water demand in different economic sectors and between economic and water would need the support of sound transboundary river cooperation and governance.

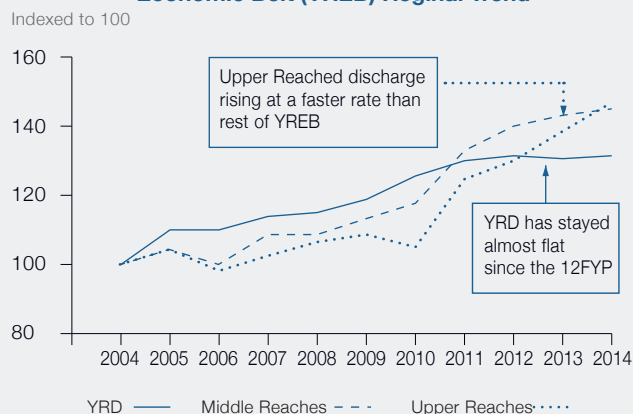
THE YANGTZE: MORE GDP ON LESS WATER & POLLUTION

THE CURRENT STATUS:

The Yangtze River Economic Belt (YREB) is the socio-economic powerhouse of China. According to CWR and MEPFECO' joint brief⁶, the 11 YREB provinces and municipalities, with 43% of China's population, generated RMB28 trillion in GRP (Gross Regional Product), representing nearly 42% of the national total in 2014. Its economy is characterized by the vibrant growth of industrial clusters dotted along the river, especially in the Middle Reaches and the Yangtze River Delta (YRD). The delta region, YRD, is the richest, representing 45% of the YREB's GDP or one fifth of the national GDP in the same year. However, since the 12th Five-Year Plan (12FYP: 2011-2015), rapid GDP growth in the Middle and Upper Reaches has overtaken GDP growth in the YRD.

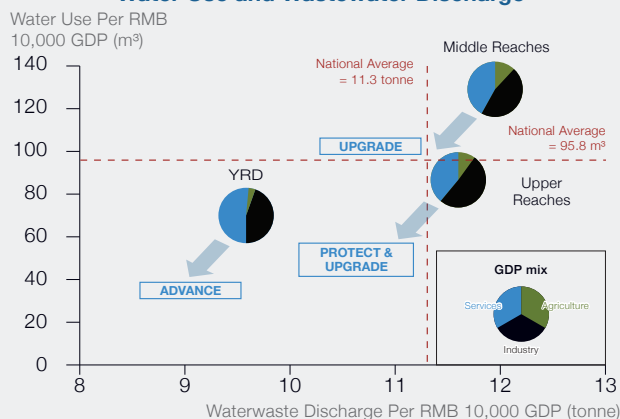
This is reflected in dispersed trends in pollution as well as water use. As shown in the left below chart, although the absolute amount of wastewater increased for all the three regions, the growth in wastewater discharge in the YRD plateaued during the 12FYP. Meanwhile, the Middle Reaches still rose, albeit at a slower rate than that during the 11FYP. As more polluting industries moved towards upstream, wastewater discharged from the Upper Reaches grew at a faster rate than the rest of YREB.

2004 - 2014 Total Wastewater Discharge Yangtze River Economic Belt (YREB) Regional Trend



Source: China Water Risk based on National Statistical Bureau of China

2014 YREB Regions: Per RMB 10,000 GDP Water Use and Wastewater Discharge



Source: China Water Risk based on National Statistical Bureau of China

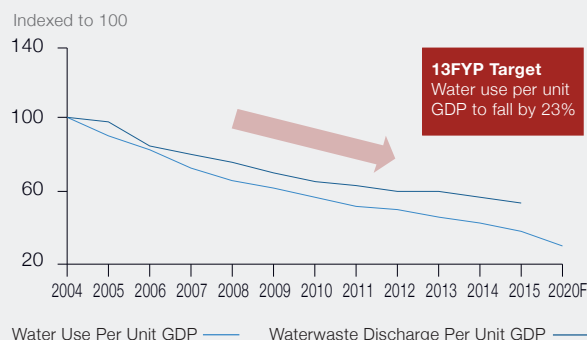
FUTURE STRATEGIES:

Therefore, although it is important to focus pollution prevention and control efforts in the YRD, it is equally important to address the rapid rise of wastewater discharged in the Middle and Upper Reaches. After all, such pollution will only flow downstream, exacerbating pollution and scarcity in the already water stressed YRD. The three regions need to be managed holistically. Through a water-nomics lens, we compared water use and waste discharge per unit of GDP. As shown in right above chart, to generate the same amount of GDP, the Middle Reaches is the most water intensive and most polluting; while, the YRD is performing relatively well compared to the national average. Therefore, broadly strategies in water management were proposed for each region: **Protect** in the Upper Reaches; **Upgrade** in the Middle Reaches & **Advance** in the YRD.

At the both national and local level, the government has started to look at targets related to 'water-nomics' indicators. As per the right-side chart, water use and wastewater discharge per unit GDP (constant 2004 price) have been steadily falling. By 2020, water use per unit GDP is expected to fall by 23% from the 2015 level⁵⁴. Pollution levels also need to fall to meet water quality targets and ensure the health of the ecological environment. Similar targets are also set for air emissions and energy. All of these mean no more 'Business as Usual'.

Whether it is changing its economic mix to deliver optimum results on both economy and environment, or looking at the planning of industries at a river basin, China is trying to adopt a more holistic approach in managing both. President Xi thus elevated pollution prevention and control to the same level of importance as 'major risks' and 'poverty alleviation'. As he committed during the CPC's 19th National Congress in October 2017: "We [China] will speed up prevention and control of water pollution, and take comprehensive measures to improve river basins and offshore areas."

Less Water & Pollution for More GDP



Source: China Water Risk based on NBSC. Calculated based on constant 2004 price.

- **Water use per capita more pronounced at the basin level than at country level:** The transboundary nature of eight of these rivers means they are not managed comprehensively. The per capita water use at a basin level can be very different to that at a national level.

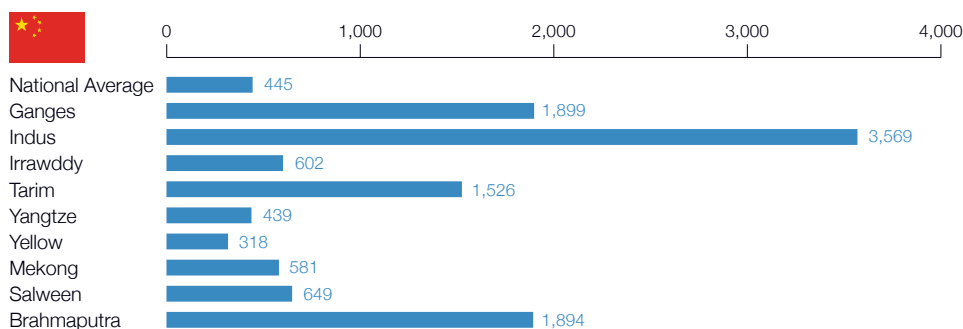
Transboundary cooperation is essential for river management ...

For example, in China, the water use per capita at national level is 446m³ (2016 figure)⁵⁵, but it more than triples in the Tarim River Basin at 1,526m³ whilst staying below national average along the Yangtze (439m³) and the Yellow (318m³). The trend is similar for Myanmar (683m³) and Salween (estimated 3,178m³)¹. Where we begin to see larger differences are in the Amu Darya, Ganges, Irrawaddy and Brahmaputra; where water withdrawals across these basins can be 4x to 30x higher than that of the respective countries – please see charts below. This is likely due to development of water infrastructure projects in less populated areas, leading to a very high water use per capita. However, note this does not hold true for India and Pakistan where a higher concentration of population along river basins likely led to relatively lower per capita figures.

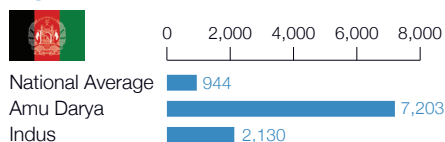
Water use/pax is more pronounced at basin levels than country levels

Water Use Per Capita (m³/pax): National Average vs Basin-level

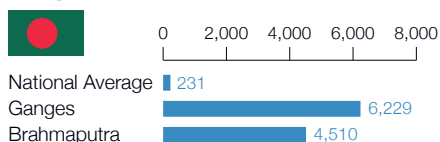
China



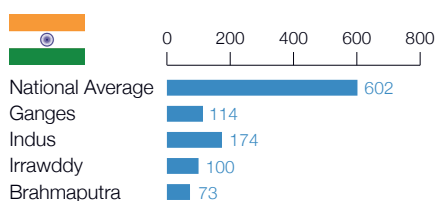
Afghanistan



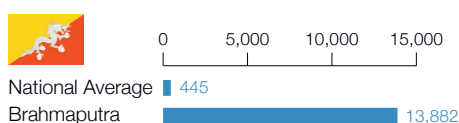
Bangladesh



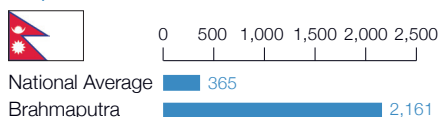
India



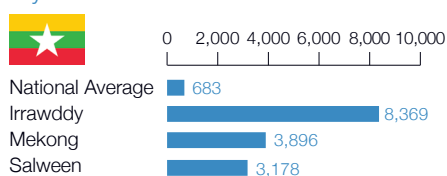
Bhutan



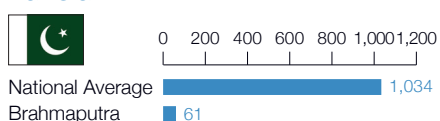
Nepal



Myanmar



Pakistan



Source: China Water Risk based on FAO AQUASTAT and CAS-IGSNRR estimates

Note: For country-level water withdrawal per capita, due to limited availability of data in FAO AQUASTAT and OECD databases, the data year ranges from 1998 to 2014. For China's total water withdrawal, 2015 figure from national statistical yearbook is used.

For basin-level data, the data of the Yangtze and the Yellow are from year 2014; while the rest are estimates based on irrigation data (2005), population data (2015) and other relevant indicators due to data availability

People, water & economy: Tough choices in managing trade-offs

Balancing the economy, limited water & more people = trade-offs

From the analysis in this chapter, we can see that river management is never only about managing water. Decisions made for water and the economy as well as the growing population will result in trade-offs. A holistic and comprehensive approach that integrates water management with social and economic development are thus needed to balance these tradeoffs. Better coordination between different administrative levels along the river is also needed not just within the HKH 8 but for the entire basin within the HKH 16, as actions upstream could have impacts to the downstream. So, which rivers should be prioritised?

Four priority rivers: Ganges, Indus, Yangtze & Yellow

In this regard, our analysis indicates four rivers: they are the Ganges, Indus, Yangtze and Yellow. We have come to this recommendation based on three key measures: 1) areas under 'high' and 'extremely high' water stress; 2) population; and 3) GDP exposure. Many other measures such as employment, food and energy security should also be factored in but for the purposes of providing an overview, we have kept it to these three basic but key measures. They are summarised in the table below:

HKH River Basin Within HKH 16	% of areas under above High Water Stress	Population (million)	Total estimated GDP (USD billion)
Amu Darya	28%	28	37
Brahmaputra	-	163	168
Ganges	55%	614	790
Indus	62%	276	380
Irrawaddy	-	30	38
Mekong	-	57	160
Salween	-	9	23
Tarim	37%	11	70
Yangtze	4%	458	1,981
Yellow	63%	122	696
Total HKH River Exposure	30%	1,768	4,344

Six high water stress river basins form three groups

It should be noted that we have only selected four rivers despite the fact that there are six HKH River Basins with areas facing 'high' and 'extremely high' water stress, with varying degrees of GDP and population exposure. This is because they fall into following three categories:

The Ganges, Indus & Yellow: 1bn people; USD1.9tn of GDP...but >50% of their basin areas face high water stress

1 **High water stress and high exposure** - the Ganges, Indus and Yellow: these three river basins all have over 50% of the areas under above 'high' water stress⁵³. Their population and GDP are amongst the largest, which together have over 1 billion people and a total GDP of nearly USD1.9 trillion¹;

The Yangtze's 458mn people generate USD2tn of GDP

2 **High water stress but relatively low exposure** – Amu Darya and Tarim: both river basins have respectively 28% and 37% of areas under above 'high' water stress⁵³. However, the total population, which stood at around 39 million, is relatively smaller than the other basins. Similarly, their total GDP of USD107 billion is also relatively small and is only over 5% of the above three basins¹; and

3 **Relatively low water stress but significant exposure** – although only 4% of the Yangtze faces 'high' and 'extremely high' water stress⁵³, this basin is of strategic importance as it has 458 million people and a GDP of nearly USD2.0 trillion, representing 21% of China's national GDP^{1,44}.

However, this is not to say other rivers basins are not important. Those without areas facing water stress, also need to be carefully managed and protected as they hold significant shares of economy for some countries. For instance, the Brahmaputra River Basin represents about 64% and 96% of Bangladesh's and Bhutan's GDP, respectively. Moreover, for river basins that face similar water stress and population and GDP exposure, actions to ensure future water security may be different, due to differences in GDP, crop, industry and energy mix as well as demography.

Other river basins are also important... e.g. Brahmaputra which is 96% of Bhutan's GDP

The charts set out on the following two-page spread titled **"HKH Rivers: What's at Stake"** show each country exposure to the HKH River Basins in terms of national surface water resource contribution, population share and GDP generation. A glance across these will leave no doubt that the stakes are high for Asia. Clearly, we must start to shift our views on water beyond that of delivering access to clean water towards managing our water resources and economies concurrently for long term prosperity.

Given what's at stake, HKH Rivers must be protected...

What is also clear from these charts is that the transboundary nature of most of these rivers could hamper collective action as national priorities naturally differ. Already, tensions are high between China, India, Pakistan, Bhutan and Nepal over the Ganges, Indus and Brahmaputra.

...but transboundary nature & different national priorities may hamper action

A holistic water-nomic management approach to the river basin might be relatively easier for the Yellow and the Yangtze, which only flow within China. And as mentioned previously, along the Yangtze, ecological protection and green development are being prioritised under the national strategy of 'Yangtze River Economic Belt' development. These experiences from interprovincial coordination learned along the Yangtze may also be useful for other countries.

Solutions can be found in interprovincial action in the Yangtze ...

However, even then within China, to ensure better coordination between provinces that share the same river, more targeted research and comprehensive policies need to be set and carried out. The good news is that China has embarked on this journey. However, current transboundary cooperation across Asia is still patchy. There is evidently a lot more work to be done for riparian countries to move towards basin-wide coordination and cooperation. That said, progress made in some rivers such as the Mekong signals an optimistic future for the more urgent basins. Please see the box below.

...& also basin-wide cooperation in the Mekong

A NEW ERA OF REGIONAL COOPERATION ALONG THE MEKONG

The Lancang-Mekong River cooperation (LMC) mechanism was first proposed by Premier Li Keqiang in the 17th China-ASEAN Leaders' Meeting in November 2014. It was formally founded and the first meeting was held in March 2016. This new mechanism includes six riparian countries of the Lancang-Mekong River as members, including China, Myanmar, Laos, Thailand, Cambodia, Vietnam⁵⁶. It is worth noting that this new initiative does not compete with the existing Mekong River Commission (MRC), but provides a new opportunity to broaden regional cooperation along the Mekong. Established in 1995, the MRC only covers the four countries in the Lower Mekong River Basin: Cambodia, Lao PDR, Thailand and Vietnam. It was set up to promote dialogue and cooperation, and act as a knowledge hub for sustainable water management. China and Myanmar are not full members but have been invited as "dialogue partners" since 1996⁵⁷.

The fact that the LMC is able to bring all the six Lancang-Mekong countries to the same table is a big step. The LMC mechanism also expands beyond transboundary water management and focuses more on regional economic and environmental cooperation. This means that transboundary issue is part of a more holistic regional dialogue and cooperation mechanism. As identified during the first LMC meeting, the five key priority areas in the initial stage are *"connectivity, production capacity, cross-border economic cooperation, water resources, agriculture and poverty reduction it clearly indicates"*⁵⁸.

Since then, several regional high-level meetings and exchanges have been held, and new initiatives have been set up. For instance, on 28 November 2017, a Lancang-Mekong Environmental Cooperation Center was established in Beijing. The new center will mainly manage the *"Green Lancang-Mekong Initiative"* to promote the Lancang-Mekong environmental cooperation in areas such as policies, capacity building, biodiversity conservation, climate change adaptation and mitigation and environmental-friendly technology. Moreover, on 15 December 2017, the 3rd Lancang-Mekong Foreign Ministers' Meeting was held in Yunnan, which set out the next 5-Year Action Plan in the five key priority areas⁵⁹.

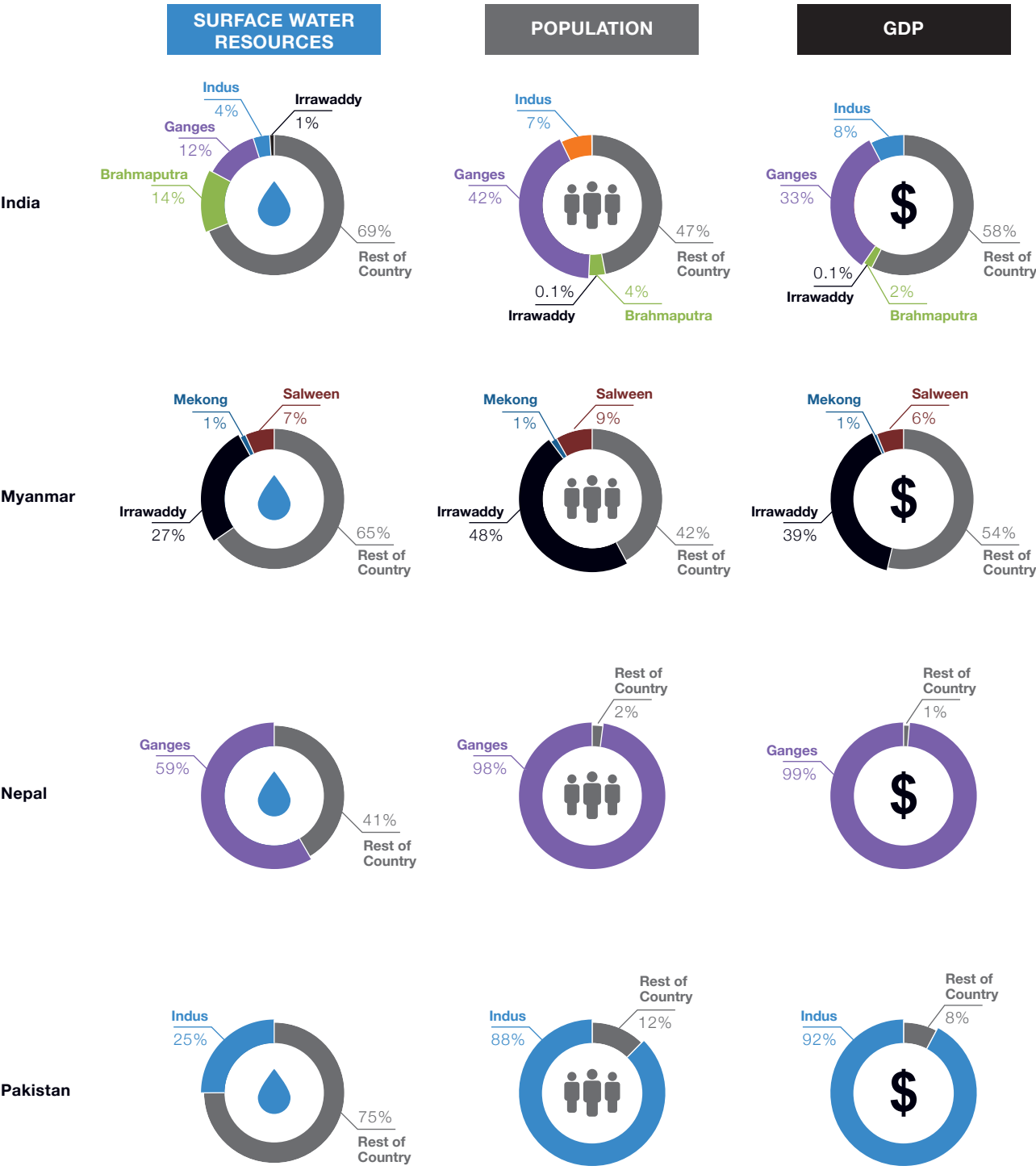
Basin-level cooperation is essential to maximize the services and values that these rivers are providing to the people in different regions⁶⁰. This enables a constructive environment for dialogues on more sensitive issues. Although in its early stage, the LMC offers a new format to approach the complex transboundary water issues.

More on challenges at a basin level in **"Quantifying risks at basin level still lags despite big impacts"** in Chapter 3 and **"Status of Transboundary Agreements of HKH Rivers"** in Chapter 4.

HKH RIVERS: WHAT'S AT STAKE FOR THE HKH 8



Source: China Water Risk report “No Water, No Growth - Does Asia have enough water to develop?” 2018



Next 50 years: Climate change accelerates urgency & brings great uncertainty

Climate change makes water-nomic management even more difficult

Compared to the developed countries in the G20, Asia clearly has a long way to go. Developing with limited water resources will not just challenge the HKH 16, but policies it sets could be highly disruptive to the global commodities trade as well as supply chains. This in itself will already be difficult and would pose a monumental challenge for the 16 countries for the next 50 years without climate change.

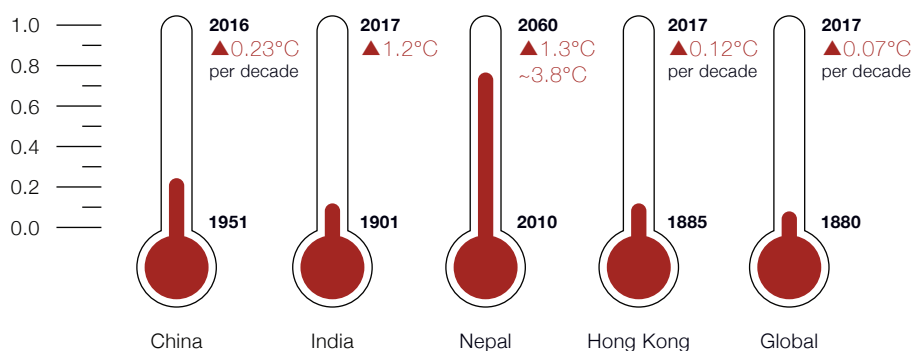
Unfortunately, population and economy are not the only dynamic factors: nature is not a static system. In making policies that carefully balance trade-offs, we also need to be aware that the changing climate will likely exacerbate underlying scarcity and bring about great uncertainties to the water cycle and direct damage to human lives and economy through extreme weather events. The impact of pollution on water availability and public health should also be weighed.

Under RCP4.5, the HKH Region's av. temperature will likely rise by at least +4°C by 2095

Unfortunately, climate change is already evident in the HKH. Wu *et al.* (2017) projected future changes in temperature and precipitation of the HKH Region (same definition as used by ICIMOD) using 21 *Coupled Model Intercomparison Project phase 5* (CMIP5) models under two scenarios, RCP4.5 and RCP8.5⁶¹. Under RCP4.5, the average temperature of the region is expected to increase by 1.97°C from 2030 to 2065 and a further 2.56°C from 2065-2095¹. This will put the average temperature increase of the HKH Region well above 4°C before the end of this century.

Rivers are vital sources of water for people & the economy ... they are vulnerable to climate change

Annual Mean Temperature Rise



“ **Global:** “The yearly global land and ocean temperature has increased at an average rate of 0.07°C (0.13°F) per decade since 1880; however, the average rate of increase is twice as great since 1980” <https://www.ncdc.noaa.gov/sotc/global/201713> ”

Imperative that the HKH 16 considers its future energy policy with water in mind

As shown in the last two chapters, waters from the HKH Rivers are vital sources of water for the people and the economies of the 16 countries. Since sources of water from glacial melt to snow and rain vary for each river, it is important to examine these to determine rivers most vulnerable to climate change. For example, Afghanistan and Pakistan are extremely dry with less rain, which means more people are reliant on water from rivers; whereas in Bangladesh, rainfall plays a more important role. It is important to look at the impacts of climate change on the various components of the water cycle and what these mean for each of the 10 HKH Rivers in the next chapter.

It is thus imperative that the HKH 16 consider its future energy policy with water in mind. Adding power of the wrong type could accelerate climate change, resulting in tight water-nomics leaving countries with less wriggle room. Development could also favour less energy intensive industries as typically, saving energy means saving water. Please see “**Power & Economic Mix for Water & Climate**” in the following page for examples of China’s actions on these fronts.

Simply put, the stakes are too high not to cooperate. Water can either divide or unite Asia. It’s time to direct our focus on the common goal of a water and economic secure Asia, we can only achieve this together.

POWER & ECONOMIC MIX FOR WATER & CLIMATE

Since the adoption of the Paris Agreement by 195 countries (including the HKH 8), the prospect of an energy future powered by clean and renewable energies has become more promising. HKH 8 countries have all made commitments to reduce emissions through actions such as promoting non-fossil fuels in their Nationally Determined Contributions (NDCs) submitted to UNFCCC. For instance, China committed “to increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030”⁶²; while, India’s NDC clearly states its aim “to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030”⁶³.

The falling costs of wind and solar have made them competitive alternatives to cheap but dirty coal. In China, the total on-grid capacity for wind reached 149GW in 2016⁶⁴ and solar PV installation amounted to 85GW by the first quarter of 2017⁶⁵; both will respectively reach 210GW and 105GW by 2020⁶⁶. In June 2017, Qinghai, a Northwestern province with a population over 5 million, even ran entirely on renewable energy for 7 continuous days⁶⁷.

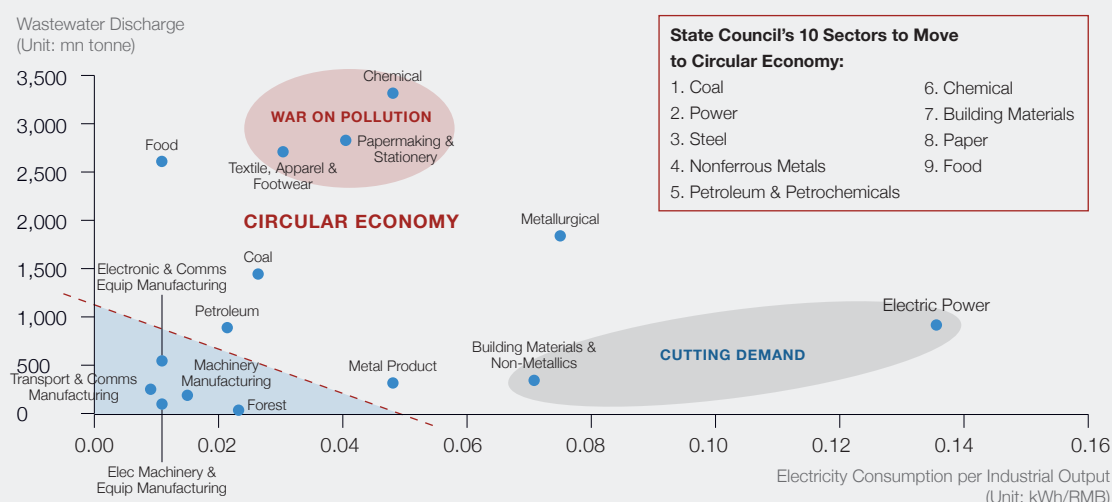
The benefits of promoting renewable energies are more than just reducing GHG emissions. According to China Water Risk (CWR) and the International Renewable Energy Agency (IRENA)’s joint brief in February 2016, renewables have the potential to reduce both water use and carbon emissions, in particular through the development of solar PV and wind turbines, and cooling technologies of thermal power plants. Dual savings in water and carbon can be achieved: if China continues to promote renewables and meet the ‘Remap’ scenario proposed by IRENA, by 2030, water use intensity of power generation can be reduced by as much as 42% while carbon emissions intensity could fall by 37%⁶⁸.

Other than switching to renewable and cleaner energy sources, efficiency improvement in both energy generation and consumption, as well as demand-side management are also important. As the population continues to rise and economy grows, without controlling total energy demand, both GHG emissions and pressure on water resources may still increase.



As shown in the below chart, the industries which are relatively more water-polluting and electricity hungry are exactly those that the Chinese government is targeting to move to a circular economy. In China, circular economy is not a “niceto-do” as part of a water corporate stewardship strategy, it is a “must-do” to protect the environment and save energy. Moreover, industries with high wastewater discharge are targeted by the ‘Water Ten Plan’ since Premier Li Keqiang declared ‘War on Pollution’ in 2014. Meanwhile, energy intensive industries are targeted to cut back on excessive production and improve efficiency, thereby cutting demand for electricity.

2014 Electricity Consumption vs. Wastewater Discharge By Industrial Sector



Source: China Water Risk, MEP, NBSC

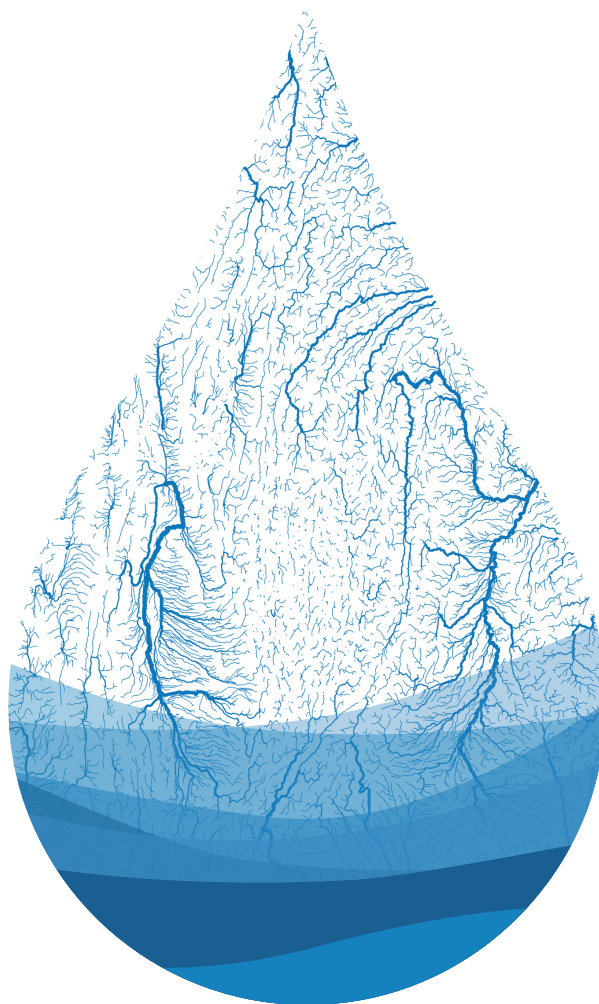
Note: Due to lack of industrial output data for 2014, we calculated based on 2012 figures and added value growth rate by sector in 2013 and 2014

To balance the economy & the environment to ensure long term prosperity, China has no choice but to herd China’s key sectors towards a circular economy. This means less water, less energy, less resource waste and more recycling - all crucial for China if it is to ensure economic growth with its limited resources.



CLIMATE CHANGE

IMPACT ON EACH RIVER & COUNTRY



CLIMATE CHANGE : IMPACT ON EACH RIVER & COUNTRY

- The 10 HKH Rivers have an annual average internal surface water resources of around 3.2trn m³, accounting for a third of the surface water resources of the HKH 16. While three different hydrological models show a total range of 2.7–3.8trn m³, the annual flow of each river basin varies dramatically from 10-43bn m³ in the Tarim to 666-971bn m³ in the Yangtze.
- The water-stressed Ganges' annual flow is only a third of the Yangtze's, but it houses 35% more people. For perspective, the maximum average annual flow of the Ganges will not even fill up Lake Erie, yet it supports a population that is almost 2x the US. By comparison, the Yangtze's maximum average annual flow could fill up two Lake Erie supporting a population 1.4x the US. Rising urbanisation will clearly add pressure to the basin.
- Climate change affects river flows, aggravating water security in already water stressed basins. Unlike the Arctic & Antarctica, the glacier & snow melt from the Third Pole empties into Asia's rivers sustaining billions of lives and livelihoods. Climate change is thus more than droughts, floods & sea level rise; aside from glaciers, monsoon patterns could also be impacted. Understanding its impact on runoff mix (glacier melt, snow & rain) is thus key.
- The upper reaches of the four "priority rivers" are vulnerable. Glacier & snow melt form a material component of their runoff mix: Upper Ganges (20%), Upper Indus 62-79%, Yangtze (29%) & Yellow (25%). Studies also show that the Upper Indus is more reliant on glacial melt compared to the Upper Mekong where snow melt is more important. There is no such data on the Irrawaddy & Amu Darya, but this does not mean they are not exposed.
- Despite a material water source, there is no comprehensive glacier database for Asia. Using ICIMOD & China's 2nd national glacier inventory, we estimate total ice reserves supplying the HKH River Basins to be 7,574km³. This largest accumulation of ice outside the two poles is often called Asia's Water Tower. If melted, it will provide almost 7trn m³ of freshwater, enough to fill two Great Lakes (Michigan & Erie) + almost 40 Three Gorges Dams.
- There are 58,316-62,994 glaciers related to the 10 HKH River Basins covering an area of 67,864-74,571km²; equivalent to the entire land area of the Netherlands, Switzerland & Singapore at the upper range. Already, China has lost glaciated areas greater than the land area of Thailand between 1970s and 2000s; the annual melt in Western China could fill up 1.6 Three Gorges Dams. Mountain communities are clearly feeling the impact.

The 10 HKH Rivers are vulnerable to climate change; their flow components from glacier melt, snowfall to rainfall altered, even monsoon patterns will shift ... Ganges, Indus, Tarim & Amu Darya will all see reduced runoffs by 2055.

- With glacier melt, altitude matters. Glaciers <5,700m above sea level (masl) are more sensitive to climate change. Unfortunately, >60% of the total glacier area of the HKH Region lie within 5,000–6,000 masl. By 2050, projected shrinkage will range from 20% (Upper Indus) to 59% (Upper Mekong). The Upper Ganges, with 60% of its glaciers <5,700masl, could see 36-42% glacier area losses by 2050, which is 3-7x the area of Hong Kong.
- However, available studies fail to provide a complete picture. Aside from the lack of research and funding, many results are not comparable due to varied approaches, scopes & definitions of watershed boundaries. To obtain a comprehensive basin-wide view, these should be standardised and multi-disciplinary research promoted. Given the importance of glacier melt, funding of glacier inventory monitoring and research should also be prioritised.
- Aside from glaciers, historical (1955-2005) & future (2006-2055) trends in temperature, snowfall, rainfall & runoff under RCP 4.5 were made by CAS using 5 climate models. Results are not encouraging: (1) Temperatures continue to rise, the increase will double in 6/10 basins; (2) Snowfall continues to decline, losses likely >2x for Indus, Tarim & Ganges; (3) More rain in future except for Indus, Tarim & Amu Darya; and (4) Mixed impact on runoffs, with Ganges, Tarim, Indus & Amu Darya facing shrinkages in flow. This assumes we stay within +2°C.
- Although climate projections are full of uncertainties, the trend is clear: changes across all 4 indicators are greater in the next 50 years than the past 50 years. It is worth noting here that more rain & runoff may not translate to more water supply as infrastructure to store water and to avoid floods will need to be built. In China, where the Yangtze & Yellow faces large upticks in rainfall, RMB1.6trn is allocated to build sponge cities.
- Extreme weather events must be also accounted for. There is marked increase in the occurrence of floods, landslides, droughts and extreme temperature events since 1900s as per EM-DAT; MunichRE estimates 2016 extreme weather losses in HKH 8 at USD105bn. By 2050, the ADB estimates annual losses from floods alone to reach USD52bn globally; of the top 20 most vulnerable cities identified, 13 are in Asia; 11 in HKH 16.
- The magnitude of losses warrants action, but it is important to acknowledge that dealing with extreme climate events, although necessary is “business as usual”. We must quantify the socio-economic impact of climate change on river runoffs so as to develop a cohesive basin-wide strategy for each river. That said, data has not been traditionally collected to facilitate this. Given what’s at stake, we must collaborate to plug these gaps.

As over half the population of the HKH 16 is clustered there, we are extremely exposed to both changes in river flow as well as extreme weather events...

... but we have yet to assess the socio-economic impact of such risks on each river basin. We must invest in finding our baseline, a first step would be to plug the gaps in data, monitoring and multi-disciplinary research

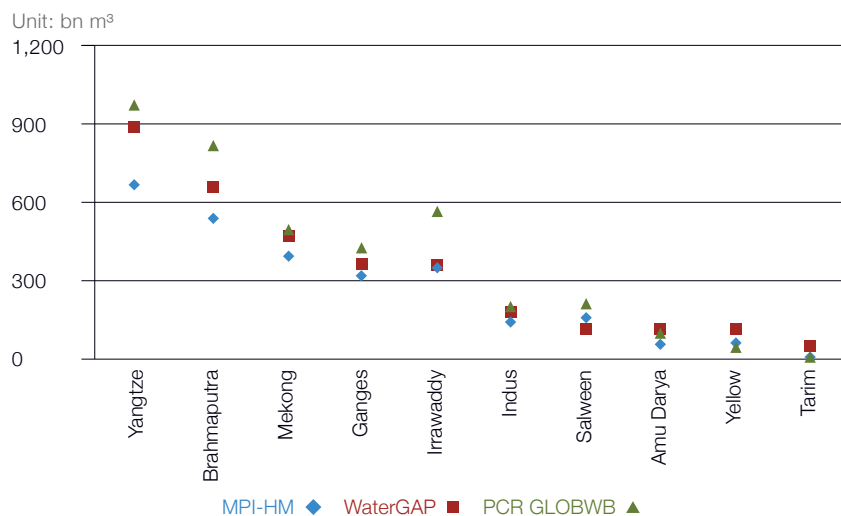
HKH Rivers: A material source of surface water

The 10 HKH Rivers' annual average surface water resources is around 3.2tn m³

To recap, the annual average internal surface water resources produced in the 10 HKH Rivers is estimated to be around 3,248 billion m³¹. This accounts for up to a third of the total surface water resources of the HKH 16, or more than a fifth of Asia's total surface water resources.

In terms of annual river flows, depending on the types of hydrological models used, the estimates ranges from 2,663 billion m³ to 3,825 billion m³ for the ten rivers¹. However, individually, the annual flow of each basin ranges dramatically from 10-43 billion m³ in the Tarim to 666-971 billion m³ in the Yangtze¹, as shown in the chart below:

HKH Rivers: Annual Flow Estimation Based on 3 Models



Source: China Water Risk based on calculation by CAS-IGSNRR, using 3 hydrological models.

Note: MPI-HM data period: 1963-2000; PCRGLOBWB data period: 1979-2000; and WaterGAP data period: 1963-2000

Key points to note are:

- Despite differences in estimations, Yangtze, Brahmaputra and Mekong are the three rivers with the largest river flows, whilst the Tarim, Yellow, and Amu Darya have the smallest flows. The latter three are all water stressed with areas under high or extremely-high water stress at Tarim (37%), Yellow (47%), and Amu Darya (28%)⁵³;
- The most populated river basin, the Ganges houses 35% more people than the Yangtze, but yet has an annual flow only a third that of the Yangtze's. For perspective, the highest estimated average annual flow of the Ganges of almost 422 billion m³ will only fill up over five-sixths of Lake Erie and yet it is home to a population nearly double that of the entire US. By comparison, the Yangtze's average flow of 971 billion m³ (highest estimation)¹ could fill up 2x Lake Erie and supports a population 1.4x that of the US;
- The Brahmaputra, enjoying an average annual flow of around 538-815 billion m³, supports 163 million people across China, Bhutan, India and Bangladesh¹;
- The Mekong, with an average annual flow of 390-492 billion m³ supports seven million people in the HKH 8 (mainly China) and another 50 million in the Downstream 8¹; and
- Although the chart above shows the annual average flow, it is important to remember there are seasonal variabilities which clearly need to be factored in. We have not explored these in this report in order to stick to an overview of the water-nomic challenges faced by Asia.

As discussed in the previous chapter, around 30% of the HKH River Basins (in terms of area) already face either 'high' or 'extremely high' water stress: 23% face 'extremely high' water stress and 7% face 'high' water stress⁵³. Changes in river flows caused by climate change, along with changes in rainfall, will clearly aggravate water security in these basins. It is clear that impact can be more significant on some basins than the others. To determine vulnerability, we examine the different components of river flow, from snow and rainfall to glacial melt.

Three different hydrological models show the total ranges from 2.7–3.8tn m³ ...

The Yangtze has the largest flow vs. the Tarim with the smallest

Max. annual flow of Ganges will not fill one Lake Erie...but has a population almost 2x the US

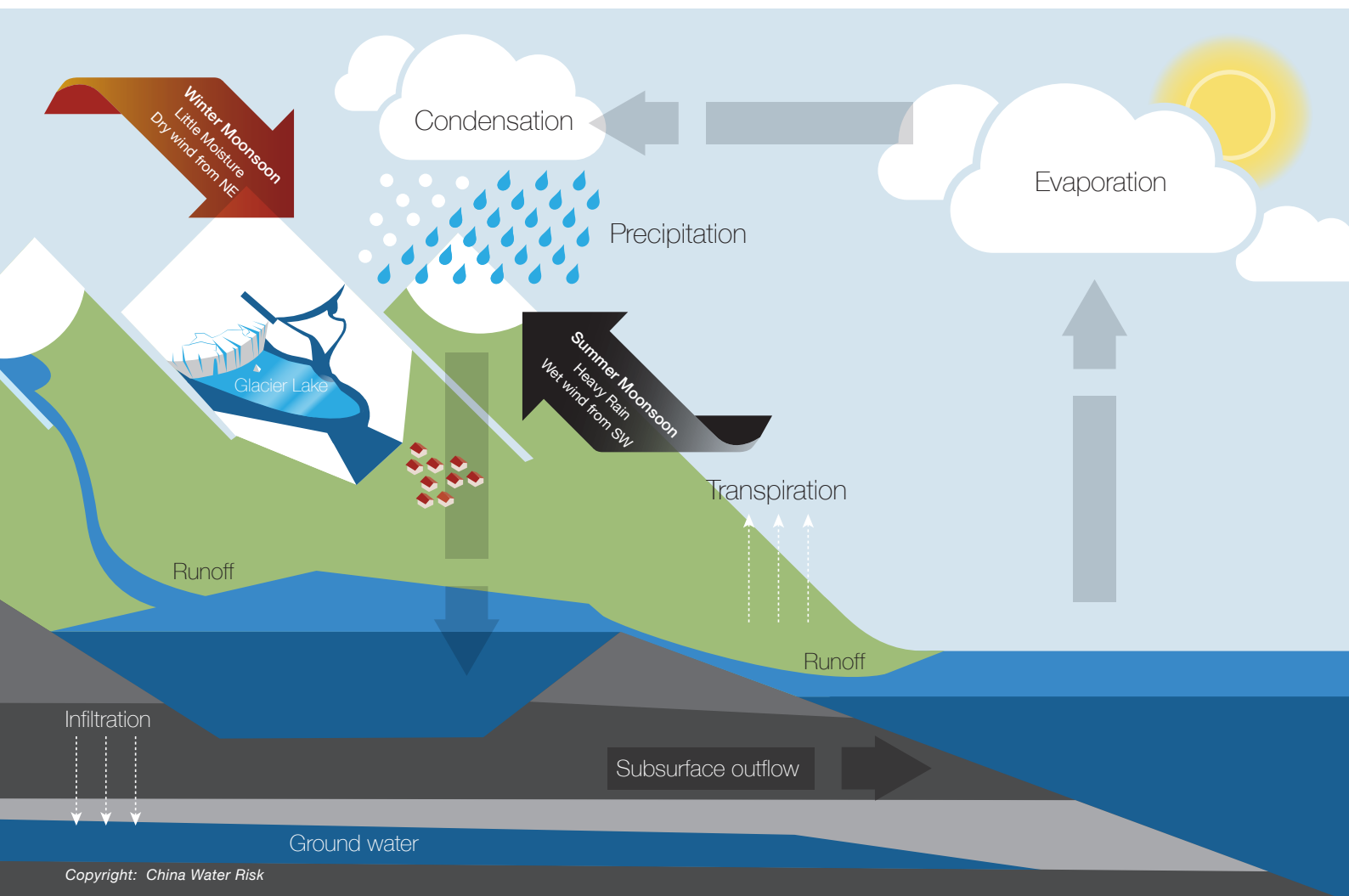
The Yangtze's max flow fills 2 Lake Eries...but has a population 1.4x the US

Already some basins are water stressed ... changes in flows & rainfall will aggravate water security

Snow, ice & rainfall: Different contributions to river flows

Glaciers and seasonable snow covers are important components of the water cycle in the HKH. Their accumulation and melting as the season changes are nature's process of storing and releasing water⁶⁹. In the upper reaches of the rivers, snow and glacier melt provide a varied yet considerable share of the river flows⁷⁰. As the rivers continue flowing from mountains to the sea, other sources such as rainfall and groundwater start to play a bigger role.

Glacial melt, snow & rain contribute to river flow



Copyright: China Water Risk

Internal renewable water resources (IRWR) is the long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation. Double counting of surface water and groundwater resources is avoided by deducting the overlap from the sum of the surface water and groundwater resources.

Total Renewable Water Resources (TRWR) is the sum of internal renewable water resources (IRWR) and external renewable water resources (ERWR). It corresponds to the maximum theoretical yearly amount of water available for a country at a given moment.

Source: FAO AQUASTAT Glossary, www.fao.org/nr/water/aquastat/data/glossary/search.html

Higher glacier & snow melt contributions = more vulnerable

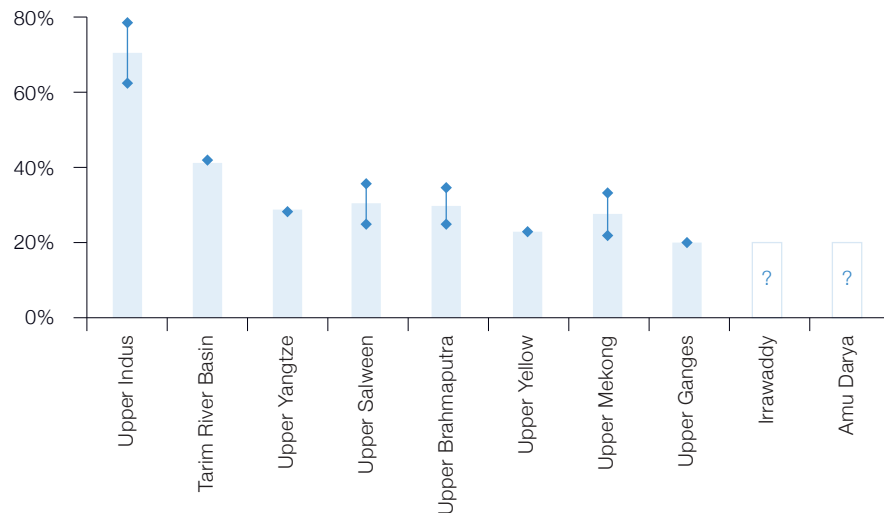
Glacier & snow melt contribute materially to the runoffs of the Upper Reaches of HKH Rivers...

Based on a few selected studies, glacier and snow melt together in general contribute to more than one fifth of the runoffs of the Upper Reaches of HKH Rivers. The combined shares range from 20% in the Upper Ganges to up to 79% in the Upper Indus³⁷⁻⁴² as shown in the chart below. We were not able to track down any data for the Irrawaddy and Amu Darya.

From 20% in the Upper Ganges...

...to 79% in the Upper Indus

Glacier & Snow Melt: Runoff Contribution in Upper HKH Rivers



Source: China Water Risk based on Lutz et al (2014), Lutz and Immerzeel (2013), Zhang et al (2013), Chen (2013), Wang et al (2007) and Gao et al (2010)

Higher percentages = higher vulnerability to climate change

Higher percentages of runoff contribution from glacial and snow melt imply higher vulnerability of the river flow to climate change. Here, the Upper Indus and Upper Tarim stand out: they have high shares of glacial and snow melt, Indus (62%-79%) and Tarim (42%)³⁷⁻⁴²; plus high exposures to high and extremely-high water stress, Indus (62%) and Tarim (37%)⁵³. The Upper Indus is particularly vulnerable, potentially putting the 380 million people who live in the Indus River Basin across three countries at risk. Moreover, 92% of Pakistan's economy is generated in this basin alone^{1,44}.

Upper reaches of four "priority rivers" (Indus, Ganges, Yellow & Yangtze) are vulnerable

The highly water stressed Yellow and Ganges River Basins also appear to be vulnerable to climate change with glacial and snow melt accounting for a quarter of the Upper Yellow and 20% of the Upper Ganges. The Upper Yangtze is also vulnerable with 29% of river flow derived from glacial and snow melt. In short, the upper reaches of the four priority rivers identified in the previous Chapter (Indus, Ganges, Yellow & Yangtze) are all vulnerable to climate change.

No data on the Amu Darya & Irrawaddy, doesn't mean they are not affected

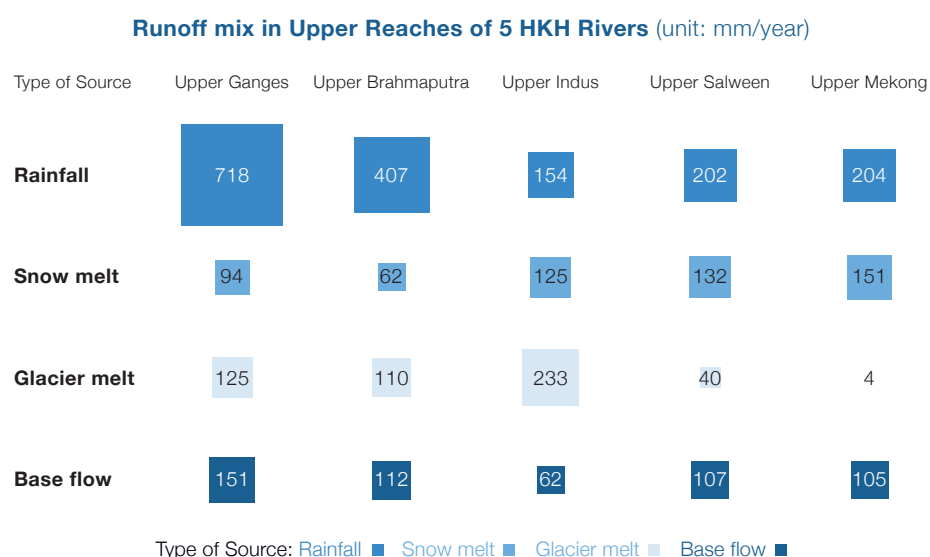
Separately, although no data is available for Irrawaddy and Amu Darya, it doesn't mean that there is no glacial melt or snow in these two river basins. In fact, there are 133 glaciers in Irrawaddy and 3,277 glaciers in Amu Darya, with total glaciers area of 35km² and 2,566km² respectively⁷¹. This lack of data and research are clearly gaps to be plugged.

Uncertainties, lack of research, data & standardisation all need to be addressed asap

There is still considerable uncertainty in quantifying the contribution of glacier and snow melt to the river runoffs. Many existing studies are not exactly comparable due to varied approaches and scopes. Other factors such as climate conditions and differences in defining boundaries of sub-watersheds shared by rivers put further constraints in understanding the different results and approaches⁷². Given what's at stake, surely we should not only plug research gaps but standardise and better coordinate future studies on climate change impact to the various types of runoff contributions.

One of the above references, Lutz et al. (2014), also provided their estimation of average runoff contribution by source (including base flow, glacier melt, snow melt and rainfall) for five HKH Rivers. The results from this study are summarised in the chart below. Please note that unit used here (mm/year) is commonly used to show the intensity of different types of runoff sources, especially rainfall. Here, it is defined as the ratio of the total average amount of water (depth) falling/flowing with the boundary of each river basin in one year.

The unit mm/year is to show the intensity to different types of runoff sources



Runoff mix can vary widely across rivers...

Source: China Water Risk based on Lutz et al (2014)

What stands out is the glacial melt contribution to the Upper Indus. At a glance, the Upper Indus is the most reliant on glacial melt across the five rivers with the largest share of glacial melt in the runoff mix. Moreover, regarding the Upper Indus, not only is it significant when compared to that in other four rivers in absolute terms, the intensity of glacial melt water contribution is greater than that of rainfall across the Upper Salween and Upper Mekong.

Glacial melt is important to the Upper Indus...

The Upper Mekong on the other hand enjoys the largest contribution from snow melt compared to the other rivers in absolute terms. In other words, it will also be more likely affected by changes in snowmelt. As we will discuss in the next section “**Past 50/Next 50 years: rising temperatures & changing water flows**”, snowfall in the Mekong has fallen in the last 50 years and is expected to continue to fall in the next few decades.

...but not the Upper Mekong, where snow melt is key

At this point, it is vital to recognise the linkages between climate change and each of these components of river flow. Climate change and rising temperature will not just accelerate glacier and snow melt, they will also affect snowfall. Rainfall patterns could also be impacted by the changing monsoon – more on this later in “**Monsoon & the Himalayas: Changing Prospects**”. In turn, changes in surface water, such as rivers and precipitation, will also affect groundwater recharge. In short, all aspects of renewable water resources are impacted by climate change.

Climate change is more than droughts, floods & sea level rise...

Such impacts are clearly more pressing in the upper watersheds of these river basins located in the Third Pole, which like the other two poles is also facing similar melt. However, while we are made aware of calving ice shelves and sea level rise through the media, there is little attention paid to the melting of the ice reserves in the HKH.

...Ice & snow in the HKH are key sources of water for billions of lives & livelihoods downstream

Unlike the Arctic and Antarctica, the glacial and snow melt from the Third Pole empty into Asia's rivers and are essential sources of water that sustain billions of lives and livelihoods. Therefore, before we start exploring the impact on the various components above for each river basin, it is worth remembering the HKH's as “Asia's Water Towers” in the following two-page spread on “**The Third Pole: Up to 7,574km³ of Ice Reserves**”.

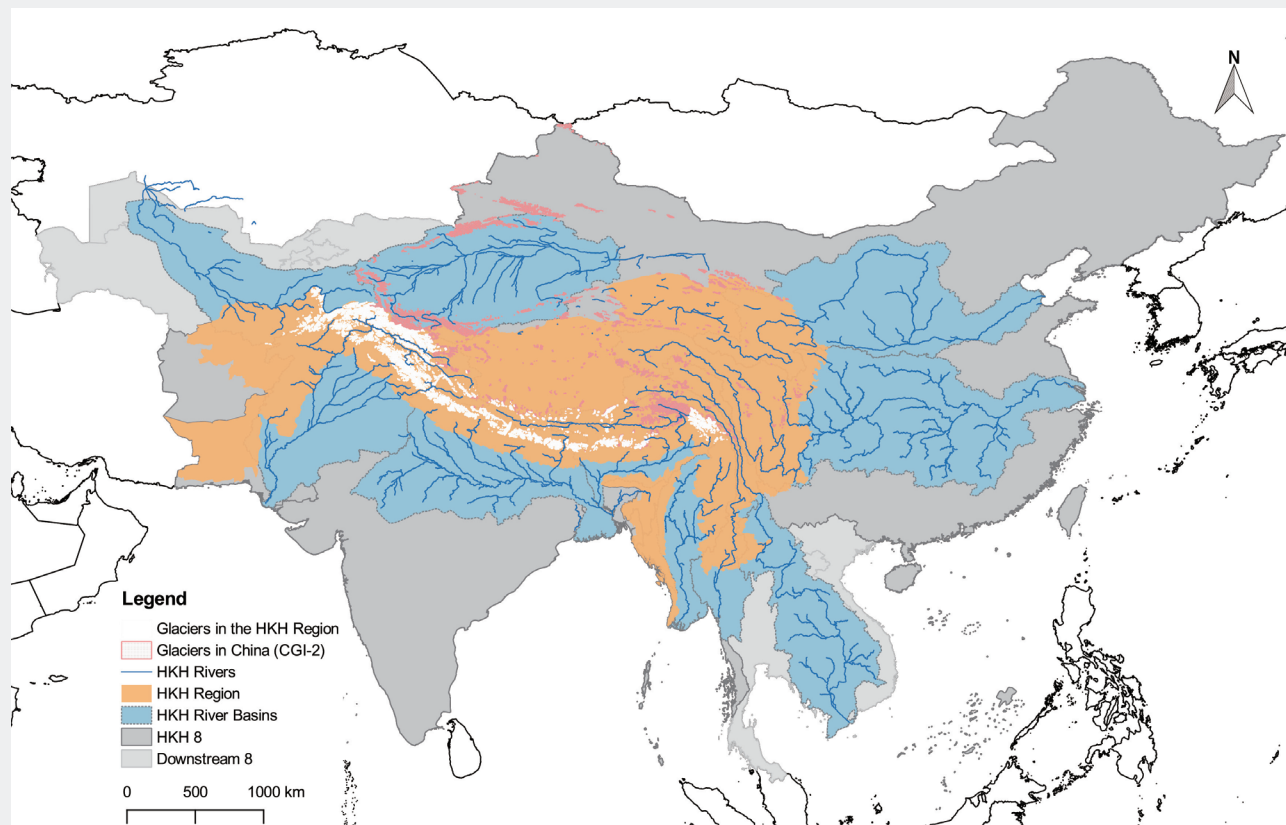
THE THIRD POLE: UP TO 7,574km³ OF ICE RESERVES

The HKH is called the ‘Third Pole’ for a reason: it has lots of ice and snow. Although there is no singular comprehensive glacier inventory for all glaciers feeding the HKH River Basins, there are datasets for the HKH Region as defined by ICIMOD well as the China’s second national glacier inventory (CGI-2). Based on these two datasets, we estimate that the total ice reserves supplying the HKH River Basins to add up to 7,574km³; the largest accumulation of ice outside the Arctic and the Antarctica^{24,71}. If melted, this volume of ice will be equivalent to 6,968 billion m³ of freshwater (*using 100:92 volume conversion from ice to water*). For perspective, this amount of water will fill two of the Great Lakes – Lake Michigan and Lake Erie, with enough left over to fill almost 40 Three Gorges Dams. These ice reserves at the roof of the world truly are the ‘Water Tower’ for Asia.

According to ICIMOD, there are 54,252 glaciers²³ located in the area it has defined as the “HKH Region” which covers a total area of over 3.4 million km², expanding 3,500km from the west to the east³⁶. For perspective, this is almost half the size of Australia or twice that of Indonesia. The HKH region is coloured in the map below. These 54,252 glaciers cover a total area of 60,054km²⁷¹ and denoted in white in the map below. For perspective, this glaciated area is around 2x the land area of Belgium. It is estimated that 87.5% of these glaciers in terms of glaciated areas are associated with the 10 HKH River Basins. This dataset however, does not include most of the glaciers feeding the Tarim River Basin due to the boundaries of the defined HKH Region.

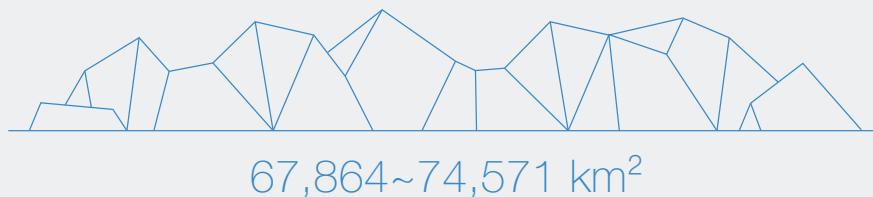
The CGI-2 on the other hand, does include glaciers feeding the Tarim River Basin, but obviously only includes glaciers within China and therefore can be used in tandem with the ICIMOD data to present a more complete picture. CGI-2 reveals that China has 48,571 glaciers covering an area of 51,800km² (denoted in red in the map below); 98.7% of these are linked to HKH Rivers in terms of glaciated areas⁷³. To put this in perspective, China’s glaciated areas feeding the HKH River Basins would cover the entire municipalities of Beijing, Tianjin and 2x the area of Shanghai.

Naturally, there will be overlapping data from these two datasets. As such, we estimate the HKH River Basins to be supplied by around 58,316 to 62,994 glaciers which cover a total area of 67,864km² to 74,571km². At the upper end of the estimate range, the glaciated area would roughly cover the entire land area of the Netherlands, Switzerland and Singapore.



Source: China Water Risk based on following sources: 1) country boundary from Data Centre for Resources and Environmental Sciences, Chinese Academy of Sciences; 2) river shape files from FAO AUQA maps; 3) glaciers in the HKH from Bajracharya & Shrestha (eds) (2011) *The status of glaciers in the Hindu Kush-Himalayan region*. Kathmandu: ICIMOD, (<http://lib.icimod.org/record/9419>); 4) glaciers in China from Wang et al. (2014) *The Second Glacier Inventory Dataset of China (Version 1.0)*. Cold and Arid Regions Science Data Center at Lanzhou. Doi: 10.3972/glacier.001.2013.db

Total Glacial Area of the HKH River Basins



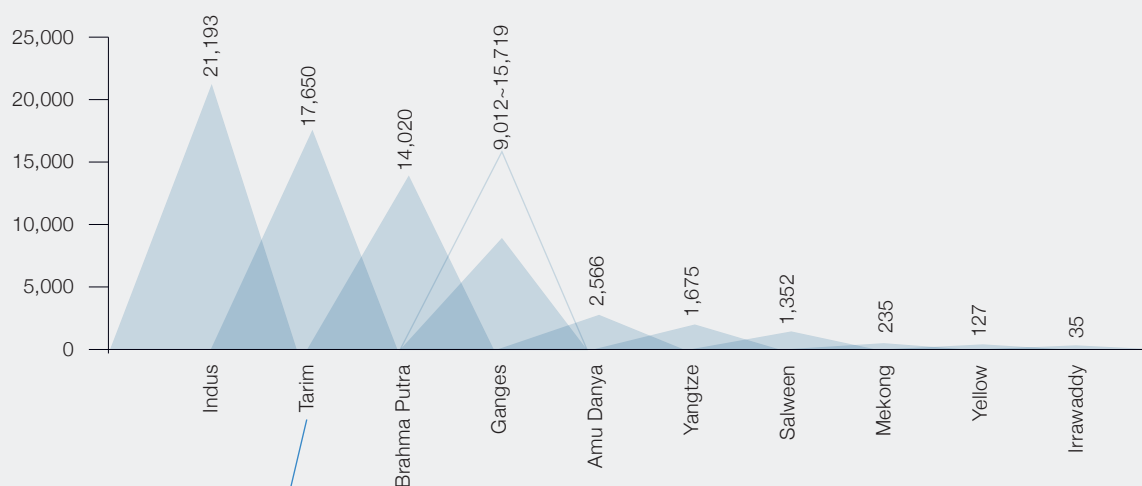
This is equivalent to the land area of ...



If melted, the water will fill...



Glacial Area Spread by Basin



The Tarim Basin is home to the **Tien Shan Mountains**, which hold the biggest share of the Tarim Basin's glaciers.



It is also known as the "Water Towers of Central Asia"

China has 48,571 glaciers. If melted ...

Freshwater resources

= 4,300 ~ 4,700 billion m³

1.6x
China's total renewable water resources OR
over 7.6x
total water use in 2016

This would fill nearly

120
Three Gorge Dams

Retreating glaciers: Altitude makes a difference

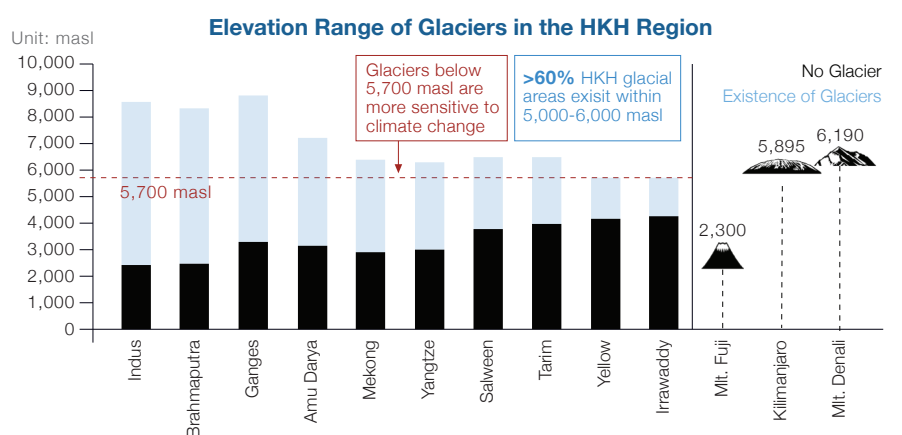
Total area of glacier losses in China (1970s -2000s) = size of Kenya or larger than Thailand

Due to climate change, the dynamic yet balanced nature process of glacier and snow melt has been shifting in recent decades. Most Himalayan glaciers have been retreating, except for some in the Karakoram⁷⁷. Substantial decrease of large-scale glaciers and permafrost have been observed in China from 1970s to 2000s: areas of large-scale glaciers and permafrost shrunk by 10.1% and 18.6% respectively over the past 30 years^{78,79}. Such glacier and permafrost losses cover 2,089 km²⁷⁸ and up to 0.56 million km²⁷⁹ respectively. The total area of such losses is equivalent to Kenya and larger than Thailand.

Aside from temperature, altitude matters. Glaciers in areas below 5,700 metres above sea level (masl) are considered particularly sensitive to climate change unless covered by thick debris⁷¹. A study of glaciers in the HKH Region show that glaciers are located between 2,409 and 8,806 masl as shown in the chart below:

Altitude matters...

...glaciers below 5,700m above sea level (masl) are more sensitive to climate change...



Source: China Water Risk based on S.R. Bajracharya et al. (2015) **Note: masl = metres above sea level**

...>60% of the total glacier area of the HKH Region lie within 5,000–6,000 masl

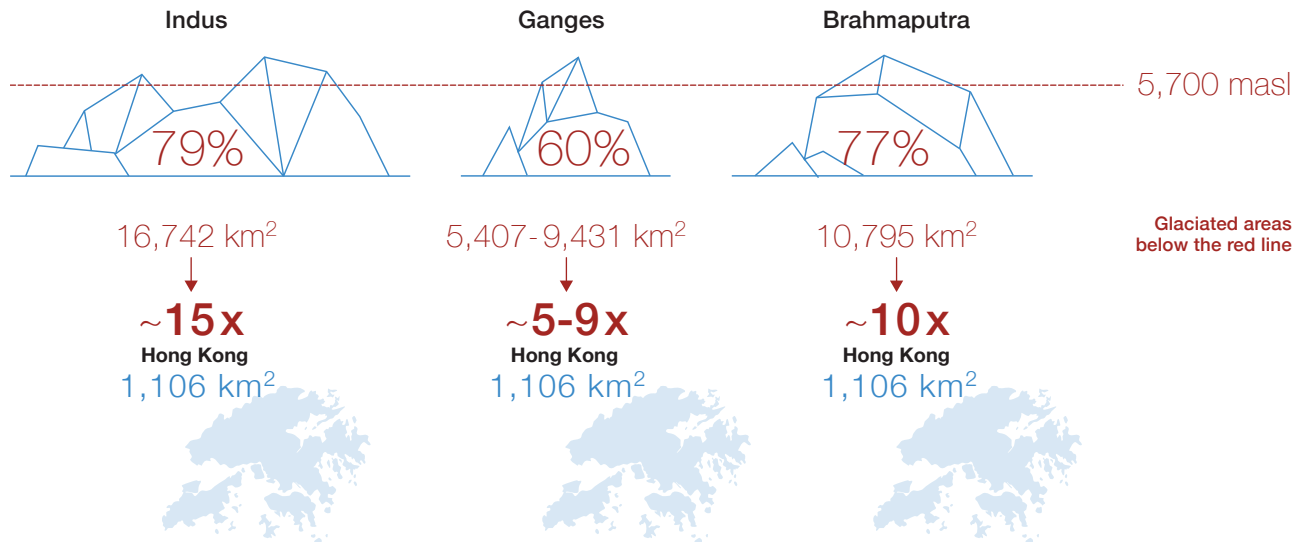
However, despite the wide elevation range across the 10 basins within the HKH Region, over 60% of the total glacier area of the HKH Region lie within 5,000–6,000 masl⁷¹, making them more vulnerable to climate change. As highlighted by the study, 79%, 60% and 77% of the glacier areas in the Indus, Ganges and Brahmaputra basins, respectively, lie below the critical elevation of 5,700 masl⁷¹.

Debris cover can either slow down or accelerate the rate of glacial melt.

Glacier melting and ablation have resulted in debris-covered glaciers. Many large glaciers in the lower altitudes do not appear white, rather look grey, covered with rocks and sand (see photograph on the next page). Depending on thickness of the debris cover, it can either slow down or accelerate the rate of glacial melt. Generally speaking, a thick layer of debris on top of glaciers can insulate the ice below from melting²². However, the behaviour of such glaciers and their response to climate change still require more research⁸⁰. The debris cover, along with the high altitude and mountainous terrain, also makes monitoring and research more difficult⁷¹.

Studies of glaciated areas in the HKH Region (outside China) have categorized about 32,000km² of areas as either debris-covered or clear ice⁷¹. At least 3,121 km² of debriscovered glaciated areas are located in the Indus, Brahmaputra, Ganges, Amu Darya and Tarim basins⁷¹. This means on average around 10% of glaciated areas in the region are debriscovered. In the Himalayas alone, it is estimated that between 14-18% of the glaciers is debris covered⁸⁰.

Glaciers in Indus, Ganges & Brahmaputra are More Sensitive to Climate Change



Source: China Water Risk based on S.R. Bajracharya et al. (2015)

Debris Covered Glacier

The photograph below shows the Bara Shigri Glacier, the second largest glacier in the Indian Himalayas after the Gangotri Glacier (pictured in the preface). Taken at around 4,600m the glacier is clearly debris covered and collapsing from within. This glacier feeds the Chenab River, a key tributary of the Indus.



Future glacier shrinkage & impact on annual flows

The annual glacier melt in Western China could fill up 1.6 Three Gorges Dams

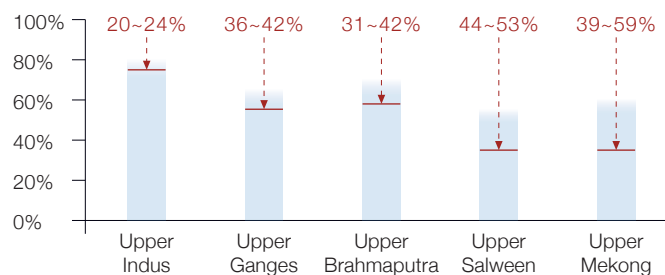
Glaciers are shrinking at different rates. Already, the glacier melting in Western China reached an annual rate of up to 62 billion m³; an amount that can fill up 1.6 Three Gorges Dams. In the Upper Yangtze River, where glacial and snow melt account for nearly 30% of the runoff³⁹, glacial melt above villages in the source region, like Zhimenda Village, has increased by 15%⁷⁸. Else in the Tien Shan mountains, Sorg et al. (2012) found five glaciers shrinking at annual rates of 0.05% to 0.76% between 1950s and 2000s⁷⁶, and noted that a few existing studies, despite their uncertainties and differences, pointed to a trend of continued retreating in the 21st century.

Indeed, in the next few decades, this trend of glacier shrinkage is expected to continue across the upper watersheds of HKH Rivers. Lutz *et al.* (2014) used eight Global Circulation Models (GCMs) to simulate the change of glacier areas in the upper reaches of five HKH Rivers under both RCP4.5 and RCP8.5 by 2050, in comparison to the status in 2007. The expected shrinkage in glacier areas range from 20% in the Upper Indus to up to 59% in the Upper Mekong during this simulation period³⁷ (see chart below).

By 2050, projected shrinkage in glacier areas range...

...from 20% (Upper Indus) to 59% (Upper Mekong)

Simulated Glacier Area Shrinkage (2007-2050) Under RCP4.5



Minimum remaining glacier area (%) by 2050

Source: China Water Risk based on Lutz *et al.* (2014)

Ganges has the largest glaciated area...

...36-42% loss of glacier area in Ganges is 3,244-7,073km², equivalent to 3-7x of Hong Kong

Glacier area shrinkage should be considered in together with glaciated area for the basin. For example, although the Mekong is projected to experience the greatest shrinkage, it has the least number of glaciers and glaciated areas. A 39-59% loss infers a glaciated area loss of around 92 to 148 km² ³⁷. Meanwhile, as can be seen from the infographic on the previous page, the Ganges, is served by the largest glaciated area so a 36-42% shrinkage in glacier area³⁷ is significant. The Ganges could lose from 3,244 up to 7,073 km² by 2050, depending on the projection model and the inventory of current glaciated areas – see the infographic on glaciated area losses by basin on the next page.

The accelerated glacial melting will result in increase in its contribution to the river flow in the next few decades. For instance, in the Upper Brahmaputra, future glacier melt could contribute to over 50% of the total projected increase of runoff increase in the long term (2041-2070) relative to 1971–2000; while, in the Upper Yellow, contribution from glacier-meltwater on future runoff is less than 1.0% of its total amount⁸¹. These future changes will likely affect the total renewable water resources (TRWR) available for relevant HKH country.

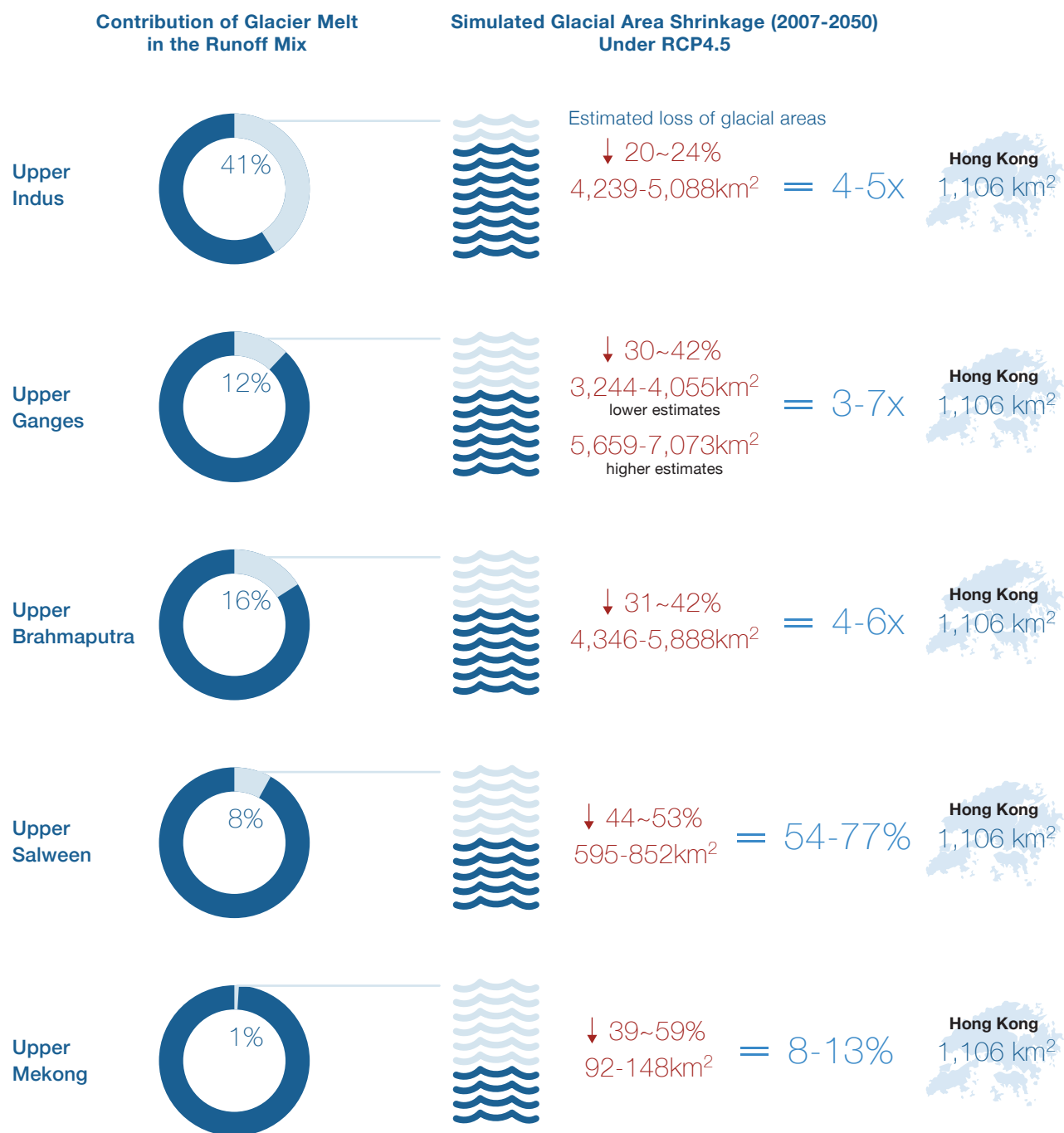
Although glacial melt is only a part of river flow, the trend is worrying across the 10 HKH Rivers

However, glacial melt is only one component of river flow; it should be considered in conjunction with future rainfall and snowfall to determine the change in river flow in each basin. Trends of temperature rise and hydrological changes across the ten HKH Rivers for the past 50 years (1956-2005) as well as projections for the next 50 years (2005-2055) are thus explored next. Although these trends reveal mixed results on runoffs; the overall trend is worrying across all ten rivers.

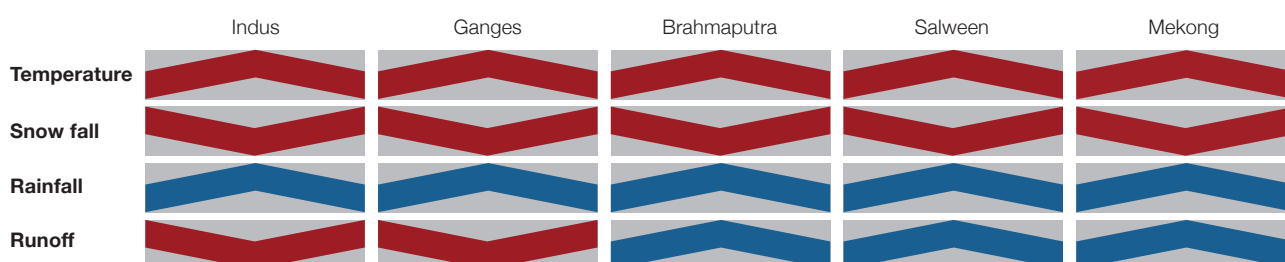
Already, mountain communities are feeling the effects

There is no doubt that accelerated glacial melt will impact river flows in long term. However, in the short term, it's important to remember that it will also impact the lives and livelihoods of mountain communities through the threat of Glacier Lake Outburst Floods (GLOFs) and summer droughts - see the photo in "IMPACT ON MOUNTAIN COMMUNITIES".

HELP ME! I'M MELTING



Projected changes of 2006-2055 compared to 1956-2005 for the entire basin



IMPACT ON MOUNTAIN VILLAGES & INFRASTRUCTURE

Summer droughts & water refugees

Glacial melt's contribution to runoff is not the only concern. Glaciers are also an important source of water to mountain communities. Most glacial melt occurs in the summer and can alleviate summer droughts, providing local communities with water. Indeed, glacial melt's share of runoff contribution peaks during the summer months. This is especially true for some of the HKH River Basins such as the Upper Indus and Upper Amu Darya.

As per Pritchard (2017), glacial meltwater in High-Mountain Asia (a geographical concept similar to the HKH Region) provides a net amount of water of 23 billion m³ each summer⁶⁹. Assuming the "absolute-scarcity" level of 500m³ renewable water resources used per person per annum⁷⁰, this amount would cover 136 million people's basic water needs over the four summer months. In the case of the Indus, summer melt from glaciers provides water for 69 million people. While this may not sound like a lot, it is greater than Pakistan's annual municipal and industrial water usage⁶⁹.

Shrinking, vanishing glaciers and changing water flows are already impacting mountain communities:

- **Floods:** As per the Internal Displacement Monitoring Centre (IDMC), floods in the Northern Indian state of Bihar, in July 2016 resulted in about 1.67 million displacements; during the same period, floods in the state of Assam led to almost half million people having to leave their home⁸². During June 2017, heavy monsoon rains caused floods and landslides, which affected 37 out of the 75 districts in Nepal⁸³.
- **Droughts:** in 2017 summer, drought conditions in the Spiti Valley in Northern India caught the attention of international media⁸⁴. Such concern is common in plain areas during dry season, but un-expected for this valley with white peaked Himalayas at the backdrop. It also has the world's highest village called Komik.

Glacier lake outburst flood (GLOF)

Glacier lakes are formed when melt water is held back by frontal moraine. The moraine is often unstable, and when water breaches, it causes glacier lake outburst flood (GLOF). The total number of glacier lakes in the HKH Region ranges from 5,701⁸⁵ to over 8,000⁸⁶, depending on detection methods and geographical coverage. Numbers also fluctuate from year-to-year. Over 200 of them have been identified as "potentially dangerous" ⁸⁶.

For instance, in Nepal, one recent study identified 131 glacier lakes with the size greater than 0.1 km² (~14 soccer fields) in 2015, of which 11 were classified as very high risk and another 31 as high risk⁸⁷. Some lakes can pose more obvious risk due to its sheer volume water: for example, Nepal's largest lake, Tsho Rolpa, was estimated to hold water that can fill 4000 Olympic-size swimming pools⁸⁸.

Although GLOFs mostly occur in remote mountain regions, they are a threat to local communities living downstream, as well as infrastructure such as roads and hydropower plants²³. For example, the GLOF of a glacier lake called Dig Tso in Nepal in 1985 caused damages that worth over USD3 million⁸⁹.

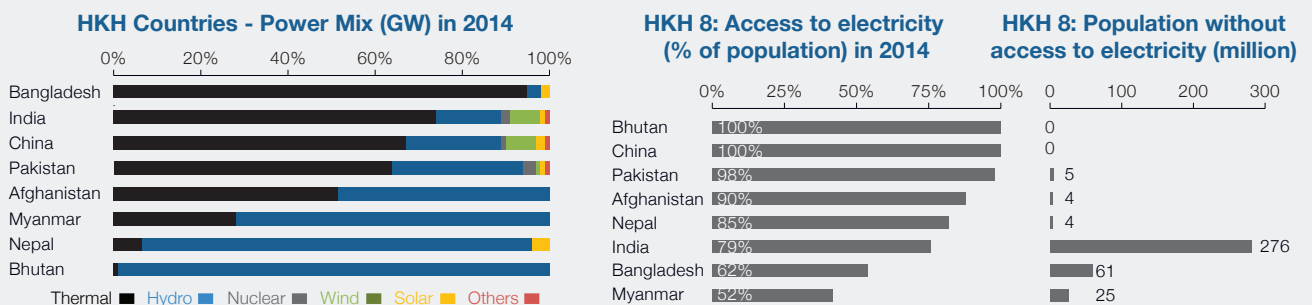


BLACK CARBON FROM RURAL COMMUNITIES

The sources and warming effect of black carbon

There are broadly three types of anthropogenic causes of global warming⁹⁰: 1) well-mixed greenhouse gases in the atmosphere, mainly CO₂, CH₄, N₂O and Halocarbons (such as CFCs and HCFCs); 2) short lived gasses (such as CO and NO_x) and aerosols (such as mineral dust, sulphate, nitrate, and black carbon); and 3) land use change.

CO₂ from burning fossil fuels as well as CH₄ from landfills & livestock farming are important contributors to the global warming. Many of the HKH 8 are still highly reliant on fossil fuels, especially thermal coal-fired power generation^{91,92} (see left-below chart). Both the extraction of coal and the operation of thermal power plants generally require significant amount of water withdrawal, which has caused water stress in river basins such as the Yellow⁹³ and the Ganges⁹⁴.



Meanwhile, aerosols also have effects on the climate (both cooling and warming) through interaction with clouds, absorption of solar radiation and changing albedo of snow and ice, etc⁹⁰. In fact, recent studies have found that aerosols containing black carbon play an important role in the changing climate of the HKH, especially for the acceleration of glacier melting⁹⁵. Commonly known as soot, black carbon is the product of incomplete combustion of biofuels and coal, exhaust from diesel engines, as well as waste burning and forest fires⁹⁵. It impacts the climate in at least two ways: absorbing heat in the atmosphere, and reducing the ability of snow to reflect sunlight when deposited on its surface⁹⁰. One big source of black carbon is the use of traditional cook stove. There are still over 375 million people in the HKH 8 or nearly 12% of the total population without access to electricity⁹⁶. 74% of these people or 276 million are living in India; and the rest are mainly in Bangladesh, Myanmar and Nepal (see right-above charts). Many of the rural households rely on burning woody biomass or charcoal in traditional stoves for cooking and heating.

The impact of black carbon goes beyond HKH

Black carbon does not only impact the local environment, but can also transport over long distances through atmospheric movement⁹⁷. Black carbon from the Indo-Gangetic Plains can end up in the Himalayan mountains and the southern parts of the Tibetan Plateau; black carbon from central China is found on the eastern and northern parts of the plateau; while the Karakoram can receive black carbon from the Middle East and even Europe and Northern Africa^{95,97}. Studies have also shown monsoon and non-monsoon season matter for the distribution and contribution of anthropogenic sources of black carbon^{98,99}: for instance, black carbon from South Asia can account for up to 80% of surface black carbon in the Tibetan Plateau during the non-monsoon season⁹⁹.

The changing snow cover as a result of climate change and black carbon, is found to be correlated to the heat waves in Southern Europe¹⁰⁰. This interconnectivity due to atmospheric movement shows the complexity of our climate system, and also proves that climate change is indeed a global issue and needs countries to be more cooperative in actions. More on this in **"Past 50/ Next 50 years: rising temperatures & changing water flows"**.

Solutions to tackle black carbon depend on the sources of emissions. For black carbon from cooking traditional stoves, one often-proposed solution is to replace them with improved cooking stoves. Over the last few decades, India has been making such efforts through national schemes such as National Biogas and Manure Management Programme¹⁰¹. However, progress has been slow. While a new technology may offer a technical solution, it may not lead to real social change. One recent study attributed such failure to their inattentiveness to cultural and social-economic aspects of the problem¹⁰². This reminds us that a multi-disciplinary and holistic approach is needed beyond promoting renewable energies or replacing traditional stoves. Solutions are not limited to moving away from fossil fuels, but also about choosing the right industries and reducing the overall energy consumption. All of these require funding. Mobilising investment to rural communities hasn't been easy. But given the urgency of climate impacts, both governments and the private sector should focus on address black carbon as well as energy access in rural communities.

Past 50/Next 50 years: rising temperatures & changing water flows

We examined historical trends in temperature, snowfall, rainfall and runoff...

...under RCP 4.5
(stay within 1.5-2°C)

Using 5 climate models, projections were made for the 4 indicators ...

Temperatures to rise across the 10 HKH River Basins...

...from a low of 1.39°C (Mekong) to a high of 1.90°C (Amu Darya) by 2055

Temperatures expected to double for the next 50yrs vs past 50yrs in 6/10 basins

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 Basins⁵². 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.

REPRESENTATIVE CONCENTRATION PATHWAYS (RCPs)

IPCC adopted four greenhouse gas (GHG) concentration trajectories for its fifth Assessment Report (AR5) in 2014, called RCPs (including RCP2.6, RCP4.5, RCP6 and RCP8.5). In terms of global surface temperature change by the end of this century relative to the average from year 1850 to 1900:

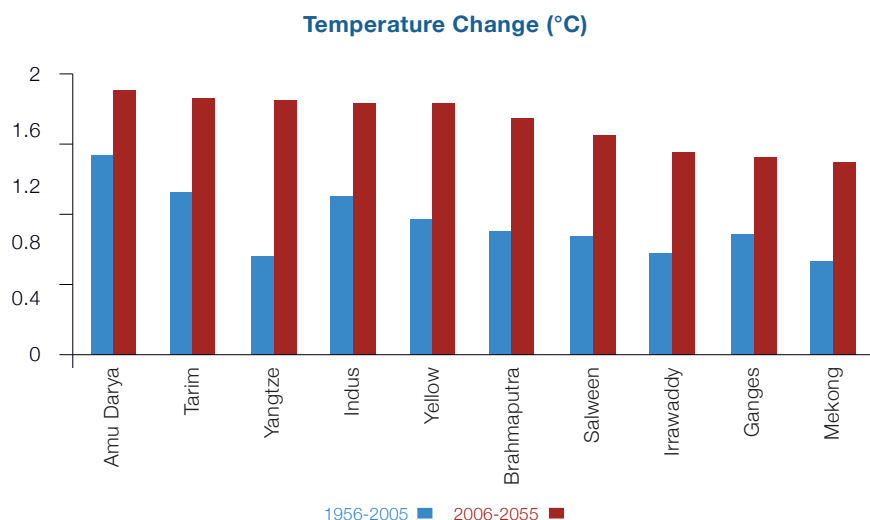
- **RCP2.6:** unlikely to exceed 2°C for (medium confidence);
- **RCP4.5:** likely to exceed 1.5°C (high confidence), and more likely than not to exceed 2°C for (medium confidence);
- **RCP6.0:** likely to exceed 2°C (high confidence), but unlikely to exceed 4°C (high confidence); and
- **RCP8.5:** it is about as likely as not to exceed 4°C (medium confidence).

Source: IPCC AR5 Synthesis Report (2014)

Using five climate ensemble models, future projection of these indicators 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 2055¹. The projected increase across the 10 HKH River Basins ranges from 1.39°C in the Mekong to 1.90°C in the Amu Darya¹ (see chart below).

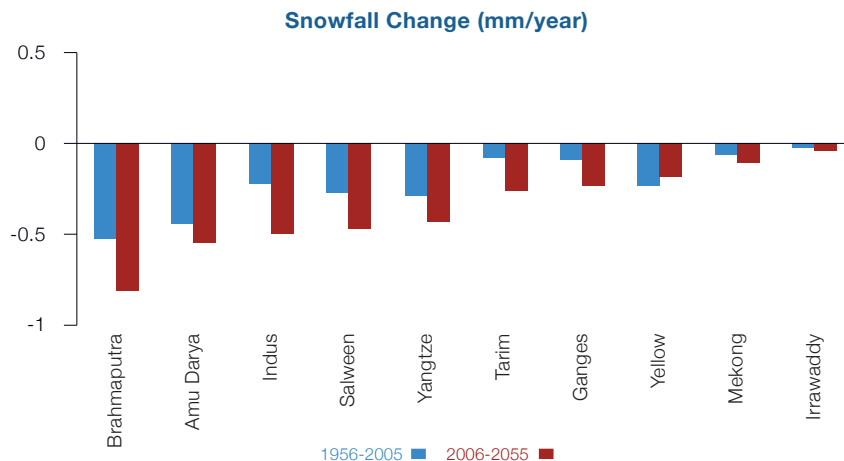


Source: China Water Risk based on data from Center for Water Resources Research, Chinese Academy of Sciences. Rainfall, snowfall and runoff change are expressed in equivalent water height. All data are calculated from five ensemble model (BCC-CSM1.1, CanESM2, CCSM4, MIROC5, MPI-ESM-LR) in IPCC AR5.

The Yangtze, Yellow, Amu Darya, Tarim and Indus are likely to see the biggest increase in temperature of 1.80-1.90°C¹. 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 basins¹⁰³. Moreover, rise in water temperature could reduce raw water quality and threaten drinking water sources^{103,104}.

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.



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 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 (see box below). 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 snowmelt³⁷.

SNOW & ICE ALERT! ... INDUS, GANGES & TARIM AT RISK

As shown previously, glacier and snow melt contribution to river flow is 62-79% for the upper Indus, 20% for the Ganges and 42% for the upper Tarim. It is also worth noting that Indus holds 44% of HKH's total ice reserves⁷¹. Projected temperature rises under RCP4.5 scenario for these two basins, Indus (+1.81°C) and Tarim (+1.84°C) during 2006-2055¹, as well as projected continued losses in snowfall, do not bode well for the future water flows in these basins.

62% of the Indus, 55% of the Ganges and 37% of the Tarim (in terms of basin areas) already face 'high' or 'extremely high' water stress. 43% of the Tarim are also considered 'arid' or with 'low water use'⁵³. Rainfalls are projected to continue increase across the 10 river basins in the next few decades. But, the Indus and the Tarim, along with Amu Darya, will see the least rise.

Water is crucial for agriculture production in these two river basins. For instance, surface water supports 53% of the in total 24.5 million ha irrigated areas in the entire Indus River Basin¹⁰⁵. Future climate trends raise serious concern over water security.

For the Ganges, although glacier melt and snow melt form a relatively small share of its total runoffs, the upper reaches of the Ganges holds large areas of glaciers and may face 36~42% of losses by 2050. See more in **"Future glacier shrinkage & impact on annual flows"**.

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 Asia¹⁰⁰.

Expect snowfall to continue to fall at faster pace...

...future snowfall losses will likely to more than double for the Indus, Tarim & Ganges

...continued greater snowfall losses in Mekong may impact Upper Mekong where 33% of flow is from snowmelt

Indus, Ganges & Tarim are most at risk due to high glacier & snow melt contribution to river flow ...

...also, changing snow cover can cause heat waves in southern Europe

Rainfall across basins are projected to increase...

...but the Indus, Amu Darya & Tarim will see less rain by 2055

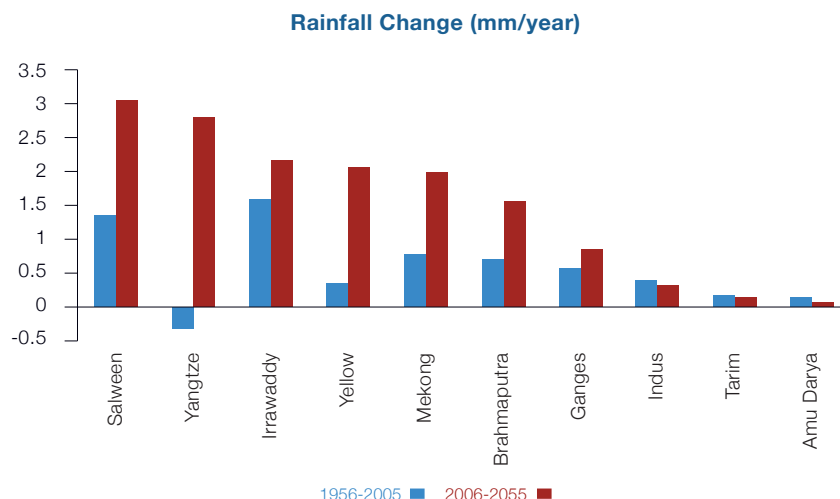
The Yangtze & Yellow face the largest swings...

But more rain may not mean more water ... when & where it rains also matter

The impact on runoffs is mixed

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.

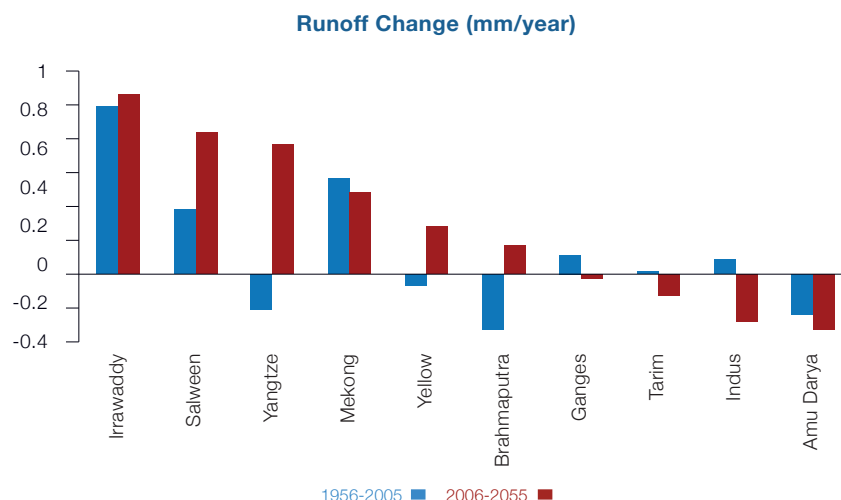
From the chart above, it is evident that the Yangtze and the Yellow face the largest swings in trend from the past 50 to the next 50 years. Both rivers are demonstrating dramatic increases in rainfall. Indeed, China experienced the wettest year in 2016 with the most number of heavy rainy days since 1961. 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 m³, which is 771 billion m³ more than the 2015 level¹⁰⁶. At 1.25x the total national water use of 615 billion m³ in 2016⁵⁵, rainfall is an important component of water resources. See how China is tackling this in the two-page spread “China Heating Up & Building Resilience”.

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 season²³. 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 respectively¹⁰¹. More on the relationship between the HKH and the monsoon in “Monsoon & The Himalayas: Changing Prospects”.

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 Brahmaputra¹⁰⁷.

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 rivers 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 communities²⁵. 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 – see examples of these in “China Heating Up & Building Resilience”.

Moreover, increases in runoff are often seasonal and happen within a short time period which could leads to floods. For instance, more than 80% of annual precipitation in much of the HKH region falls during the monsoon season¹⁰⁸. This uneven temporal distribution of precipitation has led to some serious floods during the rainy seasons, especially in mountain regions – more on this later in “Monsoon & The Himalayas: Changing Prospects”.

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 1971-2000⁸¹. 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 period⁸¹, which is evidently opposite to CAS-IGSNRR'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.

The Amu Darya's flow will continue to shrink

Already stressed Ganges, Indus, & Tarim will see reduced runoffs in the future vs. increases in the past...

...whereas the Yangtze, Yellow & Brahmaputra will now see rises in runoff

But more flow may not mean more water supply...

...need to build infrastructure to store water & to avoid floods

Climate projection results vary & uncertainties remain...

...but trend is clear: changes across 4 indicators are greater in the future than in the past

Results assume staying within the 2°C threshold

CHINA HEATING UP & BUILDING RESILIENCE

Projected headline numbers

The following projections are made in the most recent *National Assessment Report on Climate Change*⁷⁸:

- **Temperature:** continue to rise by 1.3-5.0°C by the end of this century;
- **Sea level:** will rise by 0.4-0.6m by the end of this century relative to the previous century;
- **Mean precipitation:** will increase by 2-5% by end of the century, and for the North, it may increase by 5-15%;
- **Extreme events:** will increase, in particular high temperature and heat waves, as well as extreme droughts.

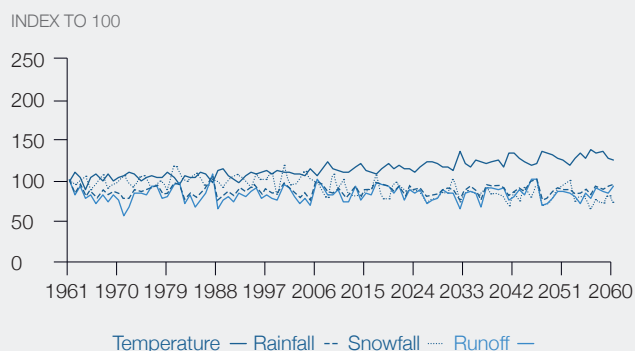
More heat from climate change than the global average. According to China's 3rd National Assessment Report of Climate Change, its average warming rate over the past 50-60 years has been 0.21-0.25°C every 10 years⁷⁸. From 1909 until 2011, the average land temperature increased by 0.9-1.5°C, which is more significant than the global average increase of 1.06°C in the same period¹⁰⁹. In recent 15 years, although the warming rate has slowed down, temperature level is still rising⁷⁸. In fact, 2016 was the third hottest year on records in China (after 2015 and 2007), 0.81°C warmer than an average year¹⁰⁶.

Sea level rise threatens prosperous coastal areas. The impacts of changes in the cryosphere will be felt on the coastal areas (see box below). The potential contribution of China's cryosphere to the sea level rise is estimated to be 0.14-0.16mm/a, in which glacier melting accounts for 0.12mm/a⁷⁸. For the High Mountain Asia (which refers to the Himalayas, Hindu Kush, Karakoram, Pamir, Tien Shan, and Tibetan Plateau mountain ranges), it is estimated that glacier changes could contribute 7.9-10.8mm to global sea-level rise by 2050, depending on glacier mass simulation methods being used¹¹⁰.

Yangtze & Yellow exposed

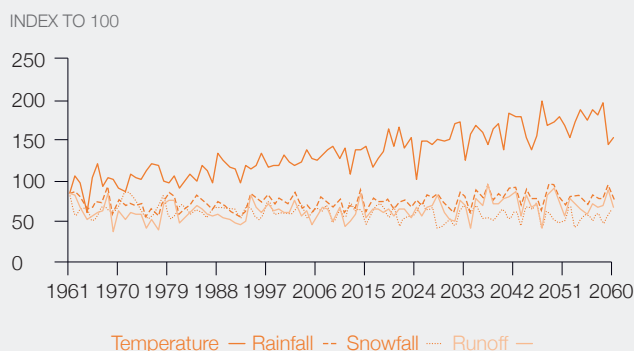
As shown in previous section, climate change is projected to be more pronounced in these two river basins under RCP4.5 scenario: Yangtze and Yellow will likely see 1.83°C and 1.8°C temperature increase during 2006-2055, respectively¹. The rate of change is expected to be more volatile in the Yellow than the Yangtze (see charts below).

Yangtze River: Climate Change Trend (1961-2060)



Source: China Water Risk based on data calculated by Center for Water Resources Research, Chinese Academy of Sciences based on the version 1.1 of the Beijing Climate Center Climate System Model (BCC_CSM1.1) in IPCC AR5

Yellow River: Climate Change Trend (1961-2060)



Source: China Water Risk based on data calculated by Center for Water Resources Research, Chinese Academy of Sciences based on the version 1.1 of the Beijing Climate Center Climate System Model (BCC_CSM1.1) in IPCC AR5

Both the Yangtze and Yellow are of strategic importance to China. According to China's Third National Climate Change Assessment⁷⁸, the Yellow saw a 15.6% drop in water resources during 1980-2020 compared to 1956-1979; while the Yangtze gained about 4.5%. Moreover, areas experiencing drought have increased at a rate of 0.53% every 10 years during 1949-2010 for the Yellow, and 0.13% for the Yangtze.

Given the significant share of population and economy along these rivers, how we tackle climate change matters for China's water, food & energy security as well as long-term growth.

Extreme weather events cost China >RMB4.5 trillion since the 21st century

Since the 21st century, natural disasters caused by extreme weather events have cost China at least RMB4.5 trillion, according to Chinese official statistics¹¹¹. This is more than double the expected investment for implementing China's 'Water Ten Plan'^{112,113}. In 2016 alone, natural disasters affected nearly 190 million people (some people may experience more than one event in one year) and resulted in total economic losses of RMB503 billion (~USD75 billion)¹¹⁴. Floods were the costliest: 62% of the total economic losses or RMB313 billion (~USD47 billion), were due to floods and related geological disasters (such as landslide)¹¹⁴. As a result, government spending on flood prevention has tripled from RMB69 billion in 2010¹¹⁵ to RMB208 billion in 2016¹¹⁶.

Urban areas in China are vulnerable due to the sheer number of people and assets at risk. According to a study in 2014¹¹⁷, 641 Chinese cities were found to be in danger of flooding. Also, in recent decades, urban flooding has become more intensified in regions such as the Yangtze River Basin. By comparing rainfall records of cities in the Yangtze River Delta over two periods, 1961-1980 and 1981-2010, increases in heavy-rainy days were found in both the central cities and suburbs. The increases were more intensive inside cities: for instance, days of heavy-rainy days rose 32% for Ningbo¹¹⁸.

Waterproofing infrastructure and economy

To reduce future economic losses, China has adopted both 'hard' and 'soft' approaches. It continues to build hard infrastructure embed resilience in urban planning through initiatives such as 'sponge cities' (*see below*). For soft approaches, it seeks to use financial instruments such as disaster insurance (*see below*), promote low-carbon industries, and also set policies to optimise crop mix and industry mix.

RMB1.6 trillion to build 'sponge cities' for the rainy days

Since President Xi Jinping embraced the concept of 'sponge cities', this has been piloted in major cities like Beijing, Shanghai and Shenzhen and is being promoted across the country¹¹⁹. A 'sponge city' refers to the ability of a city in storing, permeating and purifying rainwater. According to national guidelines released in October 2015, a 'sponge city' targets to collect and recycle 70% of its rainwater. As per the plan, by 2020, at least 20% of urban areas in 658 cities need to meet this target; by 2030, this percentage is expected to increase to 80%¹²⁰.

The unit investment for upgrading to 'sponge cities' is estimated to range from RMB100-150 million per km². As a result, nation-wide annual investment could reach RMB400 billion (~USD60 billion) by 2020, and even quadruple to RMB1.6 trillion (~USD240 billion) by 2030¹²¹. However, considering the economic damage from floods of nearly USD32 billion in 2016 alone (as per EM-DAT)¹²², such investment certainly makes sense in a long run, not to mention the benefits of saving lives and reducing interruption of social-economic activities.

Government-led disaster insurance schemes to help rural farmers

The booming Chinese economy is accompanied by the rising economic losses from natural disasters in the past decades. Since the 1980s, China has been testing disaster insurance schemes to mitigate such losses. For instance, in 1986-1988 and 1992-1996, the Ministry of Water Resources (MWR), together with the Ministry of Civil Affairs (MOCA), the People's Insurance Company (Group) of China (PICC) and the Ministry of Finance (MoF), launched two periodic pilots for flood dredging and retention areas in Huaihe Basin¹²³. Unfortunately, these early pilots weren't successful (*see box below*).

China's flood insurance pilots in Jiangxi in the 1980s

In 1985, MOCA launched an eight-year program on rural disaster relief insurance in 102 pilot counties which also covered flood loss. One such was PICC's 1992 pilot in Jiangxi province of downstream Yangtze river basin. According to the policy, villagers pay an RMB62 premium to permanently insure their households with up to RMB2,000 coverage. However, the premium was compulsorily collected by the local government or withdrawn from rural supply and marketing cooperatives, causing complaints from villagers who barely understand insurance or risk management. Many villagers later forced the insurance agent to return the money.

Based on Hongqiao Liu, "China Flood Insurance - Lessons & Opportunities", published on China Water Risk website: <http://chinawaterrisk.org/resources/analysis-reviews/flood-insurance-in-china-lessons-opportunities/>

In recent years, especially since the 13FYP (2016-2020), policies have been set to promote disaster insurance for rural farmers¹²⁴. For instance, in Guizhou province, provincial government announced a plan to provide basic farm disaster insurance of minimum RMB10,000 per household to all farmers by 2020¹²⁵. This echoes global efforts in promoting disaster insurance: the 'InsuResilience Global Partnership for Climate and Disaster Risk Finance and Insurance Solutions' was launched during the COP23 in 2017 to provide insurance to 400 million more poor and vulnerable people by 2020¹²⁶.

MONSOON & THE HIMALAYAS: CHANGING PROSPECTS

What is monsoon?

Monsoon is a seasonable change of the prevailing directions of winds due to temperature difference between land and ocean. In summer, it carries a large quantity of water evaporated from the ocean to the land and results in heavy rainfalls. For South and Southeast Asian countries, summer monsoon plays an important role in ensuring water supply for agriculture productions, hydropower and many other aspects of social and economic development.

In Asia, the Himalaya mountain ranges and the Tibetan plateau form natural barriers for monsoon movement and lead to differences in the duration and geographical distribution of rainy seasons²⁵. For instance, in the Eastern Himalayas, it normally lasts eight months from March to October; while, in the Western Himalayas, it lasts only two months from July to August. But, with climate change, the monsoon period and intensity are set to change.

Monsoon, GDP & livelihoods

India's GDP is known to change with the monsoon. Economists and the financial media have used monsoon rain forecasts to predict economic trends. For instance, the poor monsoon in 2014 and 2015 in India led to a drop of 2% in the agricultural output growth rate due to less-than-normal rainfall¹²⁷; whereas the fairly normal monsoon in 2017 was seen as positive for the economy^{128,129}. This linkage between monsoon and India's economy can be explained by the fact that 15% of India's GDP comes from agriculture, which employs at least 44% of its >1.3 billion population⁴⁴. Some estimates put the percentage of farming-reliant population even higher at 55%¹³⁰.

Although the majority of croplands in the Indus and Ganges river basins are already irrigated (85% and 81% in 2010 respectively, as per CAS-IGSNRR estimation¹), India as a whole still relies on rain-fed for about half of its grain production^{7,131,132}. In addition, over a third of total agriculture output occurs during the summer season¹²⁷. Thus, summer monsoon rains are not only important for rain-fed agriculture production but will also affect water resources available for irrigation. Changes in summer monsoon due to climate change will therefore have significant impacts on India's food security, agricultural economy and the livelihoods of its vast rural population.

How will monsoon change in the future?

The IPCC Fifth Assessment Report (AR5) concluded that *"all models and all scenarios project an increase in both the mean and extreme precipitation in the Indian summer monsoon"*¹³³. Generally, the monsoon season is expected to start earlier and last longer, and monsoon rainfalls may become more erratic^{22,134}. However, there are still lots of uncertainties in current projections and how the future plays out also depends on our actions to combat climate change. For instance, one recent study projected a shortening of about 11 days for the Indian summer monsoon, if future temperature rise hits 4°C (RCP8.5)¹³⁵. However, other factors such as Western Pacific convection may play a counter effect and cut the projected increase in rainfall by as much as 50%¹³⁶. Land use change such as deforestation could also weaken the monsoon rainfall^{137,138}.

It is important to note that such change is not only happening in India. Monsoons beyond the HKH in East Asia and Southeast Asia will also be affected by climate change¹³³.

What's at stake and what are the challenges?

Whatever the projection results, it is clear that future monsoon will unlikely stay 'normal'. This will pose challenges for local governments and communities in managing their water resources. According to IPCC, changes in the Indian summer monsoon, as well as other factors such as the rising temperature, wheat yields in the Indo-Gangetic Plains are projected to fall significantly. Across India, monsoon sorghum grain yields are projected to fall 2%-14% by 2020 as the result of climate change, and further worsen by 2050 and 2080¹³³.

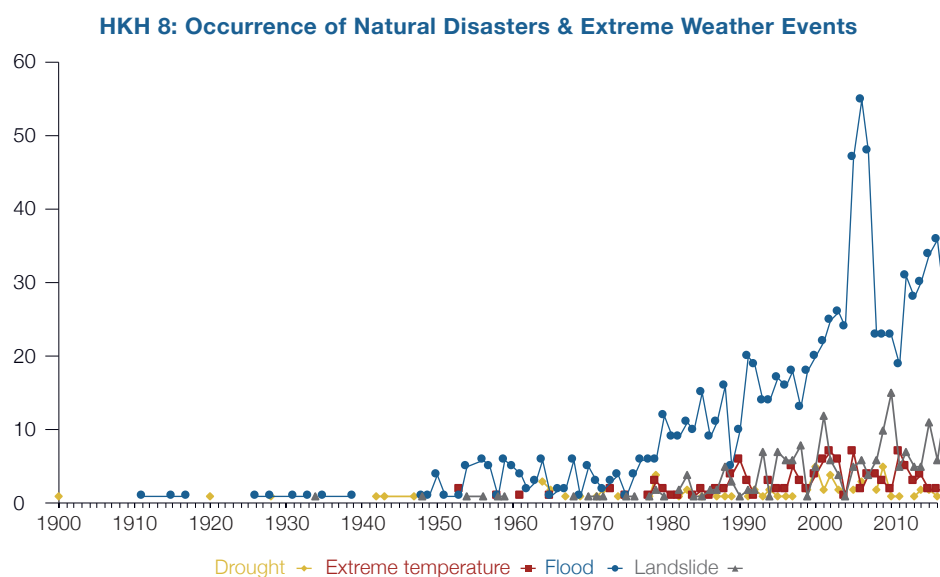
We are unlikely to 'manipulate' the complex climate system, but what we can do is to mitigate the effects of climate change by cutting greenhouse gases (both existing and new emissions), while building resilience in our infrastructure and economic systems. Given the urgency of the common threat, collective action from all stakeholders is required from all countries, especially those which share transboundary rivers. No country is exempted from these future risks.

Extreme weather events also cost lives and livelihoods in HKH 8

In addition, to the ‘less discussed’ impacts of climate change on river runoff highlighted so far in this chapter, the HKH 8 is bearing the brunt of the more “obvious” aspects of climate change in the form of extreme weather.

According to IPCC¹³⁹, we could assess and measure the impacts of climate change and extreme weather events in various aspects: from impacts on nature systems to industries and infrastructure, and to human health, well-being and security. A comprehensive analysis will require carefully selected indicators that represent all these aspects and up-to-date data to both qualitatively and quantitatively measure the impacts. There are a few tools and initiatives available that provide worldwide data and analyses, such as Germanwatch’s *Global Climate Risk Index*¹⁴⁰, the Emergency Events Database (EM-DAT)¹²², Munich RE’s *NatCatSERVICE*¹⁴¹. Here, we have used the first two tools to analyse the impacts of these events on the HKH 8; and in terms of indicators, we have focused on economic and livelihood dimensions.

The EM-DAT, founded with initial support from the World Health Organisation (WHO) and the Belgian Government, hosts “data on the occurrence and effects of over 22,000 mass disasters in the world from 1900 to the present day”. Despite the limitations in existing international disaster databases (including EM-DAT) in terms of accuracy and completeness of data¹⁴², we find it one of the best available sources for country-level event-specific data. Historical occurrence of floods, droughts, extreme temperatures and landslides across the HKH 8 since the beginning of the last century derived from this database is shown in the chart below:



Source: China Water Risk based on EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium (last update on 5 December 2017 & accessed on 12 December 2017)

For sure, earlier recordings may not be as comprehensive as those in recent decades. However, in recent decades, we can see a clear trend of increasing occurrence across all four types of events. In particular, the increasing occurrence of floods is the most obvious.

These events have clear impact on lives but the number of events may not necessarily correlate with their impact on population. As can be seen from the chart below, although droughts are rarer than floods, the total population affected by droughts could be more than that affected by floods. Also landslides, which has a higher occurrence rate than droughts, have a smaller aggregated impact on people. Nevertheless, the trends below point to more people affected by extreme weather events in the last two to three decades.

The HKH 8 also feels the “obvious” impact of climate change – extreme weather...

... 2 tools used to analyse the impact on lives & the economy

EM-DAT shows obvious increase in flood occurrence...

... Landslides, droughts & extreme temperature events are also trending up

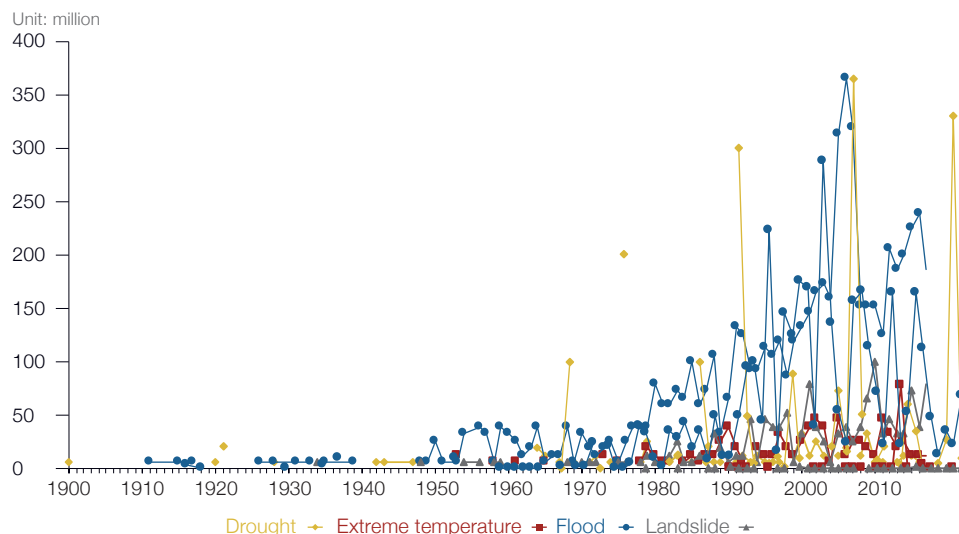
Increasing occurrence of events = more people affected

At peak impact...

...>364mn people affected by 4 drought events in 2002

...close to 288mn people affected by 13 recorded floods in 1998

HKH 8: Total Affected Population By Natural Disasters & Extreme Weather

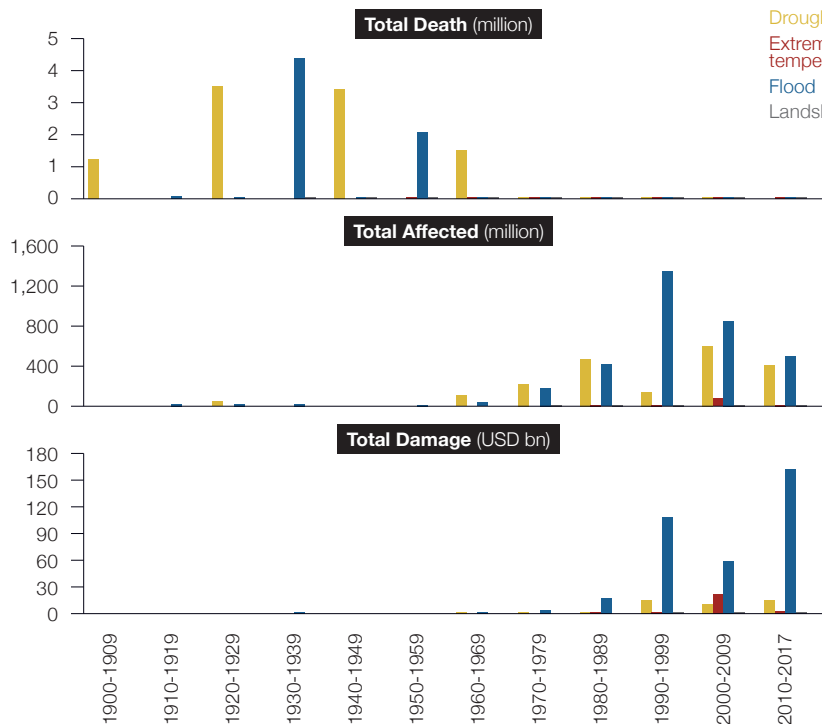


Source: China Water Risk based on EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED. D. Guha-Sapir - www.emdat.be, Brussels, Belgium (last update on 5 December 2017 & accessed on 12 December 2017)

10-year sums are used to smooth out the gaps in annual data availability

These events have also led to deaths and economic damage. Although the number of deaths has significantly declined in recent decades, the accumulated number of people affected (some of whom may have experienced more than one flood) and the total economic damage have increased greatly. We have used 10-year sums (8-year for 2010-2017) to smooth out the gaps in annual data availability so as to see these historical trends in the charts below:

HKH 8: Natural Disasters & Extreme Weather Events



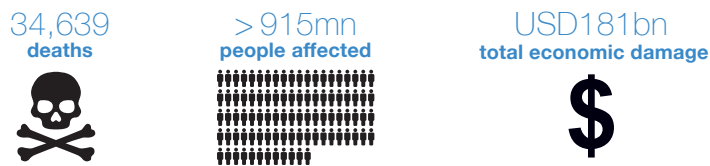
Total deaths of people include both “the number of people who lost their life because the event happened”, and “the number of people whose whereabouts since the disaster are unknown, and presumed dead based on official figures”

Total number of people affected by these events is defined as “the number of people insured, affected, and those who become homeless and therefore need shelter after the event”;

Total economic damage due to these events (in USD current value) is defined as “the value of all damages and economic losses directly or indirectly related to the disaster”.

Source: China Water Risk based on EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED. D. Guha-Sapir - www.emdat.be, Brussels, Belgium (last update on 5 December 2017 & accessed on 12 December 2017)

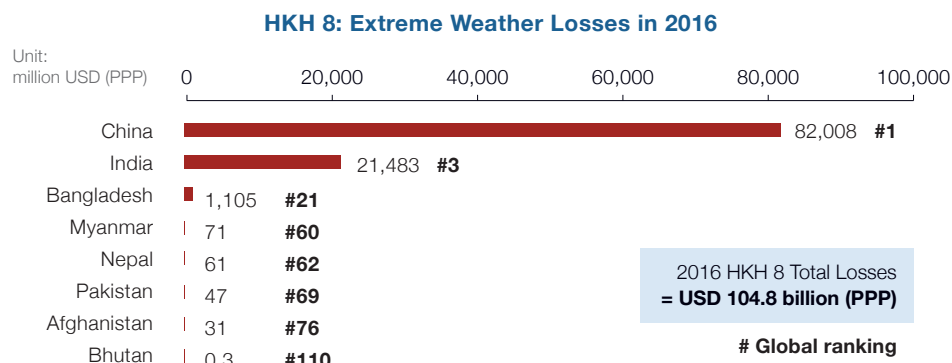
2010-2017 Impact of Extreme Weather Events



Source: China Water Risk based on EM-DAT

To further analyse economic impact from a country perspective, we look to Germanwatch's *Global Climate Risk Index 2018*, based on worldwide data collection and analysis provided by Munich RE's NatCatSERVICE. This provides country-specific data on total losses directly as a result of extreme weather events, expressed as USD million in terms of purchasing power parity (PPP)¹⁴⁰ and incorporates weather-related events including storms, floods, temperature extremes and mass movements such as heat and cold waves and so on.

In 2016, total losses due to extreme weather events in HKH 8 amounted to USD105 billion (in PPP). Globally, China and India were ranked No.1 and No.3 in terms of absolute amount of losses in 2016; USD82 billion and nearly USD22 billion respectively. The US ranked No.2 with USD47.4 billion (in PPP) in losses. The chart below shows that China and India together, accounted for almost 99% of the total extreme weather losses in HKH 8:



Source: China Water Risk based on Germanwatch's *Global Climate Risk Index 2018*

The losses in the chart above cost Bhutan and Pakistan 0.005% of their respective GDPs; China (0.39%) and India (0.25%)¹⁴⁰. These percentages vary year-on-year; the average over the period of 1997-2016 can be as high as 0.69% for Myanmar¹⁴⁰. Although these extreme losses account for a small share of GDP, impact in absolute terms (monetary and social) is significant and warrants action.

Unfortunately, these events are forecasted to rise. ADB's 2017 report¹⁴³ estimated annual losses from floods to reach USD52 billion globally by 2050. According to the report, 13 of the top 20 cities with the largest increases of annual losses between 2005 and 2050 are in Asia. Nine of these cities are located in the HKH 8 and two in the Downstream 8: Guangzhou, Shenzhen, Tianjin, Zhanjiang and Xiamen in China; Mumbai, Kolkata, Chennai-Madras and Surat in India; Ho Chi Minh City in Vietnam; and Bangkok in Thailand. Evidently, the HKH 8 has huge challenges ahead. No doubt, the destruction caused by widespread and lasting floods will affect millions of people's lives and businesses: numerous houses and infrastructure damaged; transport disrupted; not to mention the risk of spread of waterborne diseases.

Efforts in climate mitigation and adaptation should be prioritised. It is also vital to build capacity and infrastructure. Recognising this uptick, China announced in March 2018 that it is setting up a new Ministry of Emergency Management to centralise the administration of all types of natural and man-made disasters. Previously, floods, droughts, fire, earthquakes and other disasters were managed by various environmental ministries. This should facilitate faster response times in dealing with these events.

Trend points to fewer deaths, but more people affected & larger economic costs...

According to MunichRE...

...2016 extreme weather losses in HKH 8 = USD105bn

Globally, China (#1) & India (#3) suffered largest losses in 2016; #2 was the United States

The magnitude of losses warrants action...

... 13 of top 20 cities with the largest increases of annual losses (2005-2050) are in Asia; 11 of these are in HKH 16

China will form a new Ministry of Emergency Management to better respond to disasters

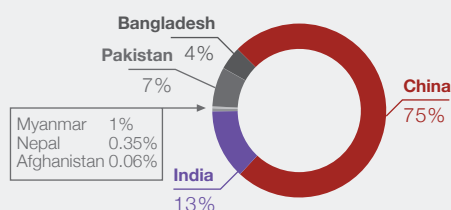
FLOODS & DROUGHTS

Floods, more costly than droughts, impact lives and livelihoods

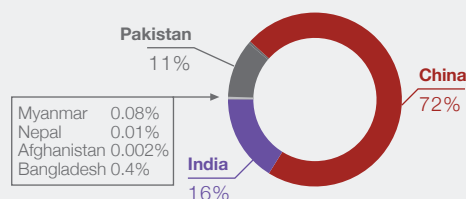
Floods and droughts were equally harmful in terms of affecting people's lives, but floods were the mostly costly, resulting in 90% of total economic costs in the most recent period of 2010-2017¹²². In fact, floods are responsible for 84% of total economic damage for the entire period from 1900 to 2017¹²².

China and India are the most affected by floods given the sheer size of population living along the rivers. During 2010 and 2017, the two accounted for 88% of people affected in the HKH 8 as well as 88% of total economic damage in the region¹²² (see chart below).

HKH 8: Accumulated Number of People Affected By Flood = 498.7 million During 2010-2017



HKH 8: Total Economic Damage By Flood = USD154 billion During 2010-2017



Source: China Water Risk based on EM-DAT - www.emdat.be (last update on 5 December 2017 & accessed on 12 December 2017)

Floods during 1990-1999 accumulatively affected the most number of people across the HKH 8, including over 1 billion in China, 279 million in India and 78 million in the rest of HKH 8¹²². However, floods in recent years (2010-2017) have been the costliest, costing USD118 billion for China, USD26 billion for India and USD19 billion for the rest of HKH 8¹²² (see chart below).

HKH 8: Impacts of Droughts (1900-2017)



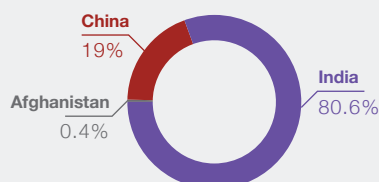
Source: China Water Risk based on EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium (last update on 5 December 2017 & accessed on 12 December 2017)

Most recently, the monsoon rains that started from August 2017 caused devastating floods across three HKH 8 Countries including Bangladesh, India and Nepal. By 1st September 2017, in total 40 million people were affected and more than 1,200 people died¹⁴⁴.

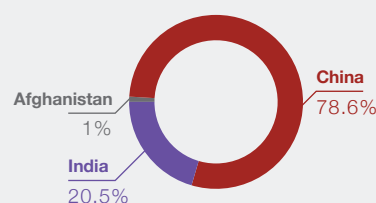
Droughts, though less frequent than floods, have material impact

During 2010 and 2017, droughts affected accumulatively 41 million people in the HKH 8. The related total economic damage amounted to USD14.6 billion¹²². Although India has the most number of people affected (accounting for 80.6% of the HKH 8 total), China experienced the most economic losses (accounting for 78.6% of the HKH 8 total)¹²² (see chart below).

HKH 8: Accumulated Number of People Affected By Drought = 41 million During 2010-2017



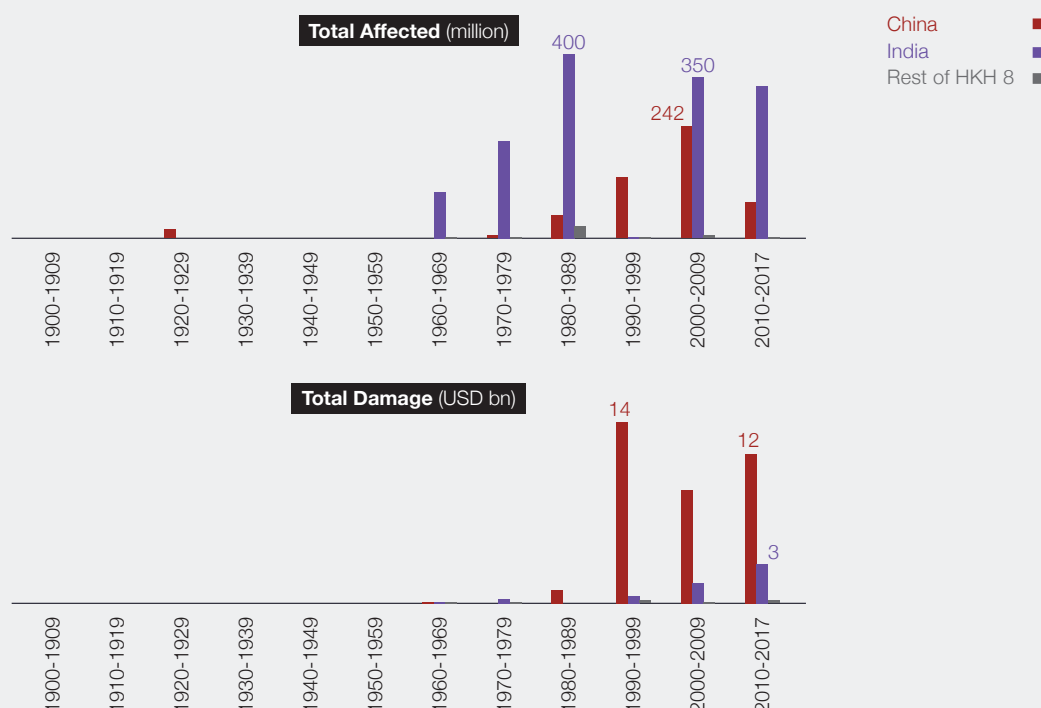
HKH 8: Total Economic Damage By Drought = USD14.6 billion During 2010-2017



Source: China Water Risk based on EM-DAT - www.emdat.be (last update on 5 December 2017 & accessed on 12 December 2017)

Moreover, as shown in the chart below, the periods with most people affected by droughts were 1980-1989 and 2000-2009. In particular, during 2000-2009, the number reached 242 million for China and 350 million for India¹²². In terms of economic damage, 1990-1999 and 2010-2017 saw the most impacts. In particular, during 1990-1999, China lost USD14 billion due to droughts¹²².

HKH 8: Impacts of Droughts (1900-2017)



Source: China Water Risk based on EM-DAT; The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium (last update on 5 December 2017 & accessed on 12 December 2017)

Separately, it is interesting to note that investors surveyed in our report "Toward Water Risk Valuation" (2016) was more concerned about droughts and floods as they felt that floods "are relatively easier to mitigate than water scarcity with good management and adequate insurance". The same survey showed that "over half the Investors are either "Very" or "Extremely Concerned" about risks related to water availability. No one is "Not Concerned" about competition for water resources, scarcity exposure or groundwater depletion. Only 1 % say they are "Not Concerned" about droughts". Over 70 investment professionals/asset owners from 50+ financial institutions/funds were surveyed to provide feedback on various valuation methodologies applied to 10 energy listco's.

Source: China Water Risk based on EM-DAT; CWR 2016 report "Toward Water Risk Valuation – Investor Feedback on Various Methodologies Applied to 10 Energy Listco's"

Quantifying risks at basin level still lags despite big impacts

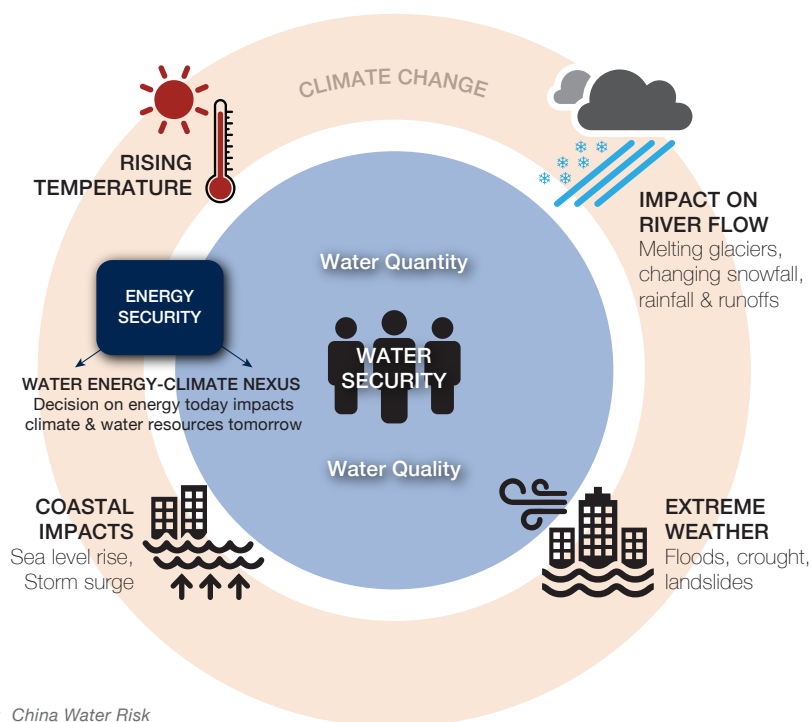
Just dealing with climate events is “business as usual”... we need to move beyond ‘band aid’ responses

It is important to note at this point that just dealing with extreme weather events is a “business as usual” approach. While adaptation and building resilience to these extreme events is necessary, it is but a ‘band aid’. We must move to tackle the symptom. Mitigating climate change to ensure water security not only includes finding the right energy mix for water and the climate, but also excessive power use.

Adaption and mitigation thus forms the base to ensure Asia’s water availability is not negatively impacted by climate change. This must be done concurrently with a water-nomics approach toward future development. We must adapt but we also need a collaborative roadmap for development away from a (over)consumption-led export growth model towards a more holistic water-nomic growth model: one that uses less power, less water and emits less pollution that is good for both water and the climate.

Cohesive basinwide strategy is needed for each river

Since much of the HKH 8’s population live along the 10 HKH Rivers (as shown in Chapter 2), such efforts should be driven by a cohesive basin-wide strategy. Not only do we need to figure out the ecological carrying capacity of the river basin, but we also need to quantify the socio-economic risk associated with (1) the impact of climate change on river runoffs and (2) the impact of extreme weather events. We need to do this for each of the 10 HKH Rivers.



Source: China Water Risk

A good first step is assessing socioeconomic risks at a basin level...

A good first step is to assess the climate impact on socio-economic risks at a basin level. Unfortunately, the current siloed structure of “business as usual” does not allow us to easily quantify such basin-level risks, be it GDP exposure as explored in Chapter 2 or impact of extreme events.

But lack of basin-level socio-economic data makes this difficult

During our data collection, we noticed that it is relatively easier to find information related to human security and economic losses of a city or a country, but much harder to get the picture of an entire river basin. This is understandable as such information is often registered at administrative level such as townships, cities and states/provinces. But, climate and water systems are simply not organised according to human administrative divisions. As a result, there is little information on socio-economic losses for specific sections of a river basin, let alone the entire basin. Moreover, such information is often segregated, making it harder to compare across basins.

These issues make it almost impossible to properly assess and quantify the climate impacts on each of the 10 HKH River Basins. Regardless, some studies have shown that economic losses and impact on human lives could be significant:

- Rasul (2014) reported that in the Ganges-Brahmaputra-Meghna (GBM) Basin, about 26 million people were affected by droughts annually with an average economic loss of USD61.9 million; meanwhile, floods and storms affected over 31 million people every year with an average economic loss of USD1.5 billion⁶⁰;
- In 2016, the Yangtze River, mainly the Middle and Lower Reaches, experienced the most serious summer floods since 1998, resulting in total affected people of 56 million and direct economic loss of over RMB166 billion (~USD24 billion)¹⁴⁵; and
- For Yellow River, runoffs from its upper reaches in 2016 were 30% less than an average year, the driest in recent 14 years¹⁴⁶. More on this in the previous two-page spread “China Heating Up & Building Resilience”.

Yet losses are high:

57mn people & USD1.6bn of losses suffered yearly from droughts & floods in GBM Basin

2016 floods affected 56mn in Yangtze; USD24bn losses

Exacerbating the difficulty in getting a comprehensive view of the water risks faced by each river basin and a picture of the real exposure of the population and economy to these risks, is that eight of the 10 HKH Rivers are transboundary rivers. Sound basin-level data collection requires good information sharing and coordination across multiple government departments and different regions. Measurements and regional boundaries also need to be standardised so that results across rivers are comparable.

Transboundary cooperation in the HKH River Basins is limited, but positive changes are under way in China (the Yangtze and Yellow) and along the Mekong. For instance, as discussed in “**A New Era of Regional Cooperation along the Mekong**”, the Mekong River Commission started with basin-wide assessment for the Lower Mekong¹⁴⁷. The Lancang-Mekong Cooperation (LMC), involving all the six Mekong countries, included “*joint research and analysis related to Lancang-Mekong water resources and influences of climate change*” in its Five-Year Plan of Action (2018-2020)¹⁴⁸. Within China, the Ministry of Water Resources is also working with local governments on water resources allocation plans for 53 trans-provincial rivers, which will holistically manage water needs across the river basins, decide on crossborder water discharge and ensure basic ecological flows¹⁴⁹. All of these set good examples for other HKH Rivers.

Transboundary issues again lend complexity ...but positive Mekong progress set good example

More research = even more money...

There is much work to be done. The limited glacier inventory, the lack of basin-level data and the magnitude of economic losses all point to the need for more funding support towards monitoring and research.

...but we are far from raising base funding targets

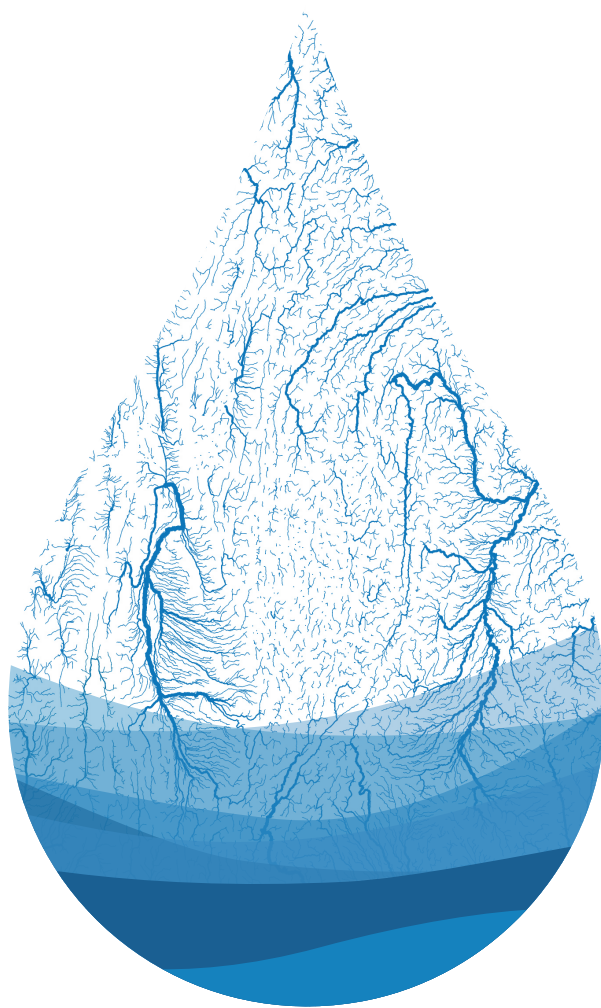
Given what's at stake, meeting the current climate finance ask to execute mitigation and adaption strategies should be the least we can do, yet we are disappointingly far from the funding targets set out by individual countries (see two-page spread on “**Status of Climate Finance**” in the next Chapter). In Asia, governments and businesses are still struggling to fulfil these goals, let alone start planning the future of our economies through a water-nomic lens.

Ultimately, Asia will also have to rethink finance, not just in innovating to meet gaps in climate finance, as well as reforming the way credit policy is currently being set. Physical water risks and associated regulatory risks (from policies designed to ensure water security) means impact on valuations more tangible & immediate. In short there is clear credit risk. The accentuation of water and climate risks at basin-levels compared to national levels as discussed in Chapter 2 mean that credit policy will likely have to also look beyond country and sectoral risks assessments toward basin-level risk assessment and quantification. More on this in **Chapter 4: “What's At Stake: Gaps & Opportunities”**.



WHAT'S AT STAKE

GAPS & OPPORTUNITIES



WHAT'S AT STAKE : GAPS & OPPORTUNITIES

- Climate action is clearly about water, our most vulnerable but vital resource. Our current arrangements of people, resources and economies shaped by previous physical conditions will likely change; we have to be ready for this paradigm shift, we have to adapt. Yet despite the gravity, there is still no figure available globally or for the HKH 16 on how much money we need to spend to ensure our future water security in a changing climate.
- There are however, broader estimates on climate finance for mitigation and adaption. The OECD expects total global climate finance to reach US\$6.9trn annually of which annual adaptation spend is USD140-300bn by 2030. For Asia & the Pacific region, ADB estimates the annual cost of adaptation to be at least USD40bn. However, the spend could be higher as current development plans may not have factored in climate change.
- Although there are neither adaptation estimates nor comprehensive data for all the HKH 8, India, Afghanistan & China have indicated amounts of climate finance that total USD6.7trn by 2030. The financing gap is daunting: approved climate finance for the HKH 8 only reached USD2bn from 2003 to 2017. With 25% of this going toward adaptation, the HKH 8 is evidently far from funding mitigation, let alone building resilience.
- Beyond losses from extreme weather events, what's at stake dwarfs this gap: the collective GDP of the HKH 16 of USD13.2trn in 2016 could be affected by systemic risks in the 10 HKH River Basins where a third of its GDP is generated and over half the population resides. Since the four priority basins carry a lion's share of this (GDP of USD3.8trn & 1.5bn people), India and China must take the lead in rethinking development and innovating financing strategies that direct capital towards building resilience and business unusual.
- Currently, global and regional development institutions play a dominant role in multilateral climate finance to HKH 8. However, public finance won't be sufficient. Here, China's efforts with green bonds issuance and public-private partnerships (PPP) to tap private finance are a start. Its regional focused initiatives such as the Belt & Road Initiative and the AIIB, can also help close the finance gap.
- Investing in resilient infrastructure and taking action in adaptation and mitigation are not just costs; they can create business opportunities and jobs. E.g. Chinese jobs in renewable energy development have already overtaken that of coal mining. Looking forward, the IFC estimates the 2016-2030 climate-smart investment potential of the HKH 8 to be USD18trn; China & India dominate at USD14.9trn and USD3.1trn respectively.

Water & climate risks, recognised as top global risks by world leaders and business elites, are here to stay, yet despite the gravity, actions and finance to build resilience severely lag ...

- Closing the finance gap is the minimum; the HKH 16 must create a new paradigm. Multiple actions will have to be taken, some of which are fundamental: a change in mind-set, governance, the way we do business and how we spend. We have identified 8 broad action areas. At the core is de-emphasizing economic growth and prioritising the environment. We need to rethink economic and development models through a water-nomic lens.
- Another priority must be to ensure water for the 1.77bn people who live in the 10 river basins so that they can continue to thrive for centuries to come. This responsibility does not just lie with the government of the HKH 8 or Downstream 8; businesses including financial institutions need to act. These actions need to be applied across multiple sectors; also, they need to be concurrent, cohesive and urgent.
- As the largest employer, water user and generally the largest polluter, agriculture practices need to be rehailed. Controlling agricultural water use & pollution through optimising irrigation, crop mix, yields and trade while ensuring water, food & job security are monumental challenges, let alone factoring in climate change. Moreover, of 119 countries in the 2017 Global Hunger Index: India ranked #100, Pakistan #106 & Afghanistan #107.
- In many developed countries, power tops agriculture as the largest user of water. With limited water resources, the water-energy-climate nexus is tight for the HKH 16. Since they have a long way to go in terms of power per capita, smart energy choices must be made today, to protect their common waters tomorrow. With abundant hydropower resources, dams are likely here to stay & stronger hydro/transboundary governance will be required.
- India & China as upper riparians can lead both transboundary & regional economic cooperation. They can also improve basin-level monitoring & data collection, as well as prioritise multi-stakeholder & multi-disciplinary research efforts to improve understanding of hydrological cycles in a changing climate; all key stumbling blocks to assessing & quantifying risk by basin. China's YREB & Greater Bay Area pilots are examples of basin action.
- As competition for water & extreme weather events become more frequent & intensive, the financial industry will have to adapt. Environmental regulations & climate change will impact investment portfolios & loan books. Rising systemic exposure at the basin-level means that banks will have to rethink credit policy to factor in environmental risks from a basin perspective. Recognizing this, China aims to embed such risks into credit policy.

Closing the funding gap is a minimum – we must create a new paradigm of ‘business usual’ in Asia if we are to ensure the continent’s water security, it is the only resource we cannot survive without...

... Asian leaders, businesses, financiers, entrepreneurs & scientists have the opportunity to pave the way.

What's at stake dwarfs the financing gap

Need to 'slow down' climate change by cutting GHG emissions ...

& adapt to fit future water & climate scenarios

Climate change has a clear impact on water resources. As shown in previous chapters, future temperature, snow fall, rainfall and run-offs across the HKH river basins are all set to change. This means that our current arrangements of people, resources and economies that were shaped by previous physical conditions will likely have to change; we have to be ready for this paradigm shift. We will therefore not only have to slow down climate change by cutting greenhouse gas emissions, but also adapt and rethink our reliance on water, how we re-design our living spaces and our economy. We need all to tailor these to fit future climate and water scenarios.

Water & climate risks are prioritised globally

Four out of the Top 5 global risks in terms of impact are climate and water related as per The World Economic Forum's 2018 Global Risks Report. They are 'extreme weather events', 'natural disasters', 'failure of climate-change mitigation and adaptation' and 'water crises'¹⁵⁰. The No.1 risk is 'weapons of mass destruction', but even armed conflicts in the future, could very likely be fuelled by climate extremes and water crises. We know this, but the urgency to resolve these issues still lacks.

'Business as usual' is no longer an option

Climate change aside, the underlying water stress for various countries and basins will mean that 'business as usual' will no longer be an option. This especially holds true for India and China²⁸, the two most populous economies in Asia. Significant human and economic losses are at stake. The strong linkage between climate, water and economic development, means that acting to build resilience to climate change is essentially about ensuring future water resources as well as socio-economic security. What is happening to the remote mountain villages today could be well be happening to cities lying further downstream tomorrow.

Adaptation costs for APAC region = USD40bn p.a.

+ spend on water & sanitation can be USD802bn by 2030

For Asia & the Pacific region, the ADB estimates the annual cost of adaptation to be at least USD40 billion¹⁵¹. However, these costs could be bigger: for example, given the linkages between water and climate, future investment needs for access to clean water and improved sanitation could be affected by climate change. Taking into account climate change factors, spend on water and sanitation would rise to USD802 billion for the region by 2030¹⁵²; this is USD15 billion more than baseline estimation without considering sector-specific mitigation and climate proofing investments.

+ extreme weather cost in HKH 8 = USD105bn in 2015

While all these appear to be significant spend compared to the economic losses caused by extreme weather events (almost USD105 billion across the HKH 8 in 2016¹⁴⁰), what's at stake is much greater. The collective economy of the HKH 16 reached up to USD13.2 trillion in 2016; around a third of this GDP was generated in the 10 HKH River Basins. More urgently, over 1.77 billion people also live in these 10 basins¹.

But 4 most at-risk basins carry a collective GDP of USD3,8trn & home to 1.5bn people...

Already, as per in Chapter 2, the exposure in the four most at-risk river basins identified: the Ganges, Indus, Yellow and Yangtze is worrying. What's worse is that this does not even take into account climate change impact on the river flow or extreme weather events. Together the four basins have a collective GDP of USD3.8 trillion¹. They are also home to almost 1.5 billion people¹. Water from these river basins also support domestic agriculture, energy and industrial production and also livelihoods. From this perspective, USD40 billion annual spending on adaptation for Asia and the Pacific region estimated by the ADB appears to be a good and cheap hedge; a worthwhile spend. Yet we are not prioritising the raising of these funds.

... global inaction also impact Asia's water; Asia's voice needs to be louder

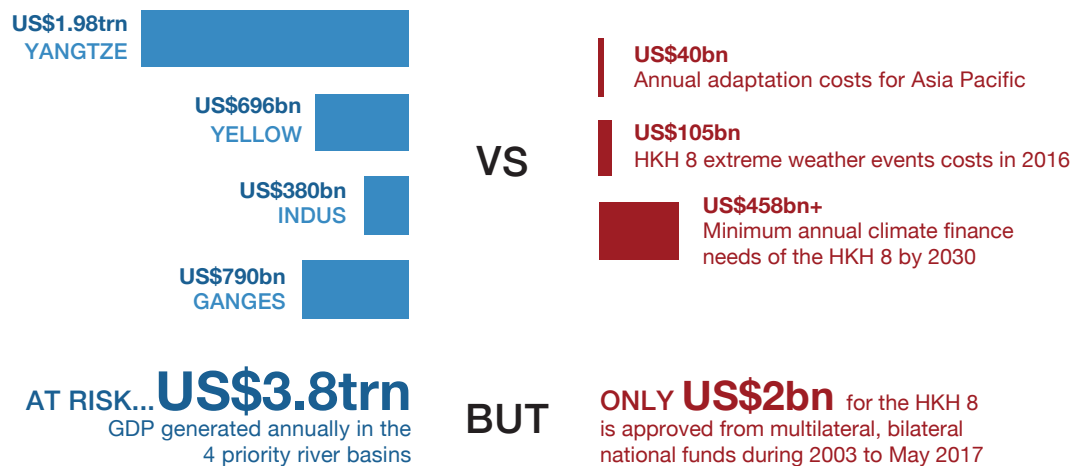
In short, what's at stake simply dwarfs the financing gap. This is not just Asia's problem. The policies that other countries pursue regarding climate change will also impact Asia's water resources. Asia's collective voice should thus be much stronger and louder.

Given impending disruptions, it is worth financing adaptation & mitigation

The rest of the world also needs to pay attention. Many of the HKH countries are important exporters of raw commodities and manufactured goods to the rest of the world. Interruptions in production and economic losses due to policy changes and extreme weather could cause worldwide business disruptions. Regulatory policies to protect the environment may favour some industries but not others. This will not only disrupt industry but bank loan portfolios and insurance cover for operational disruptions. With so much at stake, surely it is worth, at a minimum, investing in building resilience in the HKH countries and rethinking development across Asia.

For an idea of where the HKH 8 is on climate finance, please refer to the following two-page spread "The Status of Climate Finance".

Resilience: It's worth investing! What's at Stake vs. Annual Costs



Source: China Water Risk based on 1) basin-level GDP calculated by CAS; and 2) costs and finance needs from ADB (2012), Climate Funds Update (2017), Global Climate Risk Index (2018) & HKH 8 country NDCs

Global Adaptation Finance Gap: Approved vs. Needs



Source: China Water Risk based on UNEP, 2016

CLIMATE MITIGATION & ADAPTATION: MORE MONEY PLEASE!

Climate action is about water, the most vulnerable but vital resource, yet actions and financing of such actions to ensure water security lag. Despite the gravity illustrated in the previous chapters, there is still no figure available globally or for any country on how much money we need to spend to ensure our future water security in a changing climate. Here are some broad estimates:

Globally: According to OECD estimates, up to USD6.9 trillion in infrastructure investment is needed annually by 2030 to build a low carbon future and keep our planet under the 2°C limit with a greater chance than 66%³. For adaptation alone, UNEP estimates global annual spend to be USD56-73 billion today. This is over 2x of current finance flows. Evidently financing already lags today, let alone the daunting 2030 spend estimated at USD140-300 billion annually¹⁵³.

Asia & the Pacific region: the ADB estimates the annual cost of adaptation to be at least USD40 billion¹⁵¹

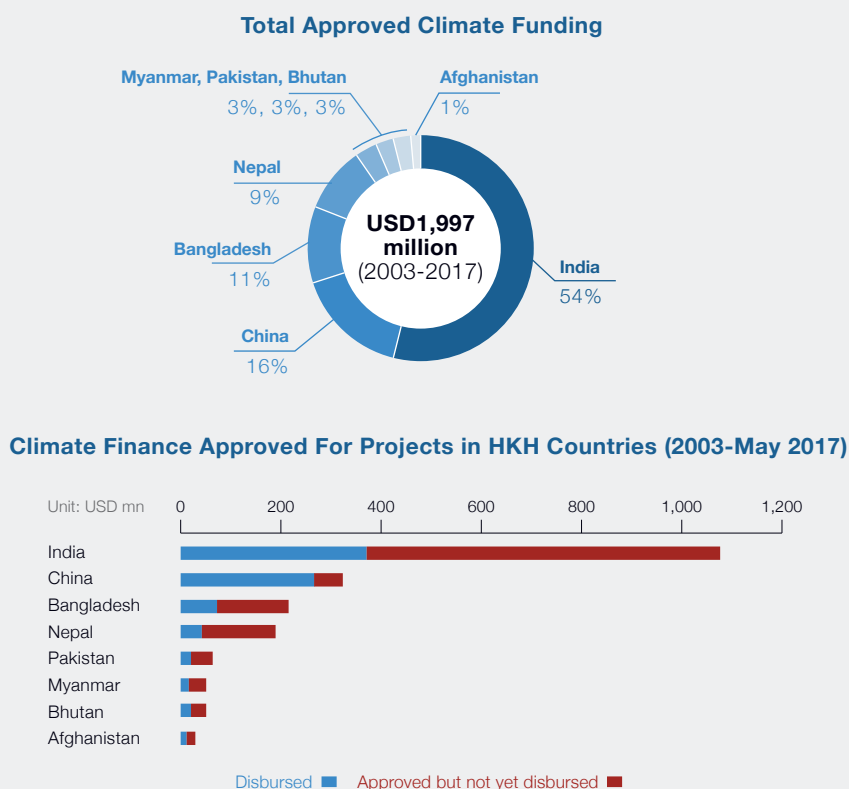
The HKH 8: There is still no comprehensive estimate of climate finance needs. However, five of the HKH 8 provided annual estimates in their Nationally Determined Contributions (NDCs) submitted to the UNFCCC. They are Afghanistan (USD1.7 billion), Bangladesh (USD4.5 billion), India (USD69.3 billion), Nepal (USD0.27-0.36 billion) and Pakistan (USD6.7-9.7 billion). The annual average financial needs of these NDCs amount to USD82.5-85.6 billion. India has set its total climate finance needs during 2015-2030 at a minimum of USD1,040 billion, of which USD206 billion is for adaptation and USD834 billion for mitigation⁶³. Afghanistan, on the other hand, requires at least USD17.4 billion by 2030 for both adaptation and mitigation¹⁵⁴. As for China, although the government didn't provide an official overall figure, the Beijing based, International Institute of Green Finance of Central University of Finance and Economics estimated in their 2016 report that China's annual climate finance needs could reach RMB2,560 billion (~USD376 billion) by 2020¹⁵⁵. This means, India and China together could well need around USD6.7 trillion in total by 2030.

THE STATUS OF CLIMATE FINANCE

The HKH 8 still lags

Globally, from 2003 to May 2017, the total approved climate finance from multilateral, bilateral and national funds only amounted to USD15.3 billion¹⁵⁶. Asian countries (excluding small island developing states) were offered nearly USD4.2 billion, half of which or nearly USD2 billion were directed to the HKH 8. Moreover, 58% of the climate finance towards the HKH 8, or USD1,160 million, were in the form of grant; the rest being concessional loans. In addition, nearly USD172 million funding were provided at the regional level in Asia, which may also benefit the HKH 8¹⁵⁷.

India has received the most approved climate finance, accounting for 54% of the HKH 8 total (see *charts below*). However, only 35% of the approved finance towards India had been disbursed by May 2017, similar to the global average of 34%. In fact, except for China with a high disburse rate of 84%, the other HKH 8 all have relatively low disburse rates, ranging from 23% in Nepal to 50% in Afghanistan. As a result, only USD834 million had been disturbed to the HKH 8 by May 2017. Clearly, this is far from the indicated future needs for India, Afghanistan and China of USD6.7 trillion by 2030, let alone for the rest of the HKH 8.

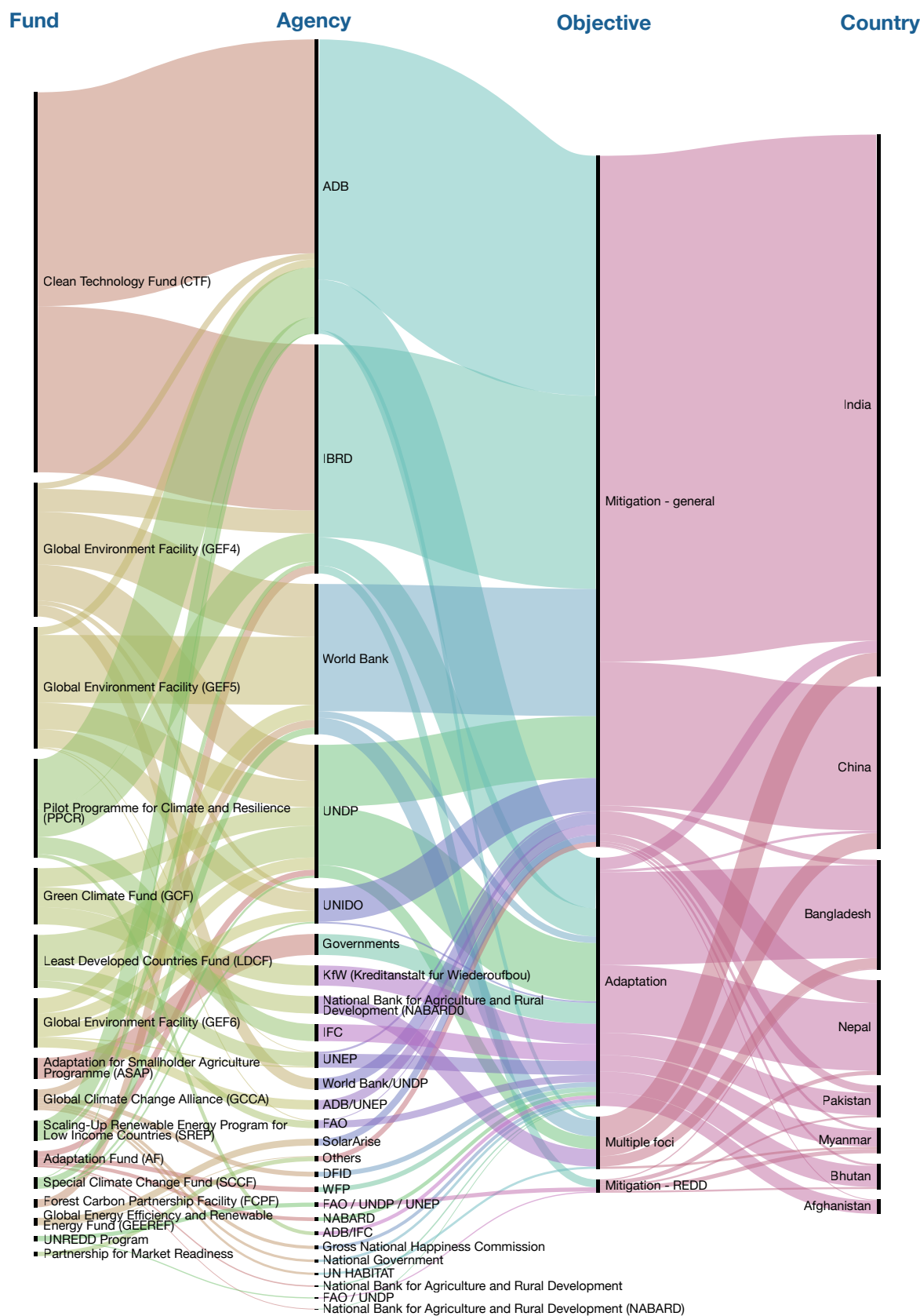


Source: China Water Risk based on Climate Funds Update (latest updates in May 2017), <http://www.climatefundsupdate.org/data>

Global and regional development institutions have played a dominant role in providing this multilateral climate finance towards the HKH 8: at least 29% from the ADB, and about 40% from the World Bank and its affiliated International Bank for Reconstruction and Development (IBRD) and International Finance Corporation (IFC); only 2% came from national governments and banks¹⁵⁶. That said, this is not comprehensive as some national funding towards water and climate-related projects may not be recorded/captured in such database due to no specific mentioning of 'climate finance' (see 'HKH Climate Finance Flow').

HKH CLIMATE FINANCE FLOW

Total approved multinational climate finance to HKH 8 = USD1,997 million from 2003 to May 2017

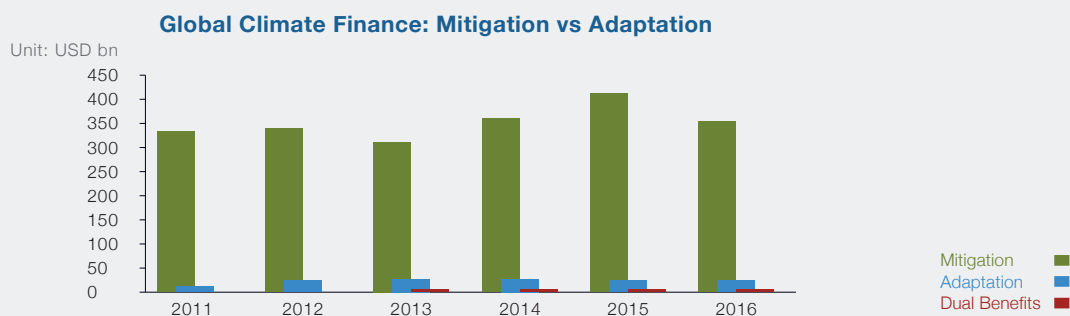


Source: China Water Risk based on Climate Funds Update (latest updates in May 2017), <http://www.climatefundsupdate.org/data>

FINANCING GAPS & OPPORTUNITIES

More money for mitigation than adaption

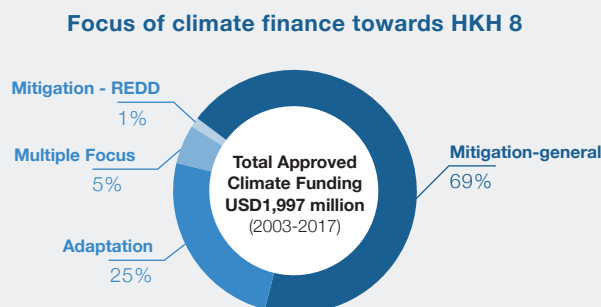
In terms of purpose of climate finance, so far mitigation attracted the majority of the current finance flow. According to Climate Policy Institute's 2017 data, 92% of the USD383 billion global climate finance in 2016 went into mitigation. Meanwhile adaptation only received USD23 billion or 6%, with the remaining 1% spent on support projects with dual benefits¹⁵⁸ as shown below:



Source: China Water Risk based on Climate Policy Initiative reports "Global Landscape of Climate Finance" 2012-2015, the updated view in 2016 & 2017
 *Note: for 2011 data, the lower range recorded in report is used.

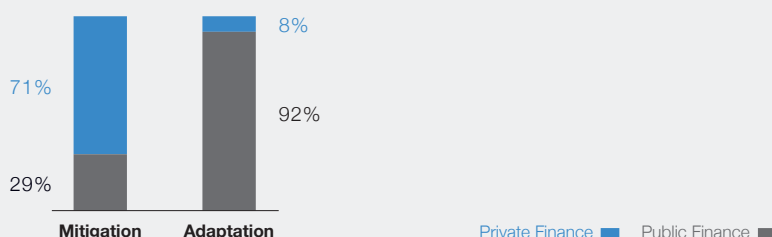
This is likely because mitigation is more straightforward and it is easier for governments and businesses to see the incentive of investing in mitigation projects such as renewables which captured nearly 68% of mitigation finance¹⁵⁸. However, given the significant gap in adaptation finance, there are urgent needs to mobilise finance towards adaptation.

If we look at approved climate finance towards the HKH 8, again financing favours mitigation with only 25% were for adaptation as shown in the chart below left. Of this adaption amount, the largest recipient was Bangladesh (37%) followed by Nepal (27%). It is important to note here that of the total approved amount towards the HKH 8, only about 4% were directly linked to water management and sanitation. In comparison, at least 54% were directed to energy-related projects¹⁵⁶. Again, water the most vulnerable resource is under-funded. Mitigation and adaptation are also financed differently. As shown in the chart below right, the private sector contributed 71% of the mitigation finance but only 8% of adaptation finance; where 92% came from public money¹⁵⁹. Note here that since private finance for adaptation wasn't tracked in relevant references for 2015/2016, we are thus using the latest available 2013/2014 figures.



Source: China Water Risk based on Climate Funds Update (latest updates in May 2017), <http://www.climatefundsupdate.org/data>

2013/2014 Climate Finance Sources: Mitigation vs. Adaptation



Source: China Water Risk based on Climate Policy Initiative "Global Landscape of Climate Finance 2015" & the updated view in 2016, UNEP "The Adaptation Finance Gap Report 2016"

Clearly public finance won't be enough for adaptation needs and countries will have to turn towards green financing innovations and private funding to build resilience.

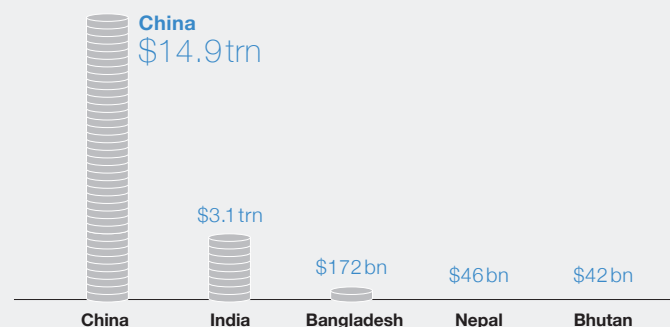
Green financing, private finance & other innovations

At the country level, China and India are ahead with their own national financial initiatives that are targeted at climate actions and green development. For instance, in China, green bond, green insurance (including disaster insurance) and carbon markets have been recognised as important instruments for climate finance¹⁶⁰. Since 2016, China has been a top issuer and the main driver for the global green bond market¹⁶¹, which reached USD156 billion in 2017¹⁶²; however, only 3% or USD4 billion targeted at adaptation¹⁶².

UNEP Inquiry into the Design of a Sustainable Financial System considered that China has “*firmly established itself as a global leader*”¹⁶³, based on a joint report with their Chinese partner that looked at the country’s progress in green finance development¹⁶⁴. In 2017, China issued a total of USD36 billion of green bonds, nearly two thirds of which were aligned with international standards¹⁶².

For the other HKH 8 countries, international climate finance remains crucial and significant investment opportunities exist. According to IFC estimates, China’s climate-smart investment potential between 2016 and 2030 can be up to USD14.9 trillion¹⁶⁵. Meanwhile, India, Bangladesh, Nepal and Bhutan’s market could be USD3.1 trillion, USD171.8 billion, USD46.1 billion and USD42.3 billion respectively¹⁶⁶. This means that together, the HKH 8’s climate investment potential is at least USD18 trillion by 2030.

Climate-smart Investment Potential (Between 2016 and 2030)



Source: China Water Risk based on IFC, 2017

In the past few years, new regional initiatives are also sprouting up, which include the China-led Belt and Road Initiative and the Asia Infrastructure Development Bank (AIIB):

- The new Belt and Road Initiative highlighted the need to “*promote green and low-carbon infrastructure construction and operation management*”. In addition to investment and trade, the new Initiative also covers areas such as climate change and ecological environmental conversation¹⁶⁷; and
- The AIIB noted in its energy strategy that the bank will focus on “*supporting and accelerating its members’ respective transitions toward a low-carbon energy mix*”¹⁶⁸.

Moreover, the ADB plans to double its annual climate finance in the entire region to USD6 billion by 2020. USD4 billion of this will go towards mitigation and USD2 billion to adaptation⁴. Although all these commitments are important sources of funding for climate action, we need to realise that public finance alone won’t be sufficient to meet all the climate finance needs of the HKH 8. The private sector needs to be on board as well. Public–private partnership (PPP) could be one solution. In China, the new initiative to build 28 pilot ‘climate resilient cities’ by 2020 uses the PPP model to mobilise private finance to meet investment needs¹⁶⁹.

No doubt that more can be done to attract private finance. After all, in the face of climate change and an uncertain water future, billions of dollars of business assets and investments are at risk.

Finally, it is important to note that investing in resilient infrastructure and taking action in adaptation and mitigation are not just a cost to the economy, it can create opportunities in economic growth and new jobs. Just look at the renewable energy development in China: the government plans to add 3 million jobs in the sector during the 13FYP period of 2016–2020 making the total number of jobs in the sector to reach at least 13 million by 2020⁶⁶. In comparison, the entire coal mining industry in China employed less than 4 million people in 2016¹⁷⁰.

Creating a new paradigm

**No water means no life,
no food, no power,
no growth for Asia**

Creating a new paradigm is not easy but given what's at stake, we must strive towards this. Multiple actions will have to be taken, some of which are fundamental: it will require a change in mind-set, the way we govern, the way we do business and how we spend. At the core of this is the realignment of the economy and the environment; more specifically water. No water means no life, no food, no power, no growth for Asia – it is as simple as that.

**We must act to protect
Asia's precious rivers**

We must protect Asia's precious water resources by not wasting it, or polluting it. Our priority must be to ensure water for the 1.77 billion people who live in the 10 river basins so that they can thrive for centuries to come. This responsibility does not just lie with the government of the HKH 8 or Downstream 8; businesses including financial institutions need to act; and these actions need to be concurrent, cohesive and urgent.

**Our priority must be to
ensure water for the
1.77bn people who live
in the 10 basins**

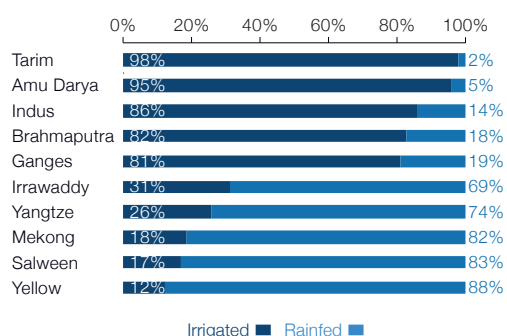
We have summarised these actions into eight broad strategies:

**De-emphasize economic
growth & prioritise the
environment; rethink
multiple policies**

- 1 **Protect Asia's rivers to ensure water resources for one in two and a half Asians:** by ensuring proper and efficient use of water from Asia's rivers and limiting as well as preventing water pollution. Infrastructure to protect against extreme weather events should also be built to avoid 'water refugees' and migration due to the lack of water. Improved water quantity and quality can help increase the ecological carrying capacity of the river as a step toward water security. These need to be carried out concurrently with improving access to clean water, health and sanitation in rural areas;
- 2 **Rethink our economic and development models through a water-nomic lens:** This includes a pantheon of action. For water stressed countries, overarching policy from government to prioritise the environment and de-emphasize economic growth is a start. Water use quotas could also be considered, as could the trading of water use and discharge rights. These could be set nationally, regionally or by sector to tighten water use and encourage tech upgrades of irrigation and industrial equipment, as well as to rein in pollution – please see “Beautiful China: re-balancing the economy & the environment” for examples. Meanwhile, as discussed in Chapter 2, optimising GDP, industry and crop mix as well as managing virtual water trade, could also help save water and reduce pollution: policies can be set to favouring more GDP and less polluting & water intensive industries in the future, while encouraging dirty thirsty industries to go circular;
- 3 **Control agricultural water use & pollution while ensuring food security:** To recap, agriculture is the largest user of water across the HKH 16. It is also generally the largest polluter due to excessive use of fertilisers, pesticides and insecticides. Strategies in agricultural water savings and fertiliser/chemical use must therefore play an integral part in resolving water management issues. However, increasing irrigated land area may offset water savings from improving irrigation efficiency. As shown in the chart below left, five HKH River Basins have significant shares of croplands that are rain-fed, whereas 81% of farmland in the Ganges and 98% of the Tarim are irrigated:

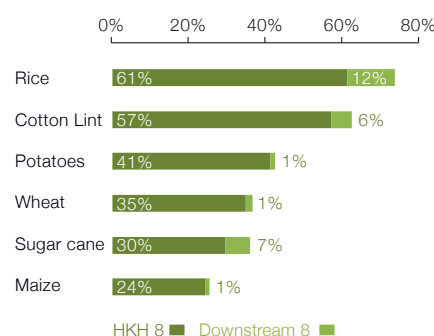
**Manage agri water use,
pollution & yields to push
more crop per drop...**

**Cropland in HKH River Basins:
Irrigated vs Rainfed**



Source: China Water Risk based on data provided by CAS, which are calculated based on 30 meter Global Land Cover Dataset GlobLand30. The data year is 2010.

**HKH 16: % of global crop
production in tonnage**



Source: China Water Risk based on FAOSTAT. Data in various years.

Yield Improvement and crop mix must thus be also considered to maximise output of crop per drop. Since the HKH 16 is a key agricultural region globally (rice (73%), cotton (63%), potatoes (42%), wheat (36%) and sugar cane (37%) - see chart above right), decisions that are good for the HKH 16 countries will likely cause disruptions in the global food trade. Naturally, these factors must be considered in the framework of national food security, where many of the HKH 8 still rank in the hundreds out of 119 countries, in the 2017 Global Hunger Index: India (#100), Pakistan (#106) and Afghanistan (#107)¹⁷¹. Finally, the agriculture is the largest employer across the HKH 16. Balancing employment rates, controlling agricultural water use and ensuring food security is a monumental challenge, let alone having to consider these alongside climate change and the water-energy-climate nexus;

...but good for HKH 16 may be bad for other countries = disruptions in global food trade

- 4 **Choose the right type of power in the water-energy-climate nexus:** Water is used to generate power, but power is also used to clean and supply water. Moreover, the type of power we choose today could accelerate climate change and water solutions like desalination may also be limited given the amount of power it currently requires. We have to make smart energy choices for both climate and water today. In many developed countries (such as the US and the UK) the power sector, not agriculture, is the largest user of water. Decisions made today at the water-energy-climate nexus are thus important in helping safeguard our water resources tomorrow. But as discussed in Chapter 2, the HKH 16 has a long way to go in terms of power per capita compared to the developed world. So with millions of people still lacking access to electricity and hydropower resources being abundant, dams on the HKH Rivers are likely here to stay – please see “**Hydro Drives Green Power in the HKH 8**”. Given this, it is imperative to get transboundary governance right on shared rivers;

Hydro is here to stay...

...so need to get transboundary governance right

- 5 **Resolve transboundary issues through better water-nomic cooperation:** There is no doubt that Asia can benefit from better cooperation in the damming of HKH Rivers to manage geopolitical, hydropower generation and climate risks (floods & droughts). Although transboundary agreements in the HKH 16 lag those in Europe, water agreements do exist between them – please refer to “**Status of Transboundary Agreements on HKH Rivers**”. These agreements form a base to build on. India and China as key upper riparian countries accounting for 62% of land area the HKH Region can play a central role. It won't be easy, but innovative mechanisms and cooperation platforms need to be sought to move things forward. Efforts led by China in the Lancang-Mekong with Downstream 8 countries are a good start. As discussed in Chapter 2, the fact that the LMC mechanism expands beyond transboundary water management to include regional economic and environmental cooperation also makes sense and helps countries achieve a more holistic approach to shared development;

India & China as upper riparians can play important roles...

... but must look beyond just water sharing to include regional economic cooperation

- 6 **Reorganise to focus on basin-level data, risk assessments and solutions:** The exposure is high: 1.77 billion people live in the 10 HKH River Basins that generate a GDP of USD4.3 trillion. As shown in Chapter 2, water stress is more acute at the basin level than at a national level, putting not only people but assets at risk. For example, water use to generate a dollar of GDP can be 0.3m³ for India nationally but 0.08m³ for both the Ganges and the Brahmaputra. Governments and corporates should therefore assess and quantify exposure to water and climate risks at a basin level. Unfortunately, as discussed at length in Chapter 3, data is currently collected and collated along county, provincial and state lines as opposed to the river basin. Given the existing high levels of water stress in some basins as well as impact of climate change on the current and future hydrological cycles, data, research and risk assessments should be reorganised and refocused. In turn, solutions, be they in terms of economic growth, food production or energy security must also be basin focused. In China, the emphasis by central government on the YREB and the Greater Bay Area are examples of basin focused pilots. These should help the regions make better decisions across the strategies identified above;

Water stress is more acute at the basin level; risks should thus be assessed & quantified by basin...

...but data lags; China has started regional pilots

Data gaps & multidisciplinary nature of research are key stumbling blocks ...

...more funding & collaboration needed

Closing funding gap is the minimum...

...ultimately the financial sector will have to waterproof loan books

China wants to embed environ risks into credit policy

China & India can lead in building resilience & seeking new development pathways

Asian business leaders & investors play key roles and supplement govt action

High stakes needs everyone on board to tackle common threat

7 **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; and

8 **Close the funding gap & drive financial reform:** Given people and assets at risk, striving to close the gap in mitigation and adaptation finance is the least that governments, corporates and financial institutions can do. As extreme weather becomes more frequent and intensive, current financial instruments such as disaster insurance and climate bond will also need to adapt to future scenarios. Water and climate risks should be taken into account before investing. The risks posed by regulations to manage water stress and climate change will also affect the loan books of banks, which will eventually have to rethink credit policy to include a comprehensive basin approach to environmental risk assessment. Again China has made a start in this space with a national policy target to embed environmental risk into credit lending. ICBC, one of China's largest banks, has already started to stress test its loan portfolio for impact from the nation's new environmental regulations – more on this in **"Banking in the Age of Water Risk"**. All these will demand more transparency and better environmental disclosure, and encourage application of new technologies from big data, blockchain to artificial intelligence.

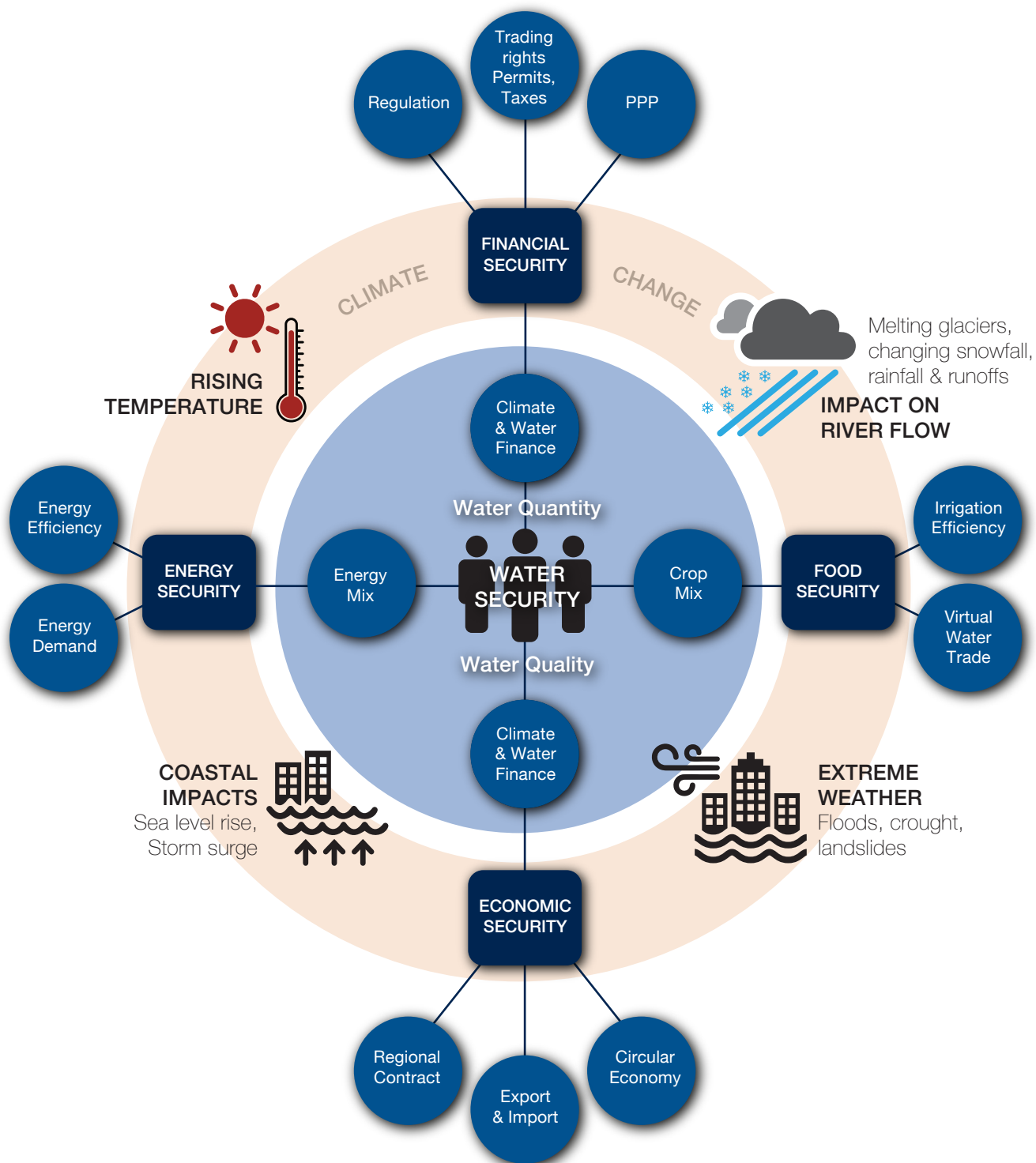
The era of water-nomics and "Business Unusual" is here. It is time to embrace these concepts to protect the people, cities and assets in these 10 river basins to ensure a water, food and energy secure Asia.

The eight broad strategies outlined above sets out a more holistic view of managing Asia's water-food-energy-climate nexus. Executing these strategies will likely change how we organise and plan our cities, economies and trade. Among the HKH 8, China and India must take the lead: both in building climate resilience and seeking new development pathways towards a clean and circular economy.

Asian business leaders and investors also have an important role to play across all these eight areas. Multiple assets and significant parts of supply chains lie along these 10 rivers and are at risk. Private investment to mitigate and adapt business risks and good water stewardship can help alleviate basin level risks and supplement government action. Business leaders and bank CEOs can steer Asia into a new way of doing old things.

The stakes are high, but so are opportunities. The new and circular economy could also bring about more jobs. Every individual, every business and every government in Asia, can make a difference in how we use and manage water and the economy. There are also many gaps, even within this report, but we hope that this has provided an overview of what's at stake across the continent so that we can get to a base understanding of our common threat and prioritise actions accordingly. There is much to do; we are all responsible for ushering in a new era of Asia water-nomics to ensure liquidity for growth for 10 rivers in Asia that feeds lives & fuels growth in 16 countries.

WATER-ENERGY-FOOD-ECONOMY-CLIMATE NEXUS

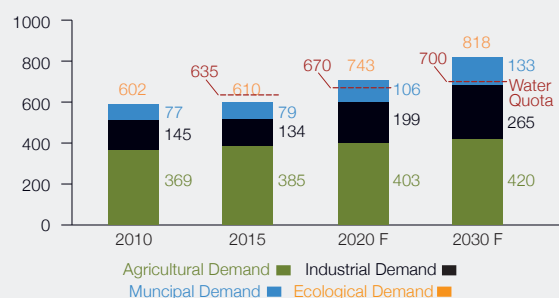


BEAUTIFUL CHINA: RE-BALANCING “ECONOMY & ENVIRONMENT”

The vision of a ‘Beautiful China’ was first brought up in 2012 and has since been the focus of the government’s efforts in re-balancing the economy and the environment. It is included in the 13FYP and recently enshrined in the constitution along with the mission to build an ‘ecological civilisation’. Government departments will also be reshuffled to deliver holistic management of natural resources and ecological environment from mountains top to the sea, and from air to the soil and groundwater; supervision and enforcement of natural environment have also been stepped up.

On the water front, since 2011, China has been promoting more stringent water management through ‘3 Red Lines’: (1) control total water use; (2) improve water use efficiencies and (3) prevent & control pollution. To control the rising demand in water, State Council has also set the national water use cap at 635 billion m³, 670 billion m³ and 700 billion m³ by 2015, 2020 and 2030. To do this, water allocation and management needs to be optimised. So far, such efforts have paid off: the total water use in 2015 was 610 billion m³, 25 billion m³ less than the previously set red line. To meet the national caps, water is allocated by province and by sector. This clearly has implications for industries and businesses. Set out below are two examples from a regional and sector perspective.

2010-2030 Water Demand & Water Quota (billion m³)



Source: China Water Risk (Based on NBSC, The Ministry of Water Resources, 2030 Water Resources Group and China Water Risk Estimates)

Regional River Focus: the Yangtze River Economic Belt

Representing over 42% of China’s population and GDP, it is no surprise that the government’s focus is on the Yangtze River Economic Belt (YREB) in its attempt to seek new pathways for green development (more in “**The Yangtze: More GDP on Less Water & Pollution**” in Chapter 2). During the CPC’s 19th National Congress in October 2017, the then Environmental Protection Minister (now the Minister of the newly formed Ministry of Ecological Environment (MEE)), Ganjie Li highlighted key environmental issues in the YREB, including lack of environmental infrastructure, dense heavy chemical industries with great environmental risk, rural non-point source pollution, and impaired ecological systems.

Addressing these had support from the top. President Xi stressed in his speech during the congress that China “*will facilitate the development of the Yangtze Economic Belt by promoting well-coordinated environmental conservation and avoiding excessive development*”. His emphasis on more balanced & harmonious development is more than a slogan. Throughout his political career, his thinking of the environment and economy has been rather consistent. From 2002 to early 2007, Xi used to be the CPC secretary of Zhejiang province. During that period, Zhejiang saw rapid economic growth but also rising pollution concerns. In various occasions, he compared ‘clean water and lush mountains’ to ‘gold and silver’. In early 2007, before moving on to his next role in Shanghai, he attributed Zhejiang’s economic success to “scientific development philosophy” and “optimisation of industry mix”. He never saw ‘dirty’ money from polluting industries as key drivers for the economy.

Actions laid out in the ‘Water Ten Plan’ and YREB-specific policies including the ‘YREB Development Plan’ are trickling down to the local level. Provincial-level ‘Ecological Red Lines’ have been set for all the 11 YREB provinces and municipalities by the end of 2017. By the end of 2018, according to a new “Action Plan to Tackle Pollution in Key River Basins (2016-2020)”, companies along the Yangtze River in key polluting industries (such as chemicals, textile dyeing, heavy metals and hazardous waste etc.) will need to conduct environmental risk assessments. Actions on the YREB could bring global disruptions as multiple global supply chains can be traced back to this river.

Annual fishing ban along the Yangtze becomes the norm

It is not only about controlling pollution sources. Efforts such as setting up national parks in the river source region, and fishing bans along the river, are also being taken to restore the ecological environment of the river. For instance, the total fish catch in the Yangtze River Basin used to be as high as 450,000 tonnes, accounting for 72% of China’s total freshwater fish catch. However, in recent years, it has fallen to 100,000 tonnes¹⁷². Given this dramatic fall in fish catch, Chinese government, in its 2017 No.1 Document, decided to ban fishing in all the aquatic biological protection zones along the Yangtze River Basin. This is a big change: in the past, such a ban was only applied to certain sections of a river.

On 28 February 2017, the Ministry of Agriculture of China issued a guiding document to completely ban fishing. The ban will be implemented throughout 2017 in all the 42 ecological protection zones along the Yangtze River. These protection zones are mainly in the mainstream and key lakes of the Yangtze River. The document also set a loose timeline of two years to help fishermen in these protection zones switch to other professions.¹⁷³ As of 1 March 2018, the annual 4-month long basin-wide fishing ban again started in several rivers including the Yangtze and the Pearl.

BANKING IN THE AGE OF WATER RISK

China wants to embed environmental risks into credit lending policies. The last two years saw the rise of Environmental Risk Analysis (ERA) globally. Chinese banks have started exploring how to do this and generally embed environmental, water and climate risk into its financial system. CWR is also part of China's ERA working group led by ICBC under the guidance of the China Green Finance Committee.

Environmental risks are becoming more material. In a vicious cycle, it is not just businesses which impact the environment but the environment is also affecting the ability of businesses to operate. In countries like China, regulatory risks to consider. These pertain to the allocation of water to ensure national water, energy, food and economic security. They also cover tighter standards with higher penalties to protect drinking water sources from industrial contamination.

As shown in the CWR report *"Toward Water Risk Valuation – Investor Feedback on Various Methodologies Applied to 10 Energy ListCo's"* based on our 2016 investor engagement⁹³, 70+ investment professionals/asset owners surveyed saw water risk to be tangible, material and immediate, 73% of which also view cost of compliance to tighter regulations as potentially material to cash flows and valuations. Yet, despite this, bankers, investors, corporates and even water resource managers and specialists have not come up with a cohesive & comprehensive strategy to tackle or value these risks.

These issues are not going away, as clearly shown in Chapter 3. They will have implications for businesses and for our future. Already we know that the costs of floods are rising and can be highly disruptive to supply chains and cost billions. Yet interestingly, investors we surveyed regarding various approaches to water risk valuation rank flood risk as their lowest concern vis-à-vis six other types of water risk..

Water risks know no borders. Thanks to trade and intricately linked supply chains, physical risks, say a flood or a drought in China could disrupt production. Similarly, a policy shift in China also has global implications. Supply chains should also be mapped and assessed for water risks as a step toward "waterproofing exposure".

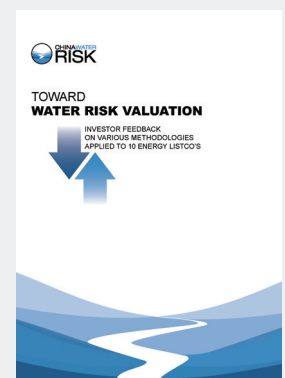
Banks with long term loan portfolios/project finance do not have the luxury of short term investment horizons of hedge funds. Their loan books could be exposed to these water-related risks, which are likely material. Indeed, from our own experience, 48% of investment professionals/asset owners who provided feedback said they were doing the survey because they were worried about water risk, yet 0-4% use the tools available to assess water risk regularly. A quarter of those surveyed was working with debt and/or fixed income.

Are these risks and their potential impacts factored in by banks? Or are banks just considering their 'water exposure' as the water used in their office buildings & branches? Some banks are more enlightened than others. In the past few years, actions vary across banks. Two of the major actions that have been collectively taken by the industry are:

- The FSB Task Force on Climate-related Financial Disclosures (TCFD) was set up to develop voluntary, consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers, and other stakeholders. The TCFD released three foundation documents on 29 June 2017 to describe and support implementation of the Task Force's recommendations.
- Meanwhile, a consortium of experts from the Bank of England, the UN Environment Inquiry and the University of Cambridge Institute for Sustainability Leadership called for enhancing ERA in financial decision-making. ICBC, one of China's big banks has stress tested the impact of environmental factors on credit risk. New and stricter environmental policies in China could impact their clients' operations and increase credit risk, which could lead to damage to the bank's reputation and even financial security.

The bottom line is that water risks have come of age. They have seeped into the mainstream. Regulations have made them more immediate and tangible. We need to factor them into valuation models be they equity or debt. Among the various capital providers, banks with longer investment horizons are more exposed. Scientists still say the current tools are not perfect but this is not an excuse not to start, because any banker will tell you that credit risk evaluation and equity valuation is an art rather than a science.

Given the level of noise, prudence dictates that banks must start evaluating water risk exposure in their portfolio, as must pension funds, institutional investors and so on. It's time to find the middle path of water risk valuation and head down it. It is also good to remember at this point how far we have come.



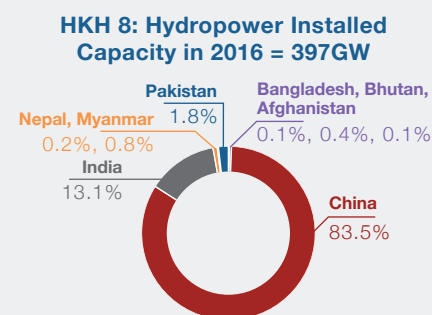
HYDRO DRIVES GREEN POWER IN THE HKH 8

Energy choices matter for water. Many thermal power plants in the HKH 8 use water for cooling, which is usually directly withdrawn from rivers nearby. As of 2014, thermal power generation dominated the power mix of five HKH countries from Afghanistan (51%) to Bangladesh (95%) (see power mix by type across the HKH 8 in **“Black Carbon from Rural Communities”** in Chapter 3). Reliance on coal and coal-fired power generation has led to great pressure on water resources in China, especially along the Yellow River basin.

If we are to move away from fossil fuels, we need to find other clean and green energy sources to meet the energy demand of a rising population, some of whom have a per capita energy consumption below the world average or even without access to electricity (more on per capita energy consumption of HKH 16 in Chapter 2). Countries such as China and India have thus been actively promoting renewable energies like wind and solar. However, the geographical limitation and intermittent nature of these energy resources mean that in the next few decades, renewables (excluding hydro) will likely form a small part of the HKH 8's energy mix.

As a clean energy source, hydropower plays an important role. The HKH Rivers provide natural advantages for HKH 8 to develop hydro. Abundant hydropower resources can provide a clean and viable energy solution for the HKH 8. The key questions are what type of hydro we will add, and where and how we will build them.

By 2016, the total hydropower installed capacity of the eight HKH Countries reached nearly 397GW (see right-side chart). This is nearly one third of the global hydropower installed capacity of 1,246GW¹⁷⁴. China alone has installed 331GW hydropower or 83% of the HKH 8's total capacity. According to its latest Five Year Plan (13FYP)¹⁷⁵, it aims to add another 10GW to reach 340GW by 2020. This is 25GW more than India's current total installed power generation capacity (315GW, as of February 2017¹⁷⁶). This difference is equivalent to Pakistan's total power generation.



Source: China Water Risk based on International Hydropower Association (IHA), Hydropower Status Report 2017

There are different types of hydropower plants: impoundment, run-of-the river/diversion, and pumped storage¹⁷⁷. Generally, larger-scale plants with dams and reservoirs will have bigger impacts such as interrupting the natural flow of the river. There are concerns over the impacts on the migration routes of certain fish species. According to the Global Reservoir and Dam (GRanD) Database¹⁷⁸ and International Rivers¹⁷⁹, which capture a quarter of over 50,000 existing dams globally, the HKH Rivers have at least 702 dams. Over half (53%) of these 702 dams are on the Yangtze. In fact, as per China's own statistics¹⁸⁰, there are 240 large-scale and 1,322 midsized reservoirs in 2015 on the Yangtze alone.

For China, large and medium-sized hydropower plants are expected to continue to dominate. For instance, by 2020, 260GW or 76.5% of China's 340GW hydropower installed capacity will be large and medium-scale plants. China's future hydro expansion will also be concentrated in its west (also part of the HKH Region), which is expected to account for over 70% of its total installed capacity by 2020. Although most development will be on its internal rivers such as the Yangtze and the Yellow, development is also taking place in other transboundary HKH Rivers. For instance, Zangmu Hydropower Plant, the first project on the Upper Brahmaputra (*YarluZangbu*), was put into operation in late 2015.

Development of dams on transboundary rivers can lead to controversies and even conflicts. According to the Environmental Justice Atlas (ejatlas.org)¹⁸¹, there are already cases such as the Myitsone dam on the Irrawaddy, the Hatgyi Dam on the Salween, the Diamer Basha Dam Project on the Indus, and the Srinagar hydro plant on the Alaknanda River (a tributary of the Ganges). Not only China, but other HKH countries are also building or planning projects to tap into hydropower from those transboundary HKH rivers. Some, like Nepal and Bhutan are hoping to export such clean electricity to India¹⁷⁴.

However, such hydropower spree on transboundary rivers may face difficulties due to lack of coordination and collaborative mechanism on these rivers (more on this in **“Status of Transboundary Agreements on HKH Rivers”** in this chapter). On top of that, changes in rainfalls and water availability as the result of climate change, will add another layer of complexity and bring further challenges. *“There is a need to manage risks so that the mountains and the plains derive sustainable benefits from the region's rich hydropower potential”*, as David Molden, Director General of ICIMOD, called at a workshop in 2016¹⁸².

Therefore, it is important to promote broader and deeper collaboration and cooperation along the HKH Rivers, to avoid potential conflicts in utilising shared water resources. This does not only apply to hydropower development, but also other economic activities running on water.

STATUS OF TRANSBOUNDARY AGREEMENTS ON HKH RIVERS

Currently, multilateral dialogue mechanisms and cooperation are lagging on the HKH Rivers. Only five of the eight transboundary HKH Rivers have certain kinds of agreements or MoUs in place (see table below). The scope of these agreements is limited, lacking guidance on how to manage resources and services provided by shared waters.

HKH River Basin Within HKH 16	Chinese pinyin name	Countries that flow through	Transboundary agreement status and year of latest agreement		Involving countries	Scope of current agreement(s)
Amu Darya	N/A	Afghanistan, Tajikistan, Turkmenistan, Uzbekistan	Yes (as part of the Aral Sea region)	1993	Kazakhstan, Kyrgyz, Tajikistan, Turkmenistan	Restoring the balance of the destroyed ecosystems
Ganges	N/A	India, Nepal, China, Bangladesh	Yes	1996	India, Bangladesh	Sharing of water by ten-day period from the 1st January to the 31st May every year
Indus	N/A	Afghanistan, China, India, Pakistan	Yes	1960	India, Pakistan	Utilisation of water resources (e.g. hydropower development)
Irrawaddy	N/A	Myanmar, China	No	N/A	N/A	N/A
Mekong	Lancang	China, Myanmar, Laos, Thailand, Cambodia, Vietnam	Yes	2011	China, Myanmar Laos, Thailand	Law enforcement and security cooperation; Commercial navigation
Salween	Nujiang	China, Myanmar, Thailand	No	N/A	N/A	N/A
Tarim	Talimu	China, Kyrgyzstan	No	N/A	N/A	N/A
Brahmaputra	Yarlung Tsangpo	China, India, Bhutan, Bangladesh	Yes	2008	China & Bangladesh; China & Bhutan	Provision of hydrological information in flood season
Yangtze	Changjiang	China	Non-transboundary			
Yellow	Huanghe	China	Non-transboundary			

Source: China Water Risk based on ICIMOD and International Water Law Project (www.internationalwaterlaw.org)

On 17 August 2014, the 1997 Convention on the Law of the Non-navigational Uses of International Watercourses (commonly referred to as the **UN Watercourses Convention** (UNWC))²⁶ entered into force. However, no HKH 8 countries has ratified this international convention so far; among the HKH 16, only Vietnam has ratified the UNWC. Nevertheless, “with the entry into force of the 1997 UN Watercourses Convention (UNWC)...and the opening up of the 1992 UNECE Transboundary Waters Convention (UNECE TWC), Asian nations now have access to two global instruments that can be borrowed from to build on the rather limited water-related treaty regimes currently in place across this region”, commented by Professor Patricia Wouters¹⁸³, a leading expert on international water law.

As the upstream country, China shares in total 40 major transboundary rivers with 16 countries. However, there are very few agreements in place including for those in its southern region, where most of the HKH Rivers are flowing to downstream countries¹⁸⁴. As commented by Professor Wouters, a “win-win” approach may well serve to promote transboundary water cooperation between China and its neighbours. In an opinion on China Water Risk’s website¹⁸³, she wrote, “China’s “upstream dilemma” poses difficult challenges....Unpacking these national claims within a regional context will require concerted efforts. Legal agreements, bilateral and multilateral, would assist with clarifying and consolidating transboundary approaches to these matters”. This does not mean that China has no transboundary agreements with its neighbours. In addition to the ones listed above for the Mekong and the Brahmaputra, China has also signed transboundary agreements with Russia and Kazakhstan¹⁸⁵.

The good news is that we have seen positive progress on the Mekong, where China has been taking a more multilateral approach and is willing to lead dialogues and cooperation (more on this in “A New Era of Regional Cooperation along the Mekong” in Chapter 2).

Transboundary agreements are integral to achieving the Sustainable Development Goals (SDGs) agreed upon by 193 nations. As per target 6.5 under SDG 6, “by 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate”. Without a formal effective framework or mechanism to facilitate dialogues, negotiation and cooperation, it will be impossible to achieve basin-wide water resources management.

ABBREVIATIONS

12th	FYP 12 Five Year Plan (2011-2015)
13th	FYP 13 Five Year Plan (2016-2020)
ADB	Asia Development Bank
AIIB	Asia Infrastructure Development Bank
APAC	Asia and the Pacific
BCC_CSM	Beijing Climate Center Climate System Model
CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Science
CFC	Chlorofluorocarbon
CGI-2	The Second Chinese Glacier Inventory
CH₄	Methane
CMA	China Meteorological Administration
CO₂	Carbon Dioxide
CWR	China Water Risk
CPC	National People's Congress
EM-DAT	Emergency Events Database
ERA	Environmental Risk Assessment
FAO	Food and Agriculture Organization of the United Nations
G20	The Group of Twenty
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GLOF	Glacial lake outburst flood
GRP	Gross Regional Product
HCFC	hydrochlorofluorocarbon
HKH	Hindu Kush Himalaya
ICIMOD	International Centre for Integrated Mountain Development
IFC	International Finance Corporation
IGSNRR	Institute of Geographic Sciences and Natural Resources Research
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LMC	Lancang-Mekong Cooperation
m³	Cubic metre
mm	Millimetre
masl	Meters above sea level
MEE	Ministry of Ecological Environment
MEP	Ministry of Environmental Protection
MEPFECO	Foreign Economic Cooperation Office, Ministry of Environmental Protection of China
MIIT	Ministry of Industry and Information Technology
MLR	Ministry of Land and Resources
MNR	Ministry of Natural Resources
MoA	Ministry of Agriculture
MOHURD	Ministry of Housing and Urban-Rural Development
MoF	Ministry of Finance
MoT	Ministry of Transportation
MRC	Mekong River Commission
MWR	Ministry of Water Resources
NDRC	National Development and Reform Commission
N₂O	Nitrous oxide
NO_x	Nitrogen Oxides
OECD	Organisation for Economic Co-operation and Development
PET	Polyethylene terephthalate
PPP	Public-private partnership
SNWTP	South-North Water Transfer Project
SOE	State-owned enterprise
TCFD	Task Force on Climate-related Financial Disclosures
TRMM	Tropical TRMM Rainfall Measuring Mission
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute
YRCC	Yellow River Conservancy Commission
YWRC	Yangtze Water Resources Commission

DEFINITIONS

China Policy

3 Red Lines – First introduced in 2011 in the central government's No. 1 Document, it refers to China's approach to water management: (1) control total water use; (2) improve water use efficiencies and (3) prevent & control pollution. National water use quotas were set for 2015, 2020 and 2030; targets were also set for water efficiency and pollution discharge.

Beautiful China – a social & economic vision of China's efforts to build an ecological civilisation. The concept was first brought up during the 18th National Congress of the Communist Party of China in 2012. This vision is included in the 13th Five-Year Plan and most recently incorporated in the revisions to China's constitution approved in March 2018.

Water Ten Plan – it refers to the 'Water Pollution Prevention and Control Action Plan' issued by the State Council on 16 April 2015. It is the most comprehensive water policy to tackle pollution in China to date, and sets out in total 238 specific actions that involve coordination & cooperation across 12 ministries and statelevel government departments.

Water-nomics – a concept that promotes holistic decision-making by wedding economic and social planning to water resources and pollution management. Water is essential for economic development. For a country or region with limited water resources, how to balance trade-offs between economic development, energy & food security, and water resource availability & quality is key.

Water

IRWR – Internal Renewable Water Resources (IRWR) refers to *"long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation. Double counting of surface water and groundwater resources is avoided by deducting the overlap from the sum of the surface water and groundwater resources"*⁷.

TRWR – Total Renewable Water Resources (TRWR) refers to *"the sum of internal renewable water resources (IRWR) and external renewable water resources (ERWR). It corresponds to the maximum theoretical yearly amount of water available for a country at a given moment"*⁷.

WTA – Water use-to availability ratio (WTA) is a commonly used indicator for water stress of a certain region. It is calculated as the ratio of *water withdrawal over total renewable water resources* over the same period (e.g. a year).

Water Poverty Mark – According to major International Organisations including UNEP, UNDP, World Bank and the World Resources Institute, when the renewable water resources drop below 1,000m³ per person per year, nations are considered water scarce, which means that the lack of water becomes a severe constraint on food production, economic development, and protection of natural systems.

Virtual Water – The virtual-water content of a product is the freshwater "embodied" in the product, not in real sense, but in virtual sense. It refers to the volume of water consumed or polluted for producing the product, measured over its full production chain. If a nation exports/imports such a product, it exports/imports water in virtual form.

HKH Related

HKH / Third Pole – The Hindu Kush- Himalayan (HKH) region is defined by ICIMOD and refers to a total area of >3.4 million km² high mountains in Afghanistan, Bhutan, China, India, Myanmar, Nepal, and Pakistan.

HKH 16 – collectively the 16 countries that are defined as **HKH 8** and **Downstream 8**

HKH 8 – refers to the 8 countries of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan, where the HKH Region is located.

Downstream 8 – the 10 HKH rivers basins span beyond the HKH 8 into another 8 countries including Cambodia, Kyrgyzstan, Laos, Tajikistan, Thailand, Turkmenistan, Uzbekistan and Vietnam.

HKH Rivers – 10 major rivers emanating from HKH Region which include the Yellow, Yangtze, Mekong, Salween, Irrawaddy, Brahmaputra, Ganges, Indus, Amu Darya and Tarim.

HKH River Basins – the entire basin areas of the above 10 major HKH Rivers

METHODOLOGY

The data sources and method used to estimate key demographical, economic hydrological and climate change parameters mentioned in the report are set out as below. For those directly cited from external sources, please refer to the reference list in the main report.

Geographical & administrative boundaries

For the geographical boundary of river basins, we used HydroBASINS¹⁸⁶ and HYDRO1k¹⁸⁷.

For the administrative boundary of countries, we used the Database of Global Administrative Areas (GADM; version 2.8, November 2015).

For identification of cities, we referred to World Urbanization Prospects (UN Department of Economic & Social Affairs 2014).

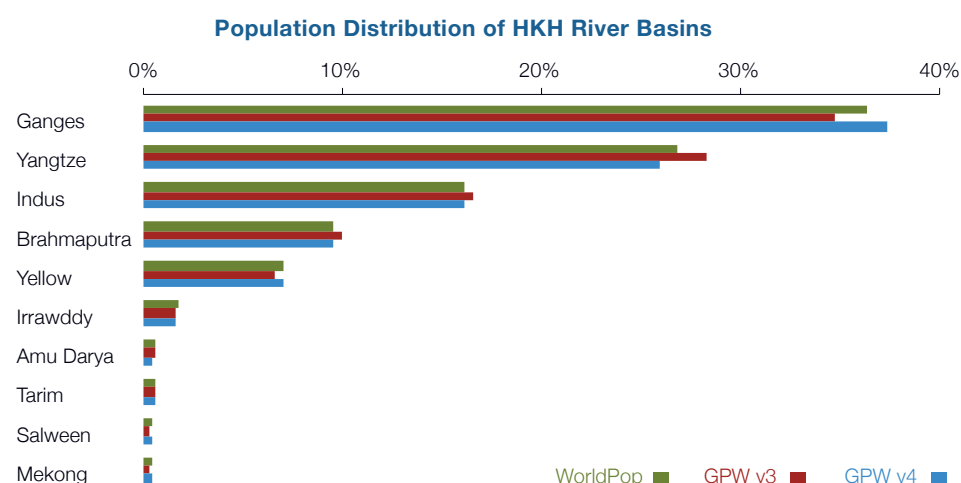
Population data & estimation

For the country-level population, we used data from the *World Population Prospects: The 2017 Revision* (UN Department of Economic and Social Affairs/Population Division 2017).

For the basin-level population in each country, we calculated based on the Zonal Statistics method in ArcGIS by using data from the WorldPop population spatialised products^{188–193} and administrative/basin boundaries as input. The WorldPop method/database has been applied in various reports published by leading international organisations^{194–196}.

In addition to WorldPop, we also used two other datasets, the Gridded Population of the World (GPW) Version 3 (CIESIN & CIAT 2005) and Version 4 (CIESIN 2016) to calculate the results for comparison and cross-checking. For the differences between the two versions, please refer to GPW website: <http://sedac.ciesin.columbia.edu/data/collection/gpw-v4/whatsnew>.

The results of population estimation based on the above three datasets are shown in the chart below. With the exception of the Ganges and the Yangtze, the differences between the results for each river basin is very small.



Source: China Water Risk based on calculation done by China Academy of Sciences from WorldPop, 2015 estimates. Uzbekistan and Turkmenistan data are not available.

Due to lack of accurate basin-level data and administrative differences, it is not easy to draw clear lines between “urban population” and “rural population” at the basin level. By using WorldPop’s 2015 data sets, we are able to identify 589 city-level administrative regions (above the population size of 500,000, including both urban and rural population) in the HKH River Basins within the HKH 16. 500 of the cities are over the size of 1 million (including both urban and rural population), and 70 of them are over 5 million. In China, nearly 95% of the cities along the HKH River Basins have a population of over 1 million, which are located either along the Yangtze or the Yellow. There are six >10 million cities, all of which are located in the Yangtze River Basin, including Chongqing, Shanghai, Chengdu, Suzhou, Wuhan and Nanyang.

GDP data & estimation

For the country-level GDP, we used data from the World Bank's *World Development Indicators* ¹⁹⁹.

Basin-level GDP figures are calculated as the sum of agricultural, industrial and services added values with references to Liao & Li (2004) & Liu et al. (2005):

- For **agriculture added value**, it is calculated by multiplying the cropland area by basin and country with the agriculture production value per unit area by country.
- For **industrial added value**, its relationship with nighttime light was analysed and country-level industrial production value density was calculated. The industrial added value by basin and country then can be estimated from basin and country nighttime light and country-level industrial production value density.
- For **services added value**, it is calculated by multiplying services added value logarithm density in different countries with population in the basin and country.

Calculate basin-level water resources

Annual average surface water resources (1998-2015) for each river basin was calculated by multiplying annual precipitation with runoff coefficient:

- Annual precipitation was calculated based on data from the Tropical Rainfall Measuring Mission (TRMM) 3B43 over the period of 1998-2015 ²⁰².
- Runoff coefficient was estimated from elevation, slope, soil type and aridity index.
 - **Elevation** was based on digital elevation model (DEM) USGS Global 30 Arc-Second Elevation (GTOPO30);
 - **Slope** was calculated from DEM;
 - **Soil type** was obtained from the World Resource Base Map of World Soil Resources ²⁰³; and
 - **Aridity index** was from CGIAR-CSI Global Aridity Index ²⁰⁴.

First, a Random Forest Model was trained using Chinese spatial runoff coefficient (calculated as precipitation divided by runoff depth, with data from China Renewable Energy Engineering Institute (2014)), elevation, slope, soil type and aridity index. Then, spatial runoff coefficients for the other HKH countries were estimated based on their corresponding data of elevation, slope, soil type and aridity index.

In addition, natural annual flows of the 10 HKH Rivers were calculated based on the below three hydrological models:

- **Max Planck Institute – Hydrology Model (MPI-HM)**, <https://www.isimip.org/impactmodels/details/95/>
The MPI-HM is a global hydrological model. It is used to investigate hydrological research questions mostly related to high resolution river routing ²⁰⁶. The data period is 1963-2000.
- **PCRaster Global Water Balance (PCR-GLOBWB)**, <http://www.globalhydrology.nl/models/pcr-globwb-2-0/>
PCR-GLOBWB 2.0 is a grid-based global hydrology and water resources model developed at Utrecht University. It is a modular model coded in Python and PCRaster-Python routines ²⁰⁷. The data period is 1979-2000.
- **The global freshwater model WaterGAP**, <http://www.watergap.de>
WaterGAP2 is a global water availability and water use model ^{208–210}. Version 2.2 of the model was used. The data period is 1963-2000.

Contribution of glacier & snow melt to runoffs

Shares of glacier & snow melt that contribute to runoff of the upper reaches of the 10 HKH Rivers are summarised based on academic studies on specific rivers ^{37–42}.

Basin-level water use by type

Except for the Yangtze River and the Yellow River, there are no comprehensive and reliable statistical data for the other HKH River Basins. There are also challenges in data comparability, as the data of irrigated areas was from 2005, while the population data was from 2015. In addition, there were great variations in country-level water use data in terms of data year.

Given these limitations, we assumed the total water use and water use by type didn't have significant changes over the time period. For each type of water use, we estimated by using the following methods:

- For **agricultural water use**, it was calculated by multiplying irrigated areas with irrigation water use per unit area ^{211,212}. The FAO database Global Map of Irrigation Areas (GMIA) is used, where irrigation statistics for sub-national units (e.g. districts, counties, provinces, governorates, river basins), from national census surveys and from reports available at FAO, World Bank and other international organizations, are being collected on a continuous basis. For most of the countries, these statistics refer to the area equipped for irrigation. Version 5 of GMIA was used in this report;
- For **industrial water use**, a regression model was established to estimate industrial added value intensity (in US dollars) by different types of land use which was based the GlobCover 2009 (Global Land Cover Map) ^{213–216}. Then, the results were used to calculate industrial water use by multiplying with industrial water use per unit industrial added value; and
- For **municipal water use**, it was calculated based on total population (*WorldPop*; see above) and country-specific domestic water use per capita.

Climate related variables

The report includes the following four climate related variables:

- **Temperature**: measured in Kelvin (K) and converted to Celsius (°C) using the equation $[^{\circ}\text{C}] = [\text{K}] - 273.15$;
- **Rainfall**: measure in equivalent water depth (millimeter, or mm);
- **Snowfall**: measure in equivalent depth (millimeter, or mm); and
- **Runoff**: measure in equivalent water depth (millimeter, or mm).

We used five ensemble models included in IPCC AR5 (BCC-CSM1.1, CanESM2, CCSM4, MIROC5, MPI-ESM-LR) to calculate the historical and future projection values for these parameters. These five models are:

- **BCC-CSM1.1**: Beijing Climate Center Climate System Model, Version 1.1, <http://forecast.bcccsn.ncc-cma.net/web/channel-43.htm>
- **CanESM2**: Canadian Centre for Climate Modelling and Analysis, <http://climatemodelling.canada.ca/climatemodeldata/cgcm4/CanESM2/index.shtml>
- **CCSM4**: Community Climate System Model, Version 4, <http://www.cesm.ucar.edu/models/ccsm4.0/>
- **MIROC5**: Model for Interdisciplinary Research On Climate, Version 5, <http://www.icesfoundation.org/Pages/ScienceltemDetails.aspx?siid=181>
- **MPI-ESM-LR**: Max Planck Institute for Meteorology Earth System Model, <https://www.mpimet.mpg.de/en/science/models/mpie-sm.html>

The time period for the historical values is between 1956 and 2005, and the time period for the future values is between 2006 and 2055 (*because some of the climate models only have historical records until 2005, thus 2005 was used as the deviding year*). Representative Concentration Pathway 4.5 (**RCP 4.5**) is used.

Note: the spatial resolution of climate data used in IPCC AR5 is about 250-300km.

ADDITIONAL READINGS

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CWR website: www.chinawaterrisk.org

RELEVANT PROJECT WEBSITES

Asia High Elevation Cryosphere Observation (AHECO) project: globalcryospherewatch.org/projects/aheco.html

Himalayan Adaptation, Water and Resilience (HI-AWARE) Project: www.futurewater.eu/projects/hi-aware/

Hindu Kush Himalayan Monitoring and Assessment Programme (HIMAP): hi-map.org

International Centre for Integrated Mountain Development (ICIMOD): www.icimod.org

The Third Pole: www.thethirdpole.net

TOOLS & GUIDELINES

Alliance for Global Water Adaptation (AGWA): alliance4water.org

Alliance for Water Stewardship. AWS International Water Stewardship Standard: <http://a4ws.org>

Ceres, Investor Water Toolkit: www.ceres.org/resources/toolkits/investor-water-toolkit

Climate Funds Update: www.climatefundsupdate.org

International Water Law Project: <https://www.internationalwaterlaw.org>

The Water Criteria of Climate Bonds Standard, www.climatebonds.net/standard/water

Trase, an initiative by SEI and Global Canopy Programme: <https://trase.earth>

Water Resources Institute. Aqueduct global water risk mapping tool: <http://www.wri.org/ourwork/project/aqueduct>

Water Risk Filter from WWF: <http://waterriskfilter.panda.org>

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NOTES



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