Avoiding Atlantis

CWR APACCT 20 Index

Benchmarking coastal threats for 20 APAC cities with finance sector input

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Climate change will drastically redraw coastlines threatening capital cities, economic growth and livelihoods in the Asia-Pacific region. Locked-in tail risks from such coastal threats should be factored into sovereign and corporate credit risk ratings as well as equity/project valuations. We have thus developed the CWR APACCT 20 Index to benchmark coastal threats to help multi-stakeholders understand and assess these complex risks.

This report details the development of the CWR APACCT 20 Index which factors in physical risks from long-term sea level rise and storm surges as well as government adaptation action which can temper risks. It is an integral part of the **CWR Coastal Capital Threat Series** which seeks to explore and assess the absolute and relative tail risks from coastal threats for 20 APAC capitals and key cities.

Over 100 finance professionals from chairs/directors of bank boards to research analysts as well as financial industry associations, asset owners and financial regulators have provided feedback on the development of this index which underpins this series of reports.

Although by no means perfect, this finance-driven and practical index can be used to re-calibrate tail risks and re-think long term capital allocation decisions. We hope that it can help APAC governments, central banks and financial regulators better prepare the region for capital threats and systemic shocks ahead.

About China Water Risk (CWR)

CWR is a non-profit think tank that aims to create a world where water and climate risks are embedded in business & finance. Since its launch in 2011, it has worked from its Hong Kong base to engage with global business and investment communities in understanding and managing various types of water risks in China and across Asia.

CWR's collaborative reports with financial institutions, IGOs, scientists as well as government related bodies have been considered ground-breaking and instrumental in understanding Asia's water challenges. They have help inform better decision-making today for a water secure tomorrow. Join the conversation at www.chinawaterrisk.org

Acknowledgements

CWR is grateful to our sponsor: The ADM Capital Foundation and our core funders: Rockefeller Brothers Fund and the RS Group for their continued funding support which has enabled the publishing of this series of reports. We are also grateful to financial industry experts and regional scientists who have provided input into the **CWR Coastal Capital Threat Series**.


CWR
Seas are rising
So must we

Preface

Debra Tan
Director & Head, CWR

To say that 2020 has been an unusual year is an understatement. However, COVID-19 lockdowns have afforded us the time to deep dive into producing this important series of reports on coastal threats that we would have otherwise not have had the time to curate.

We started exploring saltwater threats in 2019 in reports with the AIGCC and Manulife Investment Management *"Are Asia's Pension Funds Ready for Climate Change?"* as well as CLSA *"Thirsty & underwater: Rising risks in the Greater Bay Area"*. Both reports point to significant clustering of risk exposure due to the geo-locational nature of coastal threats.

Subsequent engagement with the financial sector revealed that they wanted to see more impact analyses across the Asia Pacific region. And so we worked with them to create the CWR APACCT 20 Index to benchmark absolute and relative chronic risks from coastal threats in APAC.

We are grateful to the 100+ finance professionals from chairs/directors of bank boards to credit/equity research analysts plus financial industry associations, asset owners and financial regulators who input into its design & development, which physical threats & government actions to include, proxy indicators to use plus index weightings. And we hope that they (plus the wider financial sector) will find the results and rankings useful in helping provide a path forward in assessing implications on valuations. Urgent and dire action is needed to avoid Atlantis. The consensus view of those we surveyed was 3°C-4°C by 2100; if this is what we believe, then we can no longer afford to ignore sea level rise (SLR).

Forget about 1m by 2100, thanks to our inability to rein in emissions earlier, SLR of 3m is now a plausible reality in 80 years' time. Renowned scientist Konrad Steffen, who passed away this summer near the Swiss camp research station in Greenland, worried that current observations point to 5m of SLR in 50 to 100 years if we don't get our act together. If you have time you must watch his heartfelt plea – it is powerful as it is shocking.

Such levels of SLR will be devastating for APAC. Besides Beijing, Kuala Lumpur, Vientiane & Phnom Penh, all other APAC capitals are coastal, as are our other economic hubs such as Aichi, Shanghai, Shenzhen, Osaka and Guangzhou. The region is heavily reliant on trade and export-led growth, yet the just inked RCEP trade deal could be at risk in the future unless all parties in the region commit and fast-track carbon neutrality. At 4°C, our research shows that all 23 ports of the 20 coastal capitals & cities in our CWR APACCT 20 Index will be underwater & only two out of the 25 airports (Tokyo's Narita and Taipei's Taoyuan) will be operational without serious adaptation measures.

Despite clear concentrated financial risks, we are still making stupid investment and capital allocation decisions. Because we have not accounted for a huge chunk of chronic SLR risks, we have an incomplete APAC risk snapshot that perpetuates wrong investment decisions. We are still allocating capital to vulnerable locations plus investing in carbon intensive industries which only exacerbate their vulnerability.

DO NOT fly blind into an Atlantean future; be realistic & prudent. Don't just focus on carbon transition risks, it's time to get on top of the new risk landscape. We must start assessing and accounting for coastal threats today because only then can we spread risks and drive financing to urgent adaptation to protect our cities from multi-metre SLR we have already locked-in. We are running out of time as 1.5°C of warming will be locked-in by 2030; this is 70 years earlier than expected.

So bite the bullet and take the hit – you know the permanent SLR overhang changes all vulnerable asset valuations from "freehold" into "leasehold". Pricing in chronic tail risks will also drive governments and corporates to fast-track both adaptation and decarbonisation measures. So not only will you be ensuring financial resiliency, you will also be protecting millions of livelihoods and savings. No doubt, the financial sector has a key role to play in avoiding Atlantis.

Our seas are rising, so must we. It's time for bankers to be heroes.

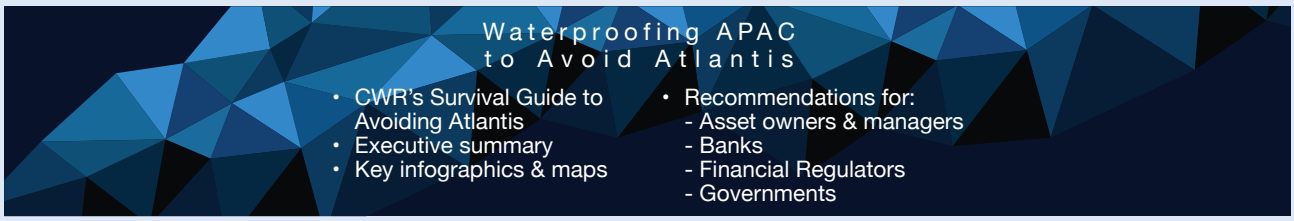
The CWR Coastal Capital Threat Series…

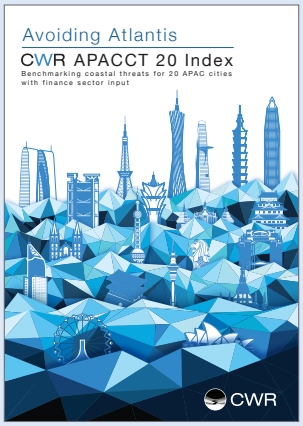
Climate change will drastically redraw coastlines threatening capital cities, economic growth and livelihoods in the Asia-Pacific region (APAC). The **CWR Coastal Capital Threat Series** seeks to explore and assess the absolute and relative chronic tail risks from coastal threats for 20 APAC capitals and key cities so that they can be factored into sovereign and corporate credit risk ratings as well as equity/project valuations.

This series of reports includes 1) the development of the **CWR APACCT 20 Index** (CWR APAC Coastal Threat Index for 20 cities) that benchmarks cities for chronic risks presented by coastal threats of sea level rise (SLR) and storm surge as well as government adaptation action; 2) factsheets for each of the 20 cities illustrating at-a-glance exposure for various climate scenarios; 3) overviews of the latest science-based research on coastal threats and evolving financial regulatory landscape to avoid systemic shocks triggered by climate change; 4) implications for sovereign risk ratings of the 14 APAC countries/territories; and 5) recommendations for asset owners, asset managers and banks; central banks and regulators; and governments to address and adjust for such locked-in chronic tail risks.

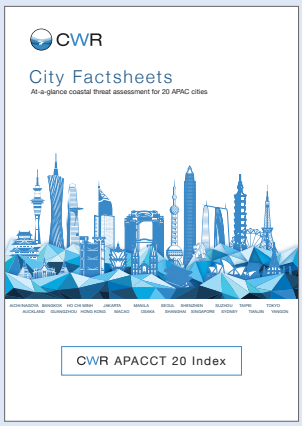
Over 100 finance professionals from chairs/directors of bank boards to research analysts as well as financial industry associations, asset owners and financial regulators have provided feedback on the development of the index that underpins this series - we thank them for their invaluable and continued input to our work. We would also like to thank regional climate scientists for their guidance in helping us better understand coastal threats.

This series of reports represents our first attempt to unpack complex interlinked coastal water risks for the APAC region. Although by no means perfect, this finance-driven and practical index can be used to re-assess tail risks and re-think long term capital allocation decisions. We hope that it can help APAC governments, central banks and financial regulators better plan and prepare the region for capital threats and systemic shocks ahead. Together, we can waterproof Asia to avoid a new Atlantis in a changing climate.

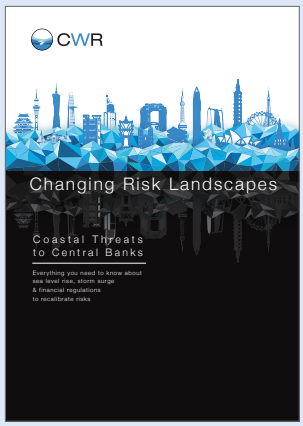




- In-depth analysis of absolute & relative chronic tail risks from coastal threats for 20 APAC cities
- Index reflects impacts on land area, population, key infrastructure – stacked locked-in SLR risks for 1.5°C, 2°C, 3°C & 4°C assessed for each indicator; subsidence + storm surge + government action also included
- Ranking of 20 cities for 1.5°C & 4°C with & without government adaptation efforts
- Feedback from 100+ finance professionals on methodology/ challenges faced in the development of the index



- City factsheets for Aichi/ Nagoya, Auckland, Bangkok, Guangzhou, Ho Chi Minh, Hong Kong, Jakarta, Macao, Manila, Osaka, Seoul, Shanghai, Shenzhen, Singapore, Suzhou, Sydney, Taipei, Tianjin, Tokyo & Yangon
- At-a-glance GDP & trade values at risk + ranking in CWR APACCT 20 Index at 1.5°C & 4°C for each city
- Overview of the city's climate threats & government actions
- Maps of locked-in SLR at 1.5°C & 4°C showing impacts on people, land & key infrastructure for each of the 20 cities



- Overview of latest sciencebased research on SLR, storm surge & subsidence
- Which RCP scenario to select & how-to tips to build coastal threat scenarios
- Tail risk implications for finance – sovereigns, banks, pensions, equity valuations, credit ratings & insurance
- Overview of the evolving financial landscape + the latest key reports & thinking from global central banks in preparing for systemic shocks triggered by climate risks

- GDP exposure of 20 key cities to coastal threats assessed for 14 sovereigns/ territories in APAC
- Relative performance evaluation - at-a-glance breakdown of how government action can reduce risks & change index rankings
- Analysis of absolute & per capita GDP vs. physical risk levels + government action to gauge chronic tail risks
- Case studies – adaptation action for Guangzhou/ Shenzhen, Jakarta, Tokyo, Shanghai; nosense climate strategies for HK, Macao & Singapore + two sectors

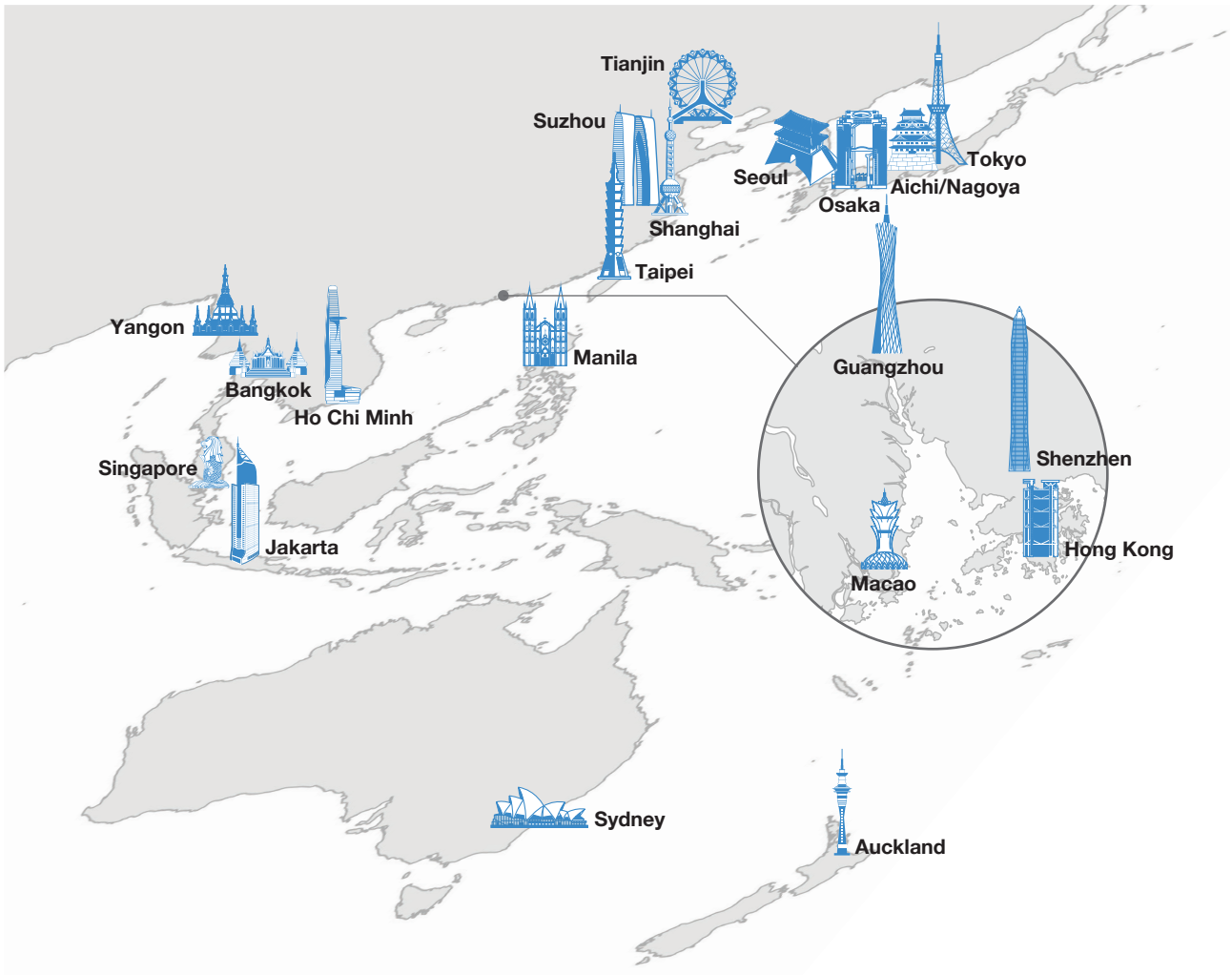
The 20 cities selected & why…

We have selected 20 coastal cities from 14 countries/territories in the Asia Pacific region (APAC) to include in this first version of the CWR APACCT 20 Index (CWR APAC Coastal Threat Index for 20 cities). We selected them as they are coastal capitals or key cities that are heavily populated and with significant contribution to country/territory GDP. While only 20 APAC cities have been included in this inaugural benchmark index, there are many more coastal cities as well as manufacturing/trade hubs in the APAC region and we hope that the index can be expanded to cover more cities in the future to help gauge sovereign risk.

Countries that have more coastal cities will naturally be more exposed to sea level rise (SLR) and storm surges – for example, both Australia and Japan have over 70% of their populations in large cities located in coastal regions. Please note that while we have not included Kuala Lumpur in this index, as the city is not coastal, it does not mean that Malaysia is not at risk - its economy is export-oriented and many of its state capitals are located by the sea.

The CWR APACCT 20 Index results for each city can be found in **"Appendix 1: CWR APACCT 20 Index City Factsheets"**, whereas coastal threat impacts on the GDP of each country/ territory of these 20 cities have been laid out in ***"Sovereigns at Risk: APAC Capital Threats"***; another report in the CWR Coastal Capital Threat Series.

The 20 cities of the CWR APACCT 20 Index…



There is no clear-cut definition of what constitutes a city as the definition could vary by country. For example, Shanghai is a city and a provinciallevel municipality, while Tokyo is the capital of Japan as well as a prefecture. For comparative reasons, this report measures the 20 cities based on their best available official administrative references. Please see the table below for the official administrative reference we used for each city.

Aichi/Nagoya = Aichi Prefecture
Auckland = Auckland Region
Bangkok = Bangkok
Guangzhou = Guangzhou
HCMC = Ho Chi Minh City
Hong Kong = Hong Kong SAR
Jakarta = Jakarta
Macao = Macao SAR
Manila = Metro Manila
Osaka = Osaka Prefecture
Seoul = Seoul Capital Area
Shanghai = Shanghai
Shenzhen = Shenzhen
Singapore = Singapore
Suzhou = Suzhou
Sydney = Greater Sydney
Taipei = Greater Taipei
Tianjin = Tianjin
Tokyo = Tokyo To
Yangon = Greater Yangon

Millions of people & billions of $$$ at risk…

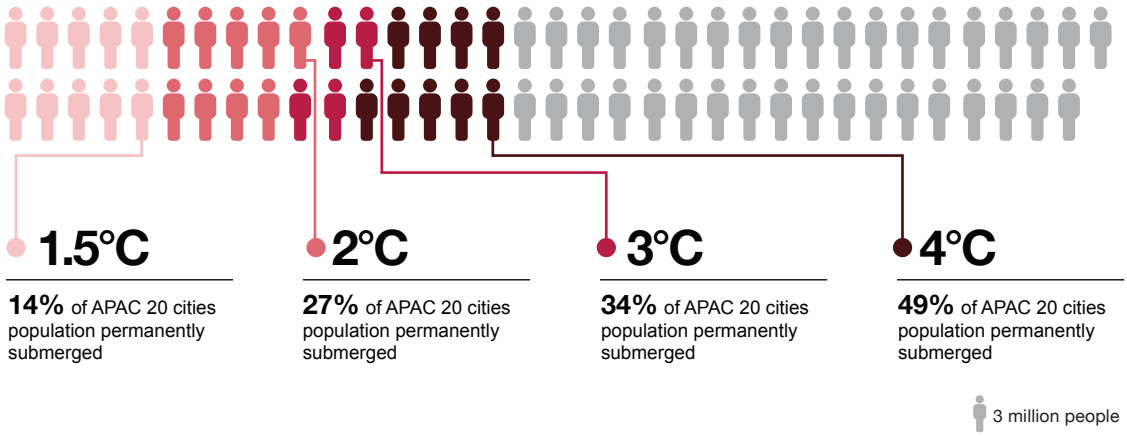
The 20 cities included in the CWR APACCT 20 Index are home to 207 million people and account for US$5.7trillion GDP or over a fifth of the GDP of the countries/territories. The ports and airports that serve these 20 cities ship around a quarter of global sea and air cargo volumes. All these are at risk – exposed to increasing coastal threats of SLR as well as storm surges for those in the path of typhoons/tropical cyclones/hurricanes. As can be seen from the graphic below, locked-in SLR impacts of our current path of 4°C is dire for the 20 APAC cities. We need to start assessing and factoring these tail risks now.

The purpose of this index is to thus help gauge the absolute and relative coastal threats facing these 20 APAC cities by benchmarking underlying long-term physical threats from locked-in SLR and storm surge exposure as well as assessing the impact of adaptation actions taken by various governments as these can alleviate the risks faced by cities to a certain extent.

Adaptation efforts vary from city to city but interestingly, we have found little correlation between ef forts and risk exposure. Also our review reveals that adaptation gaps vary even within a country – there appears to be no coordinated national approach to adaptation amongst key cities, which is surprising given the importance of the cities and supporting key infrastructure (like ports and airports) to national interests. Analysis of these no-sense climate strategies can be found in ***"Sovereigns at Risk: APAC Capital Threats"***; another report in our Climate Capital Threat Series.

The CWR APACCT 20 Index: What's at stake…

20 APAC COASTAL CAPITALS & CITIES = **207mn** PEOPLE RESIDE IN THE 20 CITIES + **$5.7trn** OF GDP AT RISK FROM COASTAL THREATS



Source: CWR APACCT 20 Index; CWR report "Sovereigns at Risk: APAC Capital threats", 2020

Note: The impacts on population are based on estimates for 2020 and do not include any further population growth and increases/decreases in urbanisation in the future. For more details, please see "CWR APACCT 20 Index: benchmarking chronic tail risks & adaptation actions to avoid Atlantis" in Section 3.

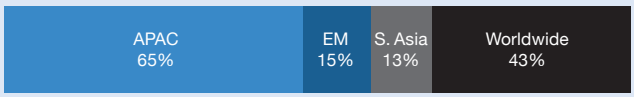
Input from 100+ finance professionals...

We wanted to create a practical index that was useful to the financial sector. To ensure that it was finance-driven, we sought feedback from the industry. We are pleased to announce that 100+ finance professionals provided input into the index development – the majority provided feedback through a survey, while a core group helped us frame this work, select cities and/or design the survey. It is worth noting here that only 34% of those surveyed classified themselves as "sustainable finance/ESG" indicating the increasing urgency by "mainst ream finance" to understand and benchmark tail risks from long term coastal threats.

We are very grateful for all their input – they have been invaluable in building consensus toward benchmarking coastal threats and help us design relative weightings in more subjective areas such as government action. We would also like to thank the Asian Investor Group for Climate Change (AIGCC) as well as the Investor Group for Climate Change (IGCC) for their guidance and support of the CWR Coastal Capital Threat Series.

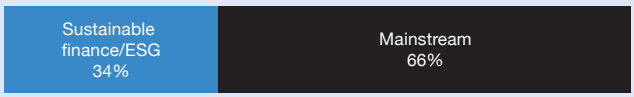
Please note that the survey was conducted on an anonymous basis to ensure honesty and integrity of the feedback. However, the charts below should help provide an idea of the breadth of input.

65% were APAC focused...



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

66% were mainstream finance...

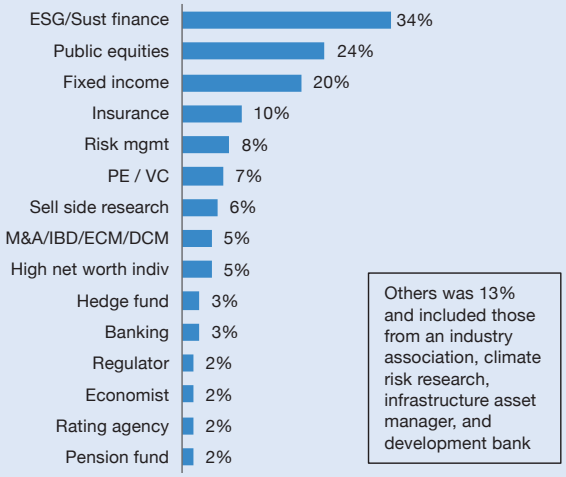


Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Wide-ranging input...

Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Which areas best describe your work?
You can pick more than one answer



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

40% wanted to use index for engagement...

While 42% said they were "just curious" to see the results, 40% wanted to use the results to engage with companies and 29% wanted to embed water risks in ESG scores.

Meanwhile, around a quarter said they wanted to use it to "seek strategic opportunities", "embed water risks in valuations" as well as "engage with policy makers". One of them summed it up succinctly - they wanted to see *"Water risk and impact to potential investments"*.

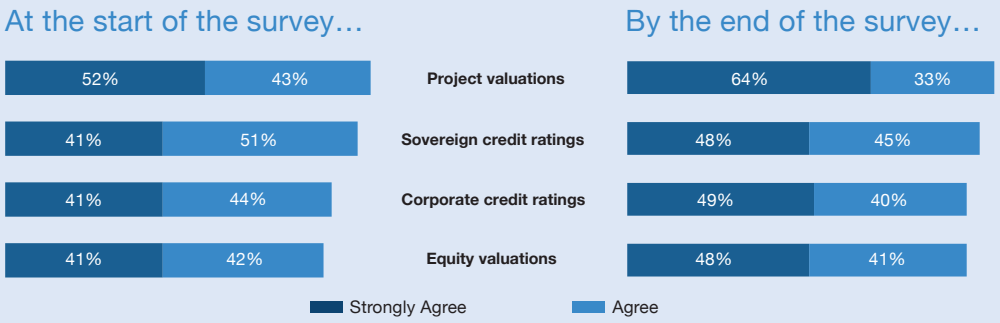
Before we start, why are you doing the survey?
You can pick more than one answer

Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

What they wanted going forward …

>89% "Strongly Agree" & "Agree" that tail risks from coastal threats impact valuations.

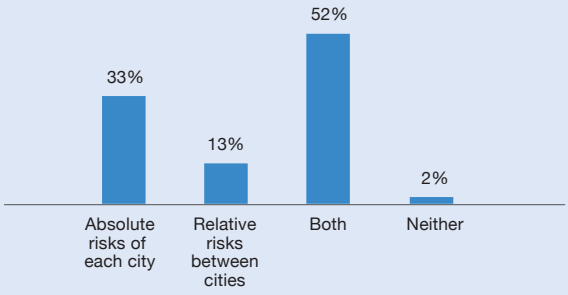
It is clear that they understood that long term SLR and storm surge risks impact valuations. The charts below show an overwhelming number of them "Strongly Agreed" and "Agreed" that tail risks from coastal threats will impact project valuations, sovereign credit ratings, corporate credit ratings and equity valuations. This share shifted from at least 83% at the start of the survey to 89% by the end of the survey for impact on equity valuations and corporate credit. Agreement on sovereigns and project valuations were even higher post survey at 93% and 97% respectively. Interestingly, the results across all types of valuations show a clear shift in favour of "Strongly Agree" post survey with the number of *"Disagrees" also falling. One noted "Changed my mind as I didn't realise all this data is available"*. Besides this, their concerns of over what's at risk also changed – more on this later in **"Finance says tail risks should be factored in valuations"**.



Source: CWR APACCT 20 Index - Finance Survey , May-July 2020

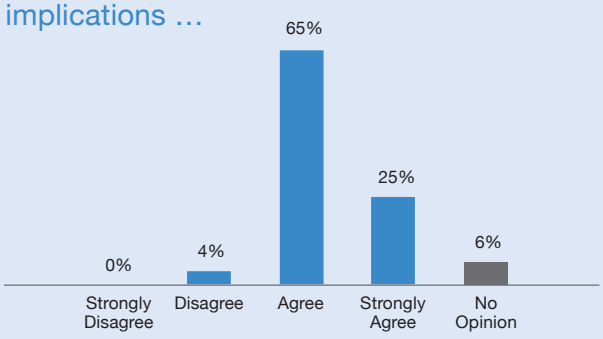
>50% want to see both the absolute & relative risks of the cities …

When evaluating coastal threats what are you interest in?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

90% said survey helped them better think through coastal threats & their financial implications …



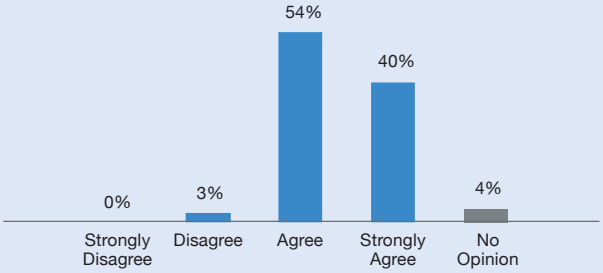
Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

94% want the index despite imperfections…

The index is far from comprehensive but is indicative of the relative risks. We are pleased to say that almost all those surveyed agree with us – that it is better to start with something than not have anything at all.

Imperfections in the index and relevant feedback are explored in detail in this report.

Now that you've seen what we are trying to do, I want this coastal threat index even though it has imperfections…



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Why build the CWR APACCT 20 Index?

We are already at 1.1°C-1.2°C; heading to 1.5°C by 2030 = locking in SLR of 1.6m-4.2m. According to the World Meteorological Organization (WMO) in January 2020, global temperatures are now at least 1.1°C above the pre-industrial period and reached 1.2°C in 2016.[1] By August 2020, the WMO warned of a 20% chance that one of the next five years (2020-2024) will be at least 1.5°C warmer.[2] This affirms the warning fired by the Intergovernmental Panel on Climate Change (IPCC) in 2018 of reaching 1.5°C as early as 2030[3]; this will trigger locked-in SLR of 1.6m-4.2m.[4] Although far out into the future (beyond 2100), there will be no way of turning back the clock on the continuous melting of our glaciers and thermal expansion of our oceans. For the past 25 years, our oceans have warmed at a rate similar to detonating five Hiroshima atomic bombs per second in our oceans.[5,6]

0.5m makes a difference for key infrastructure like ports & airports. When it comes to SLR, small changes matter. A change of half a metre may seem inconsequential, but it can have huge impacts not just on cities but key infrastructure like ports and airports. At a mere half a metre, 44 airports would be flooded worldwide; at one metre, the number almost doubles to 80 airports, says WRI.[7] This could disrupt logistics, trade and food and energy security for many Asian countries. Our analysis for CLSA's report ***"Thirsty & Underwater: Rising risks in the Greater Bay Area"*** show that as early as 2030, extreme storm tides will likely impact 43 out of the 50 ports and 4 of the 7 airports in the Greater Bay Area if no action was taken.[8]

APAC coastlines redefined at 1.5°C = up to 28mn people displaced & US$5.7trn at risk in 20 APAC cities. Already at 1.5°C, rising seas will have catastrophic consequences on our economies and people, especially in APAC where many cities are coastal and include country capitals. Swathes of its coastlines will be redefined – in this report, for the APAC 20 cities alone, we estimate that 15,006km^2 of land will be permanently submerged, displacing up to 28 million people at the 1.5°C locked-in SLR median of 2.9m[4] – see infographic **"Millions of people and billions of $$$ at risk"**. Together, these 20 cities generate around US$5.7trn of GDP, accounting for over a fifth of the GDP of the 14 APAC countries/territories where the cities are located.

1.5°C is our best-case & locked-in tail risks from coastal threats = shocks to financial system if not prepared. Many cities in APAC will be severely disrupted at 1.5°C. Abandoned cities and the upgrade/relocation of large infrastructure projects could trigger shocks to the financial system if it is not prepared. Ripple effects will be felt globally. A group of now 68+ central banks and supervisors under the Network for Greening the Financial System (NGFS) have recognised that climate and environmental risks have significant financial implications and *"are fully determined to continue their work to address climate-related and environmental risks"*.[9] All aspects of the financial sector, from asset managers, to banks and insurers, will be affected by the steps regulators are taking. Clearly, we must start factoring chronic tail risks from 1.5°C locked-in SLR today. Catch up on the changing financial regulatory landscape ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

Focus on 2100 = locked-in SLR overlooked + APAC complacent in decarbonising. Impacts from locked-in SLR are generally overlooked as climate scenario analyses focus on carbon transition risks. Also, climate impact scenarios (if done) are projected on a 2100 timeline, but sea levels will not stop rising in 2100 as temperature tipping points are passed. Not mapping and assessing how they will certainly disrupt and reshape APAC, makes the region complacent towards decarbonising – among the Top 30 per capita GHG emitters are Australia (#10), New Zealand (#21) and South Korea (#27).[10] We need to understand the latest science if we are to come up with effective strategies.

Sadly, we are on track for 3°C–5°C by 2100 = locking in 6.9m–10.8m of SLR at 4°C. Globally, we are on track for 3°C-5°C of global warming by 2100 according to the 2019 UNEP Emissions Gap Report.[11] This current trajectory means that we are set to lock-in a devastating 6.9m-10.8m of SLR at 4°C.[4] We estimate that up to 102 million people from 20 APAC cities will be displaced at the 4°C range median of 8.9m.[4] This may sound high, but the last time our planet was this hot, sea levels were 6m-9.3m higher than they are today.[12,13] See infographic **"Submerged! Locked-in (1.5°C) vs. on track (4°C)"**.

Financial consensus is 3°C-4°C as the new base case but many APAC cities will not survive. There is growing consensus and resignation in the financial industry that 3°C-4°C should be used as the base case to assess climate impacts given the stasis around global decarbonisation efforts and the Paris Agreement. However, resorting to this new base case ignores the fact that many APAC cities will likely not survive the accompanied chronic SLR tail risks that come with this scenario. As can be seen from the charts in **"APAC 20 SLR Stranded Assets Snapshot for 1.5°C, 2°C, 3°C and 4°C"**, stranded asset risks rise with every climate scenario across all key indicators of population, land, airports, ports and central business district (CBD).

Significant tail risks lurk questioning going concern assumptions = financial recalibration inevitable. Given significant exposure, these risks must be factored in. That they fall in a "timeframe beyond our lifetime" is not a valid argument as the assumption of infinite going concern is a concept that underpins all valuation models in the financial industry. Once we pass tipping points, SLR will be locked-in; surely, this certainty warrants adjustments to underlying assumptions in all financial valuations? Such chronic tail risks should thus be factored in today so that the financial system can ensure resiliency through repricing and reallocation of capital. New valuation methods do not need to be invented, current models can accommodate – at minimum, sovereign credit ratings should be re-rated and the cost of capital adjusted; terminal values should also face downward revision. This recalibration of valuations and risks across the financial industry is inevitable – more on this in ***"Sovereigns at Risk: APAC Capital Threats"***.

Coastal threat index created to close real threat assessment knowledge gap in APAC. A reason for inertia is because we cannot "see" the consequences of our actions – many key policy makers, business leaders, bankers and investors are simply not aware of the impacts. To close this knowledge gap, we have created the **CWR APAC Coastal Threat Index for 20 cities (CWR APACCT 20 Index)** with ***"CWR APACCT 20 Index City Factsheets"***. The CWR APACCT 20 Index reflects mapped stacked SLR risks for four climate scenarios (1.5°C, 2°C, 3°C and 4°C) for 20 APAC cities across key indicators (population, land area and key infrastructure assets). Storm surge threats from typhoons/tropical cyclones/hurricanes plus government adaptation actions to reduce physical risks have also been assessed and considered in the index.

Index is far from perfect but results alarm + show importance of government action. This is a first attempt to unpack complex interlinked coastal water risks for the APAC region. It is far from perfect and we faced many challenges in its development. On this front, we are grateful to have had high-level quality input from 100+ finance professionals ranging from chairs/directors of bank boards to research analysts and financial regulators. Their input has been invaluable and index weightings were adjusted depending on their input. Their input in defining the type of index to build plus how to address challenges faced in its execution are detailed in this report. The index results and rankings provide a first glance at the absolute and relative risks and they are alarming. Our review of government adaptation actions has also surfaced no-sense climate strategies from governments to corporates – these no sense strategies must go. Case studies of government adaptation across the region can be found in our report ***"Sovereigns at Risk: APAC Capital Threats"***.

All stakeholders must act = gauge tail risks, rethink valuations + reallocate capital. The NGFS has already recognised that fundamental changes must be made to account for systemic risks ahead.[14] Tail risks often overlooked and ignored are an integral part of such assessment. By adjusting for these, costly carbon transition pathways, risky business unusual start-ups and no/low return adaptation projects will likely be reconsidered investment worthy. We hope that all stakeholders from governments, central banks to investors and corporates will use this series of reports to gauge absolute and relative tail risks and rethink APAC capital allocation. Thus, we have also set out actions for these groups in ***"Waterproofing APAC to Avoid Atlantis: Executive Summary & Next Steps"***.

Only 9 years left to close emissions gap for 1.5°C = no sense climate strategies must go. This is a Herculean task – to stay within 1.5°C by 2100, new aggressive ambitions must be 5.8x those agreed in the 2015 Paris Agreement.[11] Efforts to be made are sobering – while China and some of the EU have made carbon neutrality pledges, the U.S. has pulled out of the Paris Agreement. Although COVID-19 has provided some reprieve, another decade of coronavirus is needed to get us back on track for 1.5°C by 2100.[15] Financial mispricing of fundamentals has allowed no sense climate strategies to pervade – these must be adjusted. Also, we must make all out efforts to fast track decarbonisation across APAC to avoid 4°C at all cost – mismatched climate strategies must be realigned or else we will inadvertently trigger tipping points – please see **"Tipping points & runaway melt – window to act closes by 2030"** in Section 1.

It's time to get real! Be prudent, be prepared = CWR APACCT 20 Index can be used as best, base + worst case. We have thus developed the CWR APACCT 20 Index to help kick start a much needed conversation on tail risks and adaptation, close knowledge gaps, fast-track decarbonisation and catalyse action to waterproof APAC. Despite global efforts, we will likely reach 1.5°C by 2030 – 70 years ahead of schedule.[3] This means that our 1.5°C Index can be used to gauge best-case exposure whereas our 4°C Index reflects the base case. That said, locked-in SLR impacts may be brought forward by a few hundred years due to unprecedented polar melt, so it pays to be prudent – check out **"How to use the CWR APACCT 20 Index for worst-case benchmarking"**.

We hope you find it useful & we wish you luck in avoiding Atlantis and systemic shocks. Good luck with your journey to waterproof assets/ portfolios/ cities/ territory/ country/ region against capital threats and systemic shocks triggered by climate risks. Do contact us if you get stuck! We value your continued support and welcome feedback to improve the index. Please email us at info@chinawaterrisk.org

How to read this report…

Long-term climate threats such as SLR and storm surge will impact the cost of capital and should be factored into sovereign and corporate credit risk ratings and equity valuations. The CWR APACCT 20 Index and the ***"CWR APACCT 20 Index City Factsheets"*** are envisaged to help multi-stakeholders understand the relative and absolute coastal threats facing APAC cities to quantify these complex risks. We hope that the CWR APACCT 20 Index at 1.5°C (best-case) and 4°C (base case) will help the financial sector as well as corporates to make better capital allocation decisions as the relative risks and gaps in adaptation can be identified.

This report ONLY covers the rationale and challenges behind creating the CWR APACCT 20 Index as well as the results. Implications for countries and threats to sovereign risk ratings have been analysed and explored in a separate report – ***"Sovereigns at Risk: APAC Capital Threats"***. Recommended actions and next steps for various stakeholders such as asset owners/managers, banks, central banks/regulators and governments can be found in ***"Waterproofing APAC to Avoid Atlantis: Executive Summary & Next Steps"***. Details of how to build coastal threat scenarios together with the latest developments in the financial sector regarding climate risks can be found in ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

Regarding the index, the aim was to keep the methodology as simple as possible. We wanted an index that would not only reflect which cities are most at risk and which need to do more, but also those that are the safest investment havens for now as they face fewer physical risks and/or significant government action is taking place. However, the subject matter is complex and difficult to standardise as cities face different levels and types of risks. We recognise the dangers of oversimplifying the methodology as certain risks cannot be included but we have endeavoured to include risks that are difficult to quantify through proxies. Inputs from the financial sector have thus helped drive consensus on the type of index to be built, which climate scenarios to use, the components and proxy indicators to include plus their relative weightings for the index as well as methodologies used to overcome data gaps and other challenges faced in the execution of the index. So, although far from perfect, we believe it represents a good start.

This journey of building consensus toward the creation and execution of the CWR APACCT 20 Index is detailed in in this report in four distinct sections. Feedback from the financial sector has been weaved into each of these sections to provide a fuller picture and for easy reference:

1. **Reality Check! The current risk landscape** – this section provides context, approach and rationale behind creating the index. Why 1.5°C and 4°C climate scenarios were selected, SLR tipping points, storm surge impacts and their implications for finance are included here. Snapshots of impacts for all 20 cities for 1.5°C and 4°C scenarios can be found in this section;
2. **Recalibrating finance for tail risks** – this section focuses on the type of index built so that it would be useful for the financial sector. Existing indices – how useful are they? Which physical threat factors to include, what proxy indicators to use and what type of government action to include are discussed here. SLR stranded asset risks across scenarios and terminal valuation re-calculations are also included here.
3. **CWR APACCT 20 Index results & rankings** – this section sets out the key components of the CWR APACCT 20 Index and the index scores and rankings of the 20 APAC cities at both 1.5°C (best-case) and 4°C (base case). Index rankings with and without government action have also been calculated and discussed in this section. For an at-a-glance coastal threat assessments for each individual city, please refer to **"Appendix 1: CWR APACCT 20 Index City Factsheets"**. This section also includes how to use the CWR APACCT 20 Index to benchmark worst-case SLR scenarios.
4. **5 Key Challenges** – this section explores the challenges faced in the execution of the index. These challenges are 1) SLR projection uncertainties; 2) topographical mapping granularity; 3) flooding methodology inaccuracies; 4) factoring in event-driven storm surges and 5) non-standardised government actions. Each of these were challenging for one city given research gaps, let alone finding consistent and comparable methodologies across the 20 cities.

We have started with 20 cities; but this is by no means a complete list. We see the CWR APACCT 20 Index as a conversation starter in the financial space to trigger more action to address climate tail risks that are being lockedin today. Through feedback and more funding support we aim to improve on key indicators as well as expand city coverage so that the index can be useful to multiple stakeholders.

Please contact us for collaboration and/or feedback at info@chinawaterrisk.org - together, we can work toward building consensus on correctly valuing water risks to avoid systemic shocks ahead triggered by climate change.

This is a start - finance wants more…

While dire consequences of climate threats lie ahead, the good news is that the financial sector has recognised their ability to trigger systemic shocks. One warned: *"The role of contingent capital (insurance) to mitigate financial loss or damage to physical assets cannot be relied on. Public and private balance sheets will become increasingly stressed as each consider physical loss or damage from SLR or storm surge (as well as other nat cat events)."*

Another stated that *"With sovereign credit ratings, these issues have a definite and material impact. At an issuer and project level, they should be considered depending entirely on the issuer, location, areas of operation, industry, and its own unique exposure to these risks."*

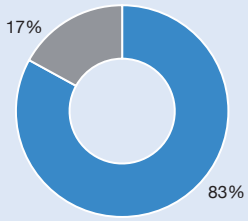
They wanted to do more to assess water related climate risk. Building financial consensus towards a valuation methodology to gauge tail risks is a start and feedback from the 100+ finance professionals certainly revealed a high level of interest (voluntary willingness toward continued involvement) in this trend. After completing the survey, a few of them also invited their peers to participate...

After the survey …

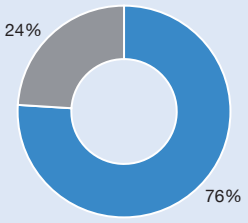
Tracking index development & getting involved

As the survey was conducted on an anonymous basis, they had to provide email contact to track development.

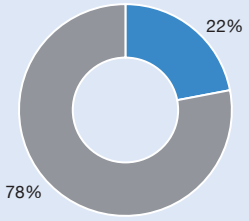
83% want to receive a copy of the report, methodology & index



76% want to be kept updated on the index's progress



22% want to be more involved in creation of the CWR APACCT 20 Index



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Expanding the CWR APACCT 20 Index

Want more cities evaluated in the index. Already, we have had requests to expand the index to more countries including cities in South Asia (Mumbai, Chennai, Colombo & Dhaka) and Malaysia (Melaka, Penang, Kuala Lumpur/Greater Klang Valley). There were also suggestions to include more cities in countries already covered such as Japan (Yokohama & Fukuoka), Australia (Melbourne, Brisbane & Perth), New Zealand (Wellington), Korea (Busan), Indonesia (Medan & Surabaya), China (Hangzhou & Xiamen) and Vietnam (Can Tho & Da Nang).

Want CWR to build indices for other types of water risks. There were also requests for different types of water risks reflecting their need to assess them. Requests centred around – rainfall/flood risk (inland & coastal flooding), fresh water scarcity impact on liveabi lity and operating feasibility for organisations, water stress, wastewater, resilience of water infrastructure (dams), water pricing/elasticity and sedimentation of watersheds.

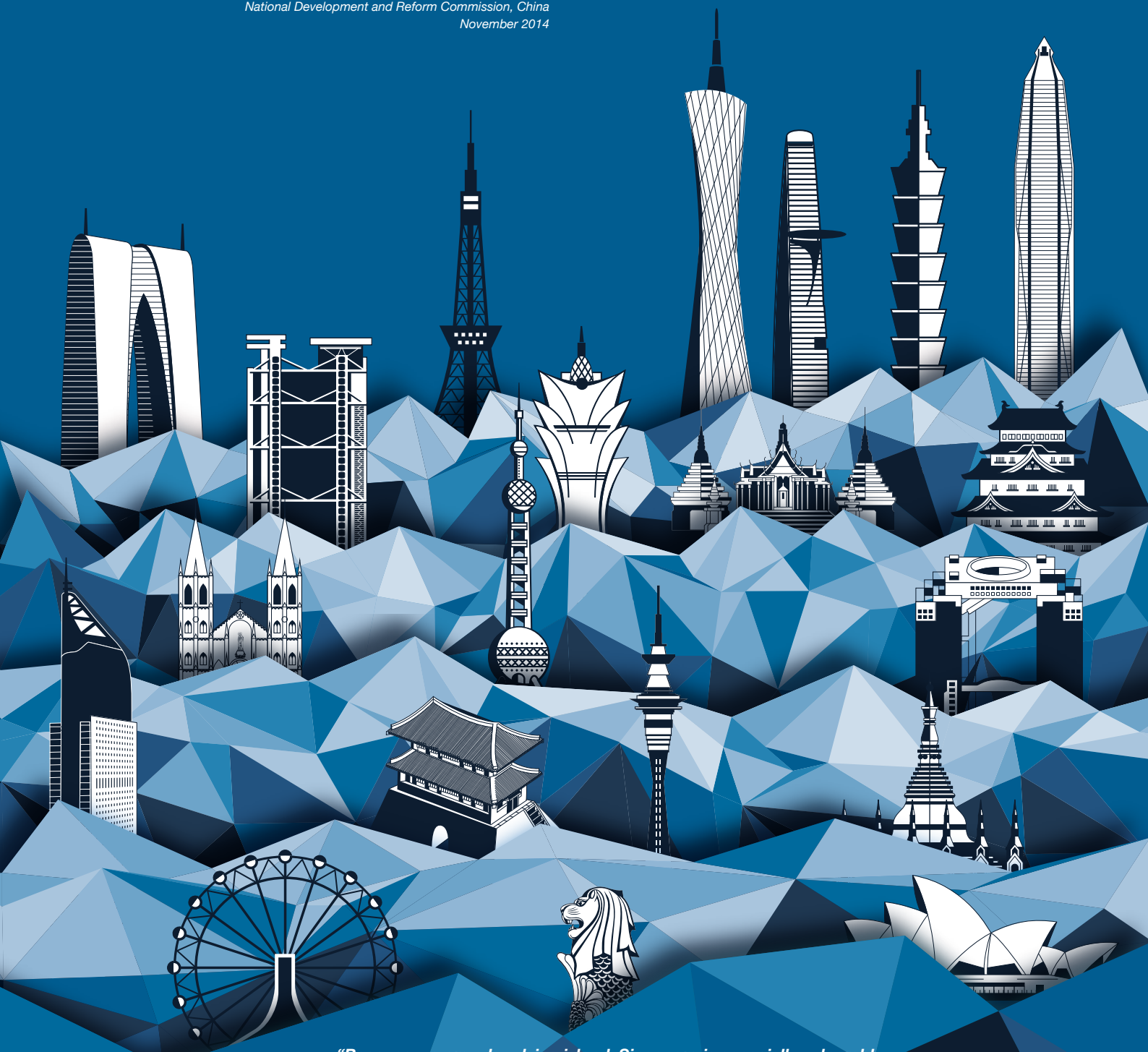
There was also a nod toward their complexities and a suggestion to explore their inter-linked nature to assess cascading risks – *"Some are drowning in water due to climate change. Others are dying from thirst / heat too. Desertification due to climate change is the flip side of water risk - a shortage of water. Maybe it's an inverse relationship but it's also an outcome like a rise in sea level. That is outside the scope of this study. Being inter related it may be worth considering in the future"*

We would love to accommodate the requests above but please bear with us as we will need to find funding support for the work. If you like what we are doing and are interested to work together, please contact us at info@chinawaterrisk.org

Contents

"Guangzhou will have 1,000m² of land underwater and the PRD area [Pearl River Delta] will have 5,000m² of land underwater if sea levels rise by 0.3m"

Jiang Kejun, Director, Energy Research Institute
National Development and Reform Commission, China
November 2014



"Because we are a low-lying island, Singapore is especially vulnerable to one grave threat, and that is rising sea levels... Not only will property values be affected, but safety and liveability also. We cannot expect to lose a big chunk of our city and expect the rest of Singapore to carry on as usual."

Prime Minister of Singapore Lee Hsien Loong
August 2019

Reality check!
The current risk landscape

Section 1

"Some portions of the ancient and massive ice sheets covering Antarctica and Greenland, together holding over 60 m (200 ft) of sea-level rise, may have begun irreversible melting already at today's temperatures. This risk becomes more certain as temperatures rise, especially if maintained over time, even at levels 1.5–2.5°C."

Leading cryosphere scientists
International Cryosphere Climate Imitative Report 2015

"The average global temperature has risen by about 1.1°C since the pre-industrial era and ocean heat content is at a record level. On the current path of carbon dioxide emissions, we are heading towards a temperature increase of 3°C to 5°C by the end of century."

Petteri Taalas, Secretary-General
World Meteorological Organization
January 2020

Realistic scenarios: heading for 3°C-4°C/locking in 1.5°C

Pledges under the Paris Agreement are not enough…

…at best we will reach ~3°C (median) by 2100 if all NDCs are met

…the US officially pulled out in 2020

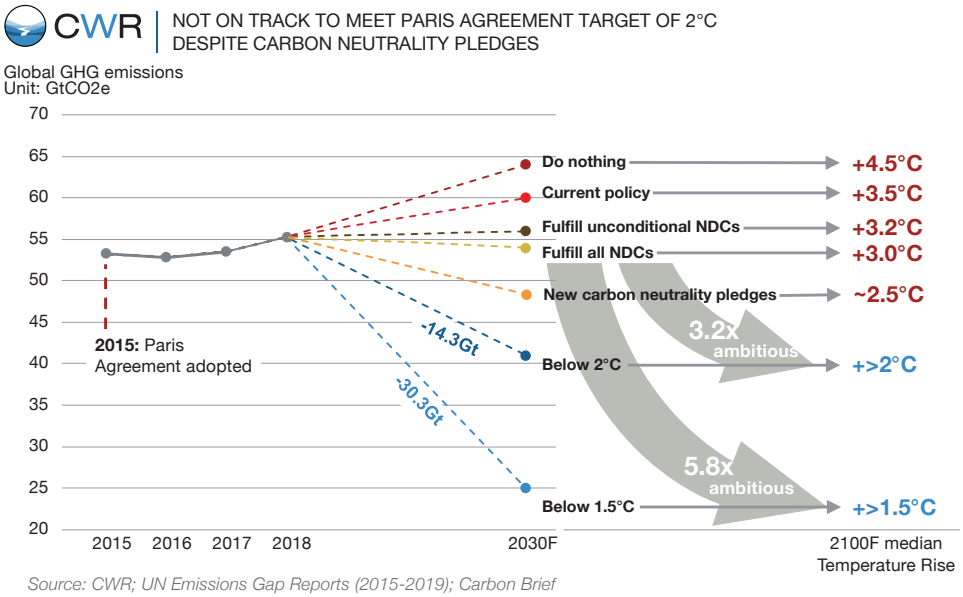
We are on track for 3°C-4°C, if we meet pledges under the Paris Agreement. To avoid the potential detrimental consequences of a warming planet the Paris Agreement in 2015 aimed to ensure we stay within 1.5°C-2°C of global warming by 2100 compared to the pre-industrial period.[16] However, pledges made under the Paris Agreement fall short. Even if we meet all unconditional Nationally Determined Contributions (NDCs) under the Paris Agreement, we are still on course for 3.2°C (range: 3.0°C-3.5°C); and adding conditional NDCs brings us to 3°C (range: 2.8°C-3.3°C).[11] If we do nothing, we are looking at over 4.5°C of warming by 2100. The UNEP Emissions Gap Report 2019 projects at least 3.5°C by 2100, given current policies.[11]

Ambitions need to be 5.8x that of Paris Agreement for 1.5°C by 2100. The chart below shows the various trajectories going forward depending on action taken. As can be seen, aggressive action needs to be taken if we were to reach the intended targets – 3.2x ambitions of the Paris Agreement for 2°C and 5.8x ambitions for 1.5°C.[11] Whilst the EU and China (plus more) made carbon neutrality pledges, they won't help avoid 1.5°C by 2030, but may steer us to ~2.5°C by 2100; China's 2060 pledge alone accounts for a 0.2°C-0.3°C drop.[17] But saying is not the same as doing plus the US has pulled out so unless there's cohesive action, we may still end up at 3°C-5°C[1].

We will likely end up warming by 4.5°C or more by 2100

For 1.5°C by 2100, we need to up ambitions under the Paris Agreement by 5.8x …

…or suffer a decade of COVID-19; making 1.5°C the best-case scenario



Source: CWR; UN Emissions Gap Reports (2015-2019); Carbon Brief

Already, global temperatures have warmed by 1.1°C; with high of 1.2°C in 2016

We are already at 1.1°C-1.2°C, COVID-19 unlikely to shift climate trajectory from 3°C-4°C. According to the WMO in January 2020, global temperatures are now at least 1.1°C above the pre-industrial period with a high of 1.2°C in 2016 yet emissions have been rising to 55.3GtCO2e in 2018.[1;11] Although there has been relief in 2020 due to the coronavirus pandemic, with carbon emissions expected to fall 4-7%, experts warn that such cuts will need to last through to 2030 to steer the world back on track for 1.5°C.[15] No one wants a decade of COVID-19 and with the economy opening back up, it is likely that we are still heading for 4°C by 2100 (range: 3°C-5°C as per the WMO). Regardless, our analysis show that 1.5°C impacts are already material for each of the 20 APAC cities – see maps of **"CWR APACCT 20 Snapshot"** for both 1.5°C and 4°C later.

Our base case is thus 4°C…

…must start factoring in chronic tail risks for 1.5°C + run scenarios to gauge threats at 4°C

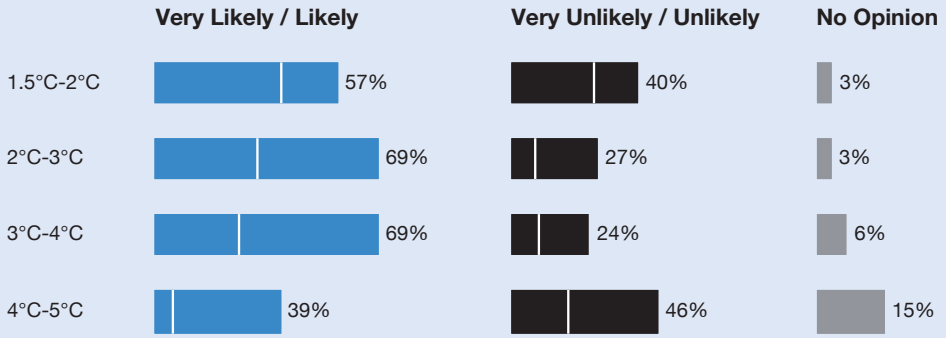
Use realistic scenarios or risk getting blindsided: adjust valuations for 1.5°C locked-in chronic tail risks + run scenarios for 4°C. As temperature increases will lead to severe repercussions, governments, companies and investors should adjust valuations and build scenario plans that can reflect the potential reality. Consensus from the finance sector indicates that the new base case should be 3°C–4°C plus they recognised physical baked-in impacts at 1.5°C - see following page for results. We thus urge the financial sector to 1) start factoring in guaranteed chronic tail risks associated with locked-in SLR at 1.5°C by recalibrating valuations and 2) run scenarios to gauge current trajectory at the high-end of the 3°C-4°C range. Also, if you think coastal threats are too far out, think again, risks have already started to manifest through storm surges and subsidence. Read on.

How finance professionals surveyed see climate change

3°C-4°C is the new base case – highest "likely" votes & least "unlikely" votes. The finance professionals surveyed agreed with this as the new base case for assessing risks. Their consensus toward 3°C-4°C is clear from the charts below. Although 69% opined that both the 3°C-4°C and 2°C-3°C scenarios are either "likely" and "very likely", they were more confident of reaching 2°C-3°C with the higher confidence reflected by the more votes for "very likely". However, 2°C-3°C received more "unlikely" and "very unlikely" votes than 3°C-4°C putting 3°C-4°C ahead as the consensus view.

Finance sector consensus indicates new base case should be 3°C–4°C…

How likely is it that the base case (highest probability) for global warming by 2100 compared to the pre- industrial period will reach:



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

…69% said this was "very likely" and "likely"; with least "very unlikely" and "unlikely" votes

Other points to note are:

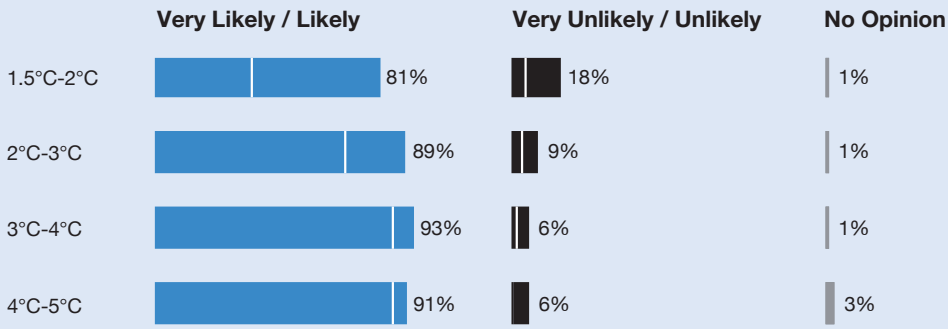
- Of all the scenarios, 1.5°C-2°C received the highest share of "very likely" votes at 39% as well as the highest number of "very unlikely" votes at 26%. In short, while they are confident of reaching 1.5°C-2°C, they are also of the view that it is an unlikely base case scenario; and
- The share of "no opinion" increases significantly at 4°C-5°C indicating less confidence at the top end of the range.

"No opinion" votes highest for 4°C-5°C signalling less confidence

Higher temperature rise brings more risk. The finance professionals surveyed also understood that rising temperatures bring rising risks. As per the chart below the trend of increasing confidence is denoted by the clear increasing share of "very likely" votes as temperature scenarios rise.

Risks rise with temperature but…

Will temperature rises bring more physical risks?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

…1.5°C-2°C of warming is not without risk …

81% recognise that 1.5°C-2°C scenario is not without risk. 81% of those surveyed said that physical risks are "likely" and "very likely" at 1.5°C-2°C.

…finance experts surveyed agreed

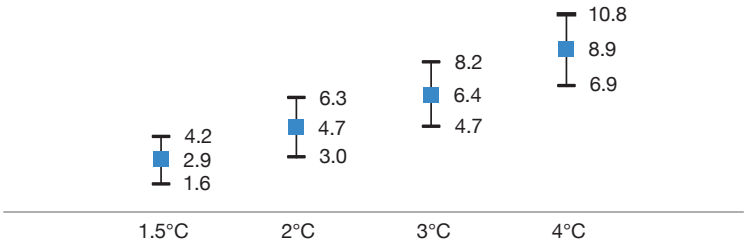
Locking in 1.5°C = redrawing city coastlines

Sea level rise (SLR) will be in multi-metres beyond 2100…

Sea levels rise as temperatures rise & they don't stop rising in 2100. As can be seen from the chart below, the range of SLR increases significantly from 1.6m at the low-end of the range for 1.5°C to 10.8m at the high-end of the range for 4°C. We have used this set of SLR estimates in the CWR APACCT 20 Index – please see **Appendix 2: "Locked-in SLR used in the CWR APACCT 20 Index"** for why we have selected these.

Seas do not stop rising beyond 2100; locked-in SLR ranges from 1.6m at 1.5°C to 10.8m at 4°C

Global locked-in sea level rise for different warming levels in metres



Note: SLR values represented in the range is the 66% confidence interval.
Source: Strauss, B. H., Kulp, S., & Levermann, A. (2015). Carbon choices determine US cities committed to futures below sea level. Proceedings of the National Academy of Sciences

Since likely to reach 1.5°C by 2030, we will likely lock-in median SLR of 2.9m…

…but given grim polar news, 2.9m may be felt by 2100

Reaching 1.5°C by 2030 means locking in 1.6m to 4.2m of SLR. In August 2020, the WMO warned of a 20% chance that one of the next five years (2020-2024) will be at least 1.5°C warmer.[2] The harsh reality is that by 2030, we will likely reach 1.5°C, thereby locking-in a median of 2.9m (range:1.6m to 4.2m) of SLR.[3,4] Although far out into the future (beyond 2100), there will be no way of turning back the clock on the continuous melting of our glaciers and thermal expansion of our oceans. For the past 25 years, our oceans are warming at the rate similar to the detonation of five Hiroshima atomic bombs per second in our oceans.[5,6] If we do not take drastic action on climate change, this rate will persist and the median SLR of 2.9m may well be a reality by 2100 – more on this later.

2.9m SLR will displace 28mn people across 20 APAC cities…

… land area equivalent to 22 Singapores will be permanently submerged

APAC is horribly exposed – even at 1.5°C coastal landscapes will be reshaped. For the 20 APAC cities analysed in this report, at a median SLR of 2.9m, at least 15,006km^2 of land will be submerged permanently. This amount of land lost to the seas is equivalent of the land area of 22 Singapores. Losing this amount of land area displaces an estimated 28 million people across the 20 cities. For perspective, this is almost the entire population of Australia and New Zealand combined. Moreover, 48% and 87% of the airports and ports respectively that serve the 20 cities will be permanently submerged, severely impairing food and energy security for some cities and countries. In short, we will lock-in an assured Atlantean future by reaching 1.5°C. Adapting our infrastructure (including finance) for this future, must thus start now - please see infographic.

At 4°C, 102mn will lose their homes as land area equivalent to 18 Tokyo Prefectures is lost to the sea…

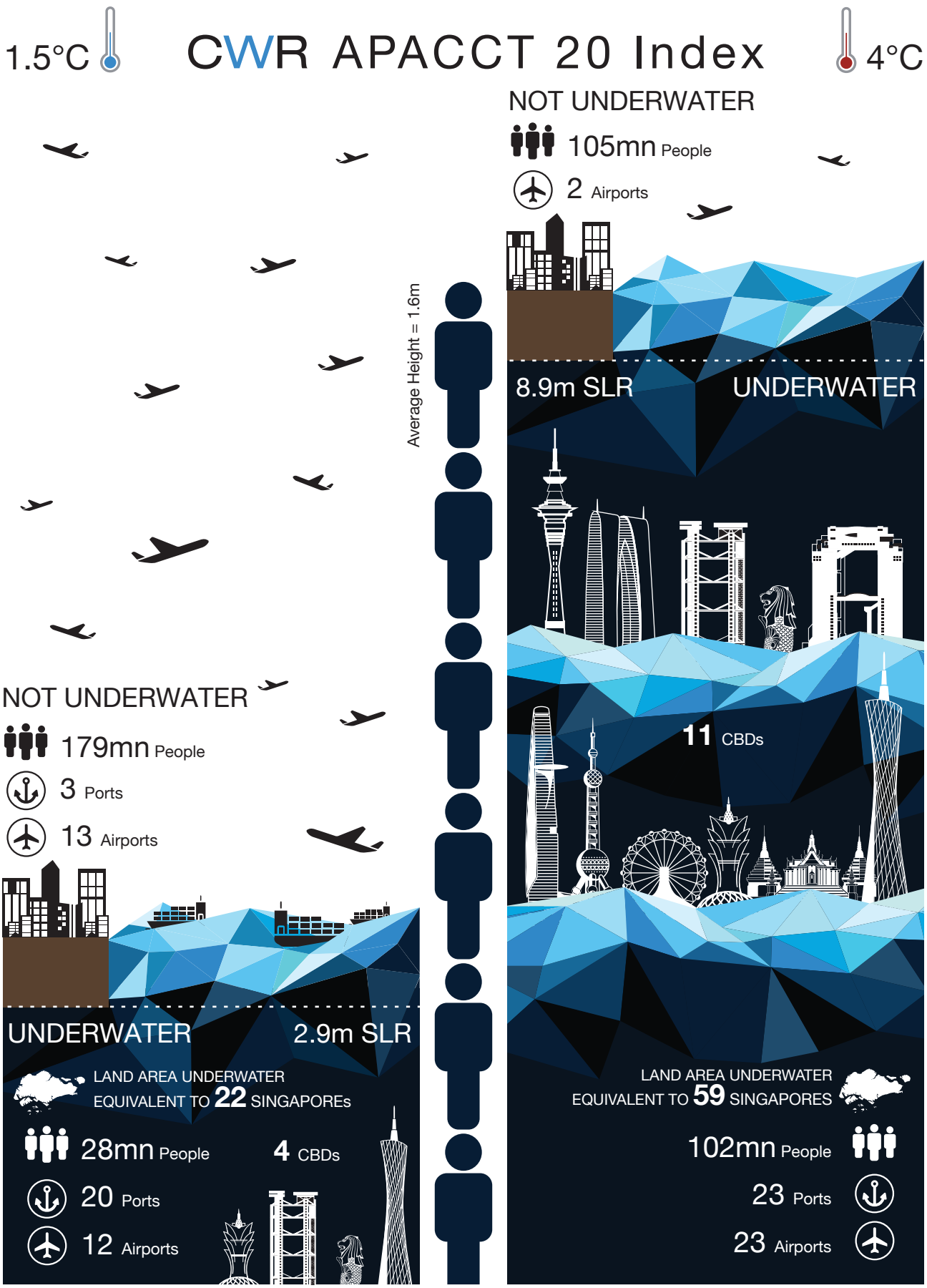
… 23/23 ports & 23/25 airports serving 20 cities will also be underwater

Risks rise exponentially at 4°C – population displaced is 3.6x that at 1.5°C. At the median of 8.9m for 4°C (which is the high-end of the new base case of 3°C-4°C), land area permanently submerged is 39,683km^2, 2.6x that of 1.5°C – equivalent to the land area of a staggering 18 Tokyo Prefectures or 6 Shanghais – and we are only talking about 20 cities. We estimate this will displace around 102 million which is half the population of the 20 cities – this is 3.6x that at 1.5°C. For perspective, this is equivalent to displacing the entire population of South Korea, Malaysia, Hong Kong, Singapore and New Zealand. Almost all key logistics infrastructure will be affected: 100% of ports (23/23) and 92% of airports (23/25) as well as more than half the CBDs (11/20). The difference between 1.5°C and 4°C is significant – please see infographic.

We analysed locked-in SLR impact on 1) land; 2) population 3) ports; 4) airports; 5) CBD; and 6) Stock Exchanges for 20 cities across 4 climate scenarios

Exposure varies by city but risks stack across key indicators for 1.5°C, 2°C, 3°C and 4°C. For each city, we analysed impacts of the four climate scenarios at the median level of lockedin (if any). The results show clearly that the cities are significantly exposed to chronic SLR tail risks - at-a-glance impacts on the individual cities can be found in infographics in the ensuing pages for both 1.5°C and 4°C. Further details of impacts for each city have been set out in **"Appendix 1: CWR APACCT 20 Index City Factsheets"**. For an overview of stacked risks for APAC exposure across all indicators, see **"APAC 20 SLR Stranded Assets Snapshot for 1.5°C, 2°C, 3°C and 4°C"** in the next section on **"Recalibrating finance for tail risks"**.

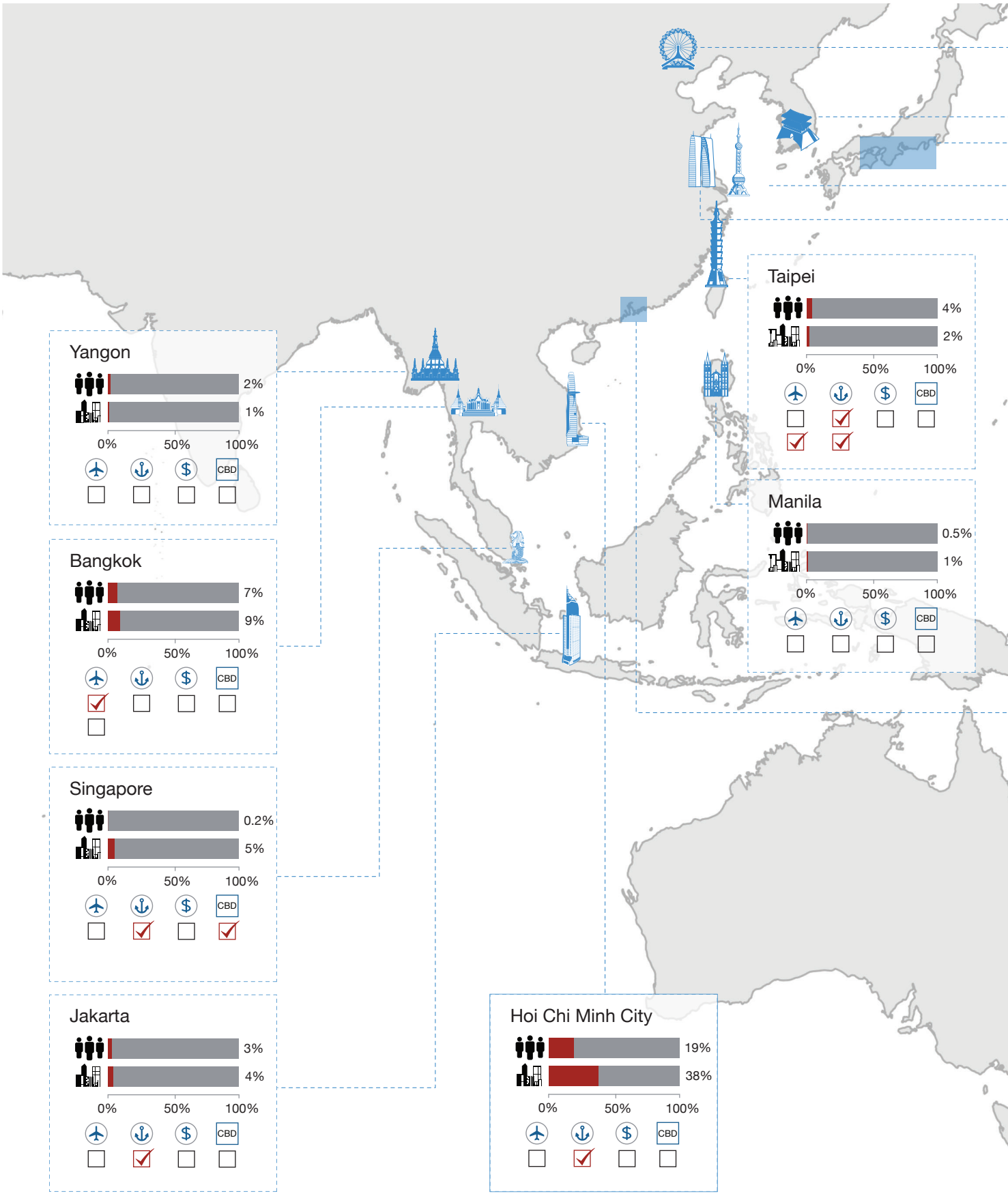
Submerged! Locked-in 1.5°C vs. On track 4°C



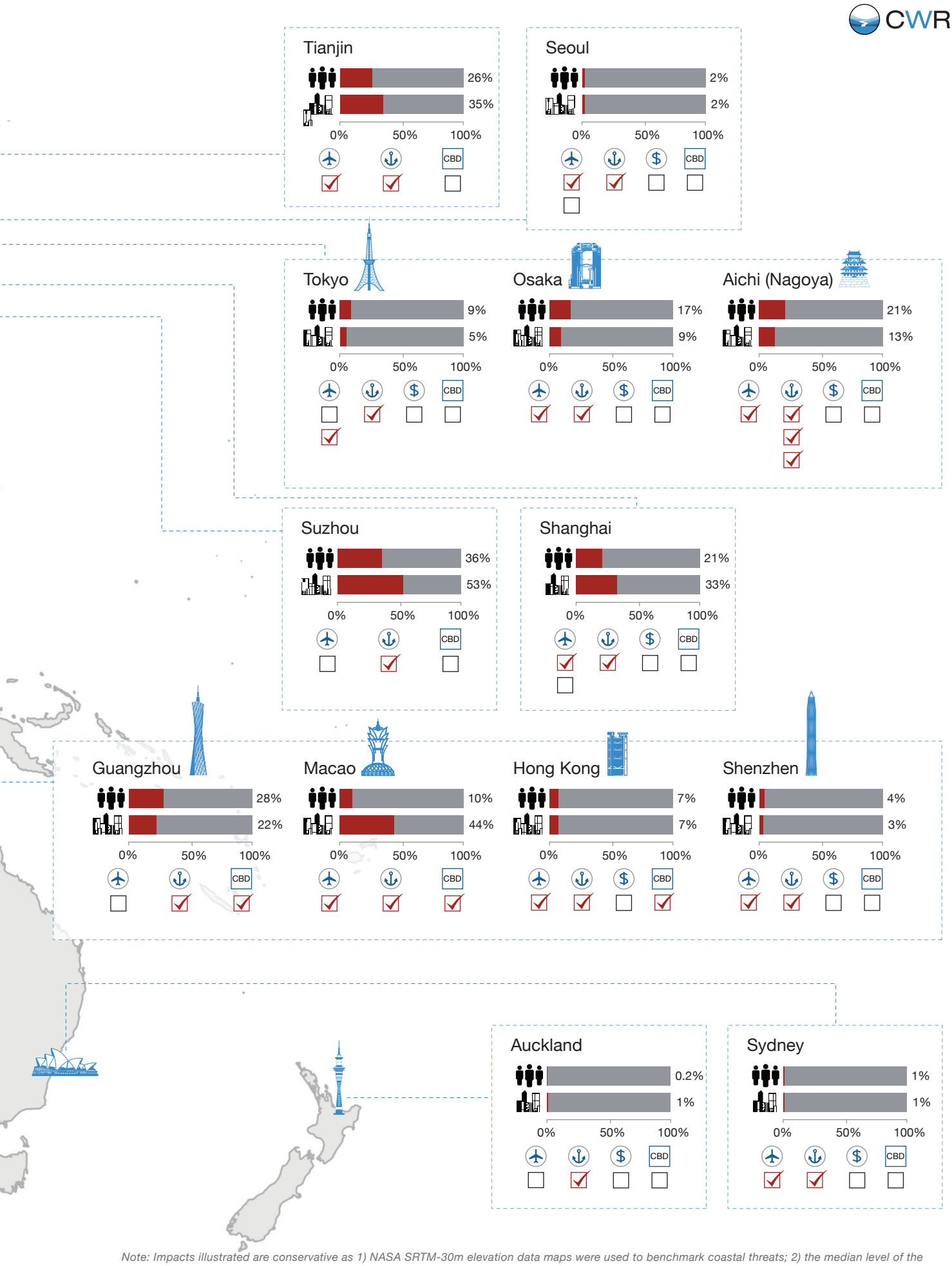
Source: CWR report "Avoiding Atlantis : The CWR APACCT 20 Index", 2020

CWR APACCT 20 Index

Snapshot: 1.5°C locked-in SLR impacts by city



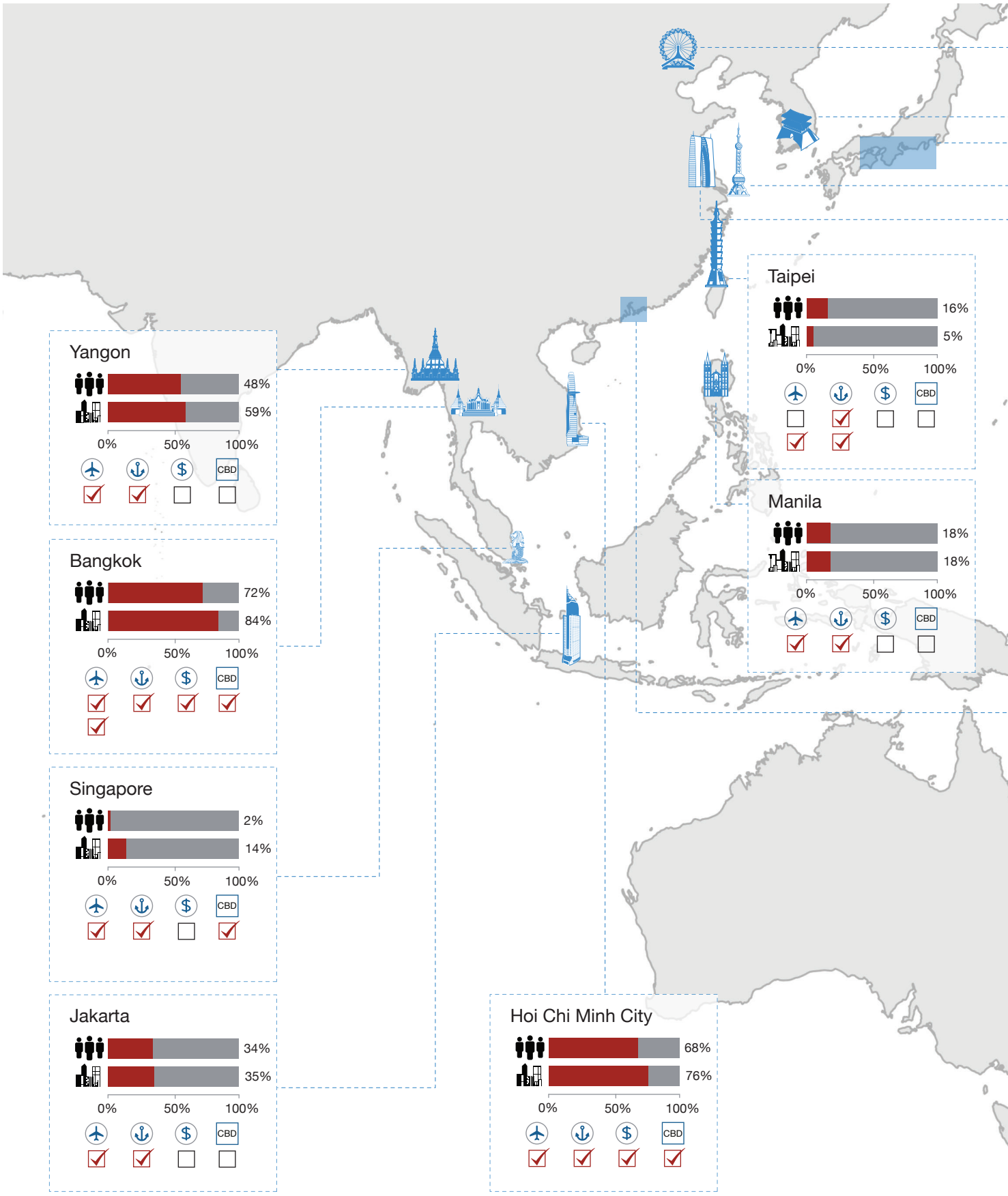
Source: The CWR APACCT 20 Index



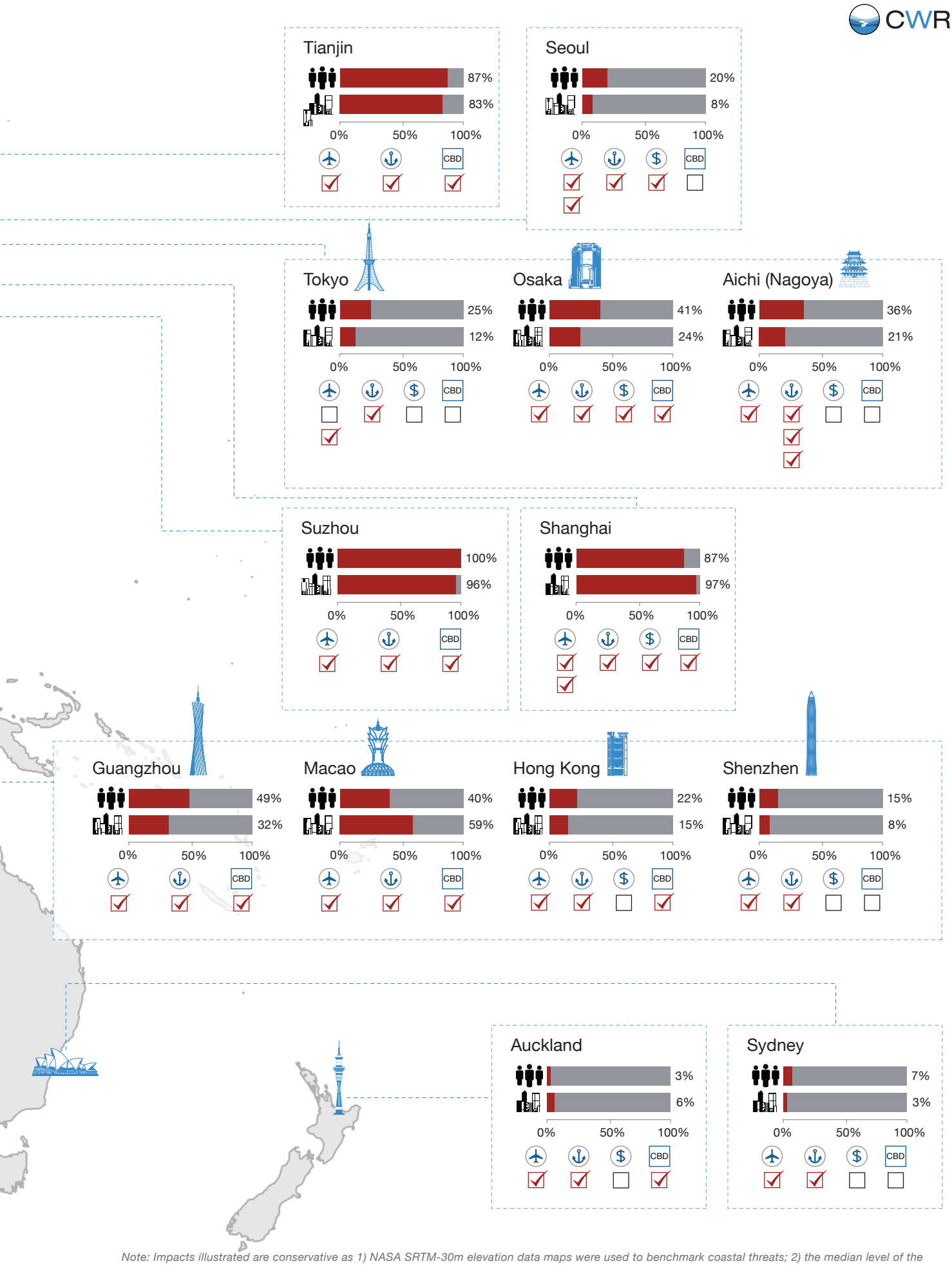
Note: Impacts illustrated are conservative as 1) NASA SRTM-30m elevation data maps were used to benchmark coastal threats; 2) the median level of the locked-in SLR range was used; and 3) local tide adjustments were not made. Since impacts will be worse at the higher end of the ranges plus our analyses generally show impacts worsen with higher granularity maps (5m), we recommend more in-depth analysis for hotspots of clustered risks that also factors in high tides – for how to do this please see ***"Changing Risk Landscapes: Coastal Threats to Central Banks"****.*

CWR APACCT 20 Index

Snapshot: 4°C locked-in SLR impacts by city



Source: The CWR APACCT 20 Index



Note: Impacts illustrated are conservative as 1) NASA SRTM-30m elevation data maps were used to benchmark coastal threats; 2) the median level of the locked-in SLR range was used; and 3) local tide adjustments were not made. Since impacts will be worse at the higher end of the ranges plus our analyses generally show impacts worsen with higher granularity maps (5m), we recommend more in-depth analysis for hotspots of clustered risks that also factors in high tides – for how to do this please see ***"Changing Risk Landscapes: Coastal Threats to Central Banks"****.*

Timing? It's more imminent than you think = be prudent

IPCC focus on 2100 timeframe = locked-in SLR impacts ignored

As the IPCC reports have been focused on a 2100 timeframe, the serious impacts of locked-in SLR projections beyond 2100 as shown in the maps in the previous pages are ignored. And while many of us have an idea that sea level rise will reshape the world as we know it, we may not know by exactly how much. Also, many of us believe impacts are too far off in the future to take action now. Unfortunately, impacts may be more imminent than we think, and SLR projections could be much higher due to the trends that have emerged on 1) SLR and temperature tipping points; and 2) increasingly frequent and extreme storm surges. These are discussed in detail below:

Impacts are more imminent than we think due to:
1. Temperature tipping points; and
2. Increasingly frequent & extreme storm surges

1. SLR & temperature tipping points – running out of time to avoid these

- **We consistently underestimate SLR.** Whilst projections regarding temperature rise correlations with CO_2 emissions are in range, the IPCC has been consistently conservative with its SLR estimates. Since the last IPCC Assessment Report (AR5) in 2014, IPCC's "Special Report on Ocean & Cryosphere" (IPCC-SROCC) in 2019 revised up median 2100 SLR projections by 14% for RCP8.5 (current climate pathway) to 0.86m. These may be small increments, but even 0.5m makes a difference - WRI estimates that globally, 44 airports will be impacted with 0.5m of SLR.[7]

IPCC consistently underestimates SLR + excludes rapid SLR from collapse of ice sheets…

- **IPCC does not include "deep uncertainties" & feedback loops that kick in at 1.5°C.** Though revised, IPCC SLR projections still do not include the "deep uncertainties" posed by marine ice cliff instabilities and feedback loops as we have yet to fully understand their complexities. These include the albedo effect of the loss of Arctic Ice; the irreversible melt and collapse of ice sheets in Antarctica as well as the disastrous impacts of permafrost – see box on feedback loops on the following page.

Scientists warn of locking-in SLR of 4m-10m+ if tipping points are passed …

- **Scientists agree on locked-in SLR of 4-10m or more.** Scientists are worried over irreversible trends once temperature tipping points are passed: *"should we exceed them, result in processes that cannot be halted unless temperatures return to levels below pre - industrial. To put it most bluntly, only a new "Little Ice Age" may re-establish some of today's mountain glaciers and their reliable water resources for millions of people; or halt melting polar ice sheets that, once started,* ***irrevocably would set the world on course to an ultimate sea-level rise of between 4-10 meters or more."***[18]

…already parts of Greenland & Antarctica have begun irreversible melt at today's ...

- **Irreversible melt of ice holding 60m+ of SLR has already started; risks rise with temperature.** *"Some portions of the ancient and massive ice sheets covering Antarctica and Greenland, together holding* ***over 60 m (200 ft) of sea-level rise, may have begun irreversible melting already at today's temperatures****. This risk becomes more certain as temperatures rise, especially if maintained over time, even at levels 1.5 –2.5°C."* [18]

We only have until 2030 (9 years) to prevent changes…

- **We don't have long – just until 2030 to avoid triggering irreversible tipping points.** The 'greatest hits' of cryosphere scientists warn that *"the windows to prevent some of these changes may close during the 2020–2030 commitment period… After 2030, changing the course of our global climate and therefore, future human history becomes far more difficult"*.[18] The graphic on the following page gives an idea of SLR impacts in the future – as you can see, it is imperative that we stay below 3°C; ideally 1.5°C.

Timelines are collapsing; 1.5°C by 2030 = 70 years ahead of time. So finance must adjust for earlier impacts

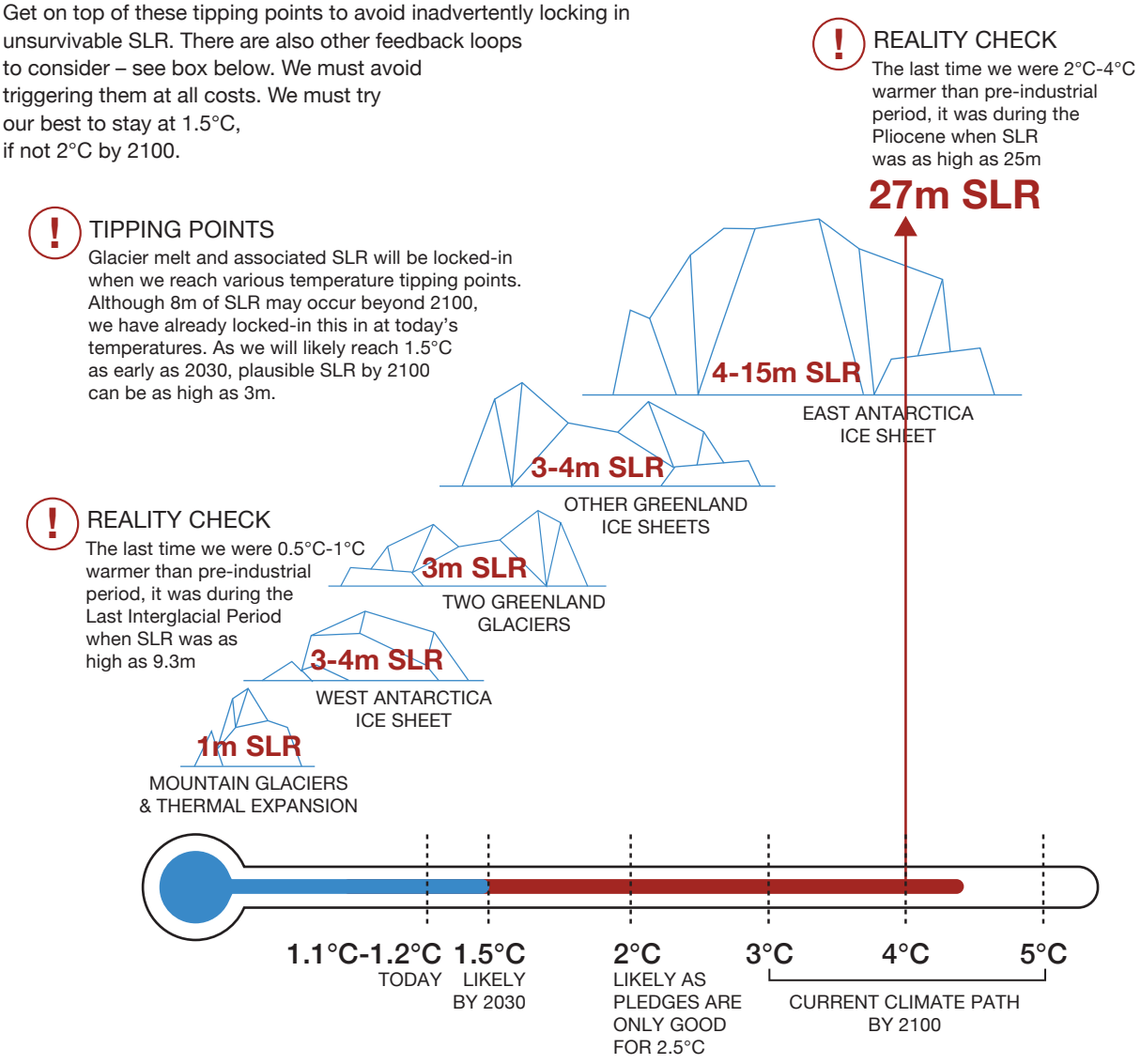
- **We are 70 years ahead of our 2100 target if we reach 1.5°C by 2030.** Given that we will likely be hitting 1.5°C 70 years earlier than projected, perhaps these "long timelines" are not so long after all.[3] These trigger points and impacts are thus worth our attention now. It is worth remembering that the last time our planet was as hot as it is now during the Last Interglacial period, sea levels were 6m-9.3m higher than they are today.[12,13]

Know our temperature tipping points; once past, only a Little Ice Age will stop SLR

- **Be prudent! Know our planetary tipping points to avoid accidentally triggering them.** If this is the first time you are hearing about these, we rest our case. We are not going to lie, there's grim news on ice melt. Our current path could bring impacts forward by hundreds of years, so know your science, use the right scenario, build the right models and make the right decisions today. Get on top of these in our other report ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***. Beware! Given grim polar news, 2.9m of SLR is an outlying plausible reality by 2100, so check out **"How to use the CWR APACCT 20 Index for worst-case benchmarking"** in Section 3.

Tipping points & runaway melt – window to act closes by 2030

It's not that far away! We will be 70 years ahead of our 2100 warming target if we reach 1.5°C by 2030. We must start paying attention to temperature trigger points and their SLR impacts. Parts of massive ice sheets covering Antarctica and Greenland, together holding over 60m of SLR, have already started irreversibly melting at today's temperatures. All 2020 observations regarding our cryosphere is grim. Given accelerated ocean warming plus rapid loss of ice in the Polar Regions, we have less than a decade to make a real difference. Get on top of these tipping points to avoid inadvertently locking in unsurvivable SLR. There are also other feedback loops to consider – see box below. We must avoid triggering them at all costs. We must try our best to stay at 1.5°C, if not 2°C by 2100.



Other feedback loops. If we cross a tipping point in our climate, vicious cycles/feedback loops take over and we become irreversibly set (i.e. locked-in) for an uninhabitable planet. Here are two other important feedback loops:

1. **Ice-albedo effect** – A more well-known feedback loop is the ice-albedo effect - the more ice that is melted, the less surface area there is to reflect sunlight. This in turn means the dark ocean surface absorbs the sunlight and accelerates melt. We are already experiencing this feedback loop.
2. **Permafrost thaw** – As our world warms, permafrost (frozen ground) in polar and tundra regions begin to melt, releasing methane, one of the most potent greenhouse gases. This in turn heats the world even more, releasing more methane. *"Permafrost experts agree that even a 30% loss of near-surface permafrost at 1.5°C warming may result in about 50Gt additional carbon emissions by 2100: this, when the 2-degree carbon budget allows only for 275Gt carbon released from all sources."* This additional release of carbon from permafrost has not yet been taken into account by current IPCC carbon budgets.

Source: CWR; International Cryosphere Climate Initiative report (2015); Rignot Expert Opinion (2018); Blackburn et al. (2020); IPCC-SROCC (2019); DeConto & Pollard (2016); Burke et al. (2018)

2. APAC is vulnerable to event-driven risk of storm surges

Many APAC capitals, financial, commercial & transport hubs are lowlying & exposed…

- **The APAC is particularly vulnerable to physical risk from storm surges.** Five of the top 10 countries most affected by "weather-related loss events" from 1998 to 2017 were in Asia according to the Germanwatch Global Climate Risk Index 2019.[19] With many of the APAC's capitals and financial, commercial and transport hubs found in low lying regions, coastal threats will be significant. Clearly there is a lot at stake, especially with expected economic growth and rapid urbanisation, which will put more people and GDP at risk. The seven typhoons and their storm surges illustrated on the following page already cost the region at least U$60bn between 2017 and 2019.[20]

…5 of Top 10 countries most affected by "weather-related loss events" were in Asia

By 2050, IPCC expects storm surges to happen at least once every year in all climate scenarios

- **Extreme sea level events every year by 2050.** Extreme sea levels brought on by events such as Typhoon Mangkhut (2018) or Hurricane Katrina (2005) have been historically rare. But according to the IPCC-SROCC in 2019 they are now projected to happen at least once every year by 2050 in all climate scenarios, especially in tropical regions. According to research by The Japan Agency for Marine-Earth Science and Technology and the University of Tokyo published in 2017, the number of strong tropical cyclones will increase by 6.6% by the end of this century compared to 1979-2008.[21]

Prime real estate flooded if Mangkhut hit directly at high tides (see map)

- **Hong Kong was lucky! Typhoon Mangkhut hit at low tide, or storm tides could have been 5.65m.** Typhoon Mangkhut was a T10 super typhoon that hit Hong Kong in 2018. It brought storm tides of 3.88m causing disruption and damage amounting to US$6bn in economic losses to the region.[22] But Hong Kong was lucky, if this typhoon hit Hong Kong at high tide at a slightly different angle, storm tides would have been 5.65m,[8] which would be disastrous as can be seen from the maps below.

Hong Kong could be hit by 9m+ storm tides by 2100

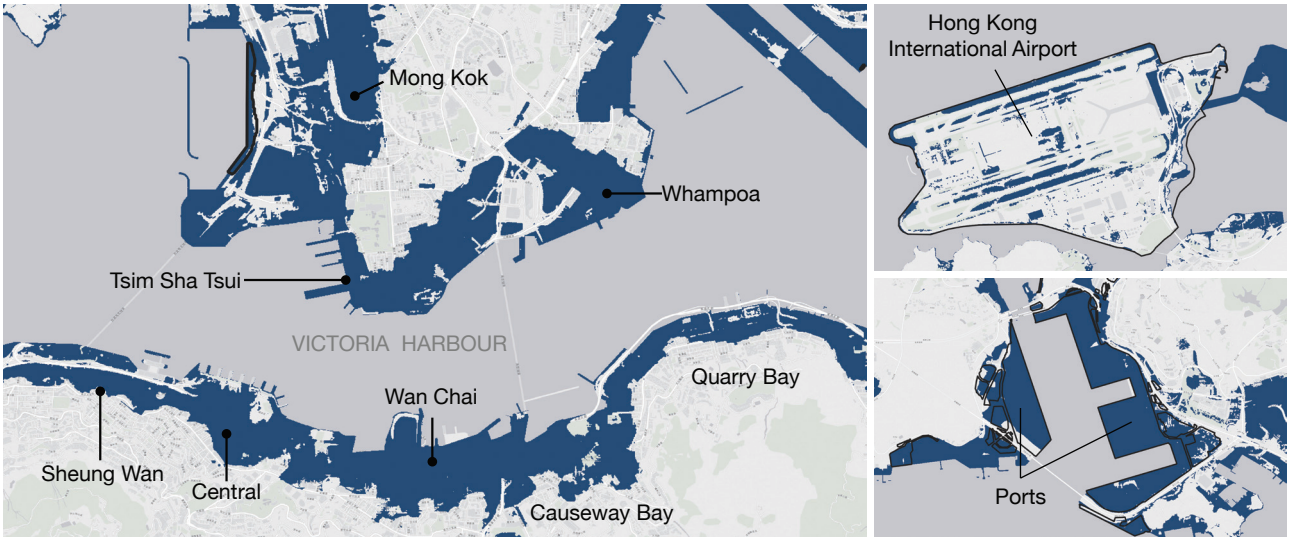
- **By 2100, "a Mangkhut" is expected to hit HK annually with storm tides of 9m+.** Mangkhut was a 1/50-100 year storm.[23] And according to IPCC-SROCC's Summary for Policymakers extreme sea level events from 1/100 year storms will likely happen annually by 2050 for low-lying megacities and by 2100 in most locations across all RCP scenarios. By 2100, actual 1/100 year storm tides could be as high as 9m – the HK government highlights areas vulnerable to storm tides below 5m and 10m above sea levels.[24] For more on calculating storm tides, see ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

2020 research expects magnitude of storm surges to increase 5%-15% by 2100 + more rain…

…acute storm surge risks turns into chronic risks

- **Beware! Check if cities are ready for future storms surges as insurers may not offer protection forever.** Recent 2020 research shows that the magnitude of storm surges is expected to increase by 5%-15% by 2100[25] and they will be coupled with more intense rainfall which in a 2°C scenario could increase by ~14%.[26] Given these projections, if these storms start occurring yearly, they may no longer be considered as acute risks but chronic resulting in the loss of insurance coverage or premiums will be exorbitantly priced. This means that risks are passed onto banks and the inability to renew flood insurance could render mortgages/buildings worthless. Storm surge threats are thus included in the CWR APACCT 20 Index; this exercise did not come without challenges – please see **"Storm surge projections – simple metrics vs. expensive modelling?"** in the section titled **"5 Key Challenges"**.

CWR | HONG KONG WAS LUCKY! MANGKHUT COULD HAVE CAUSED STORM TIDE OF 5.65M

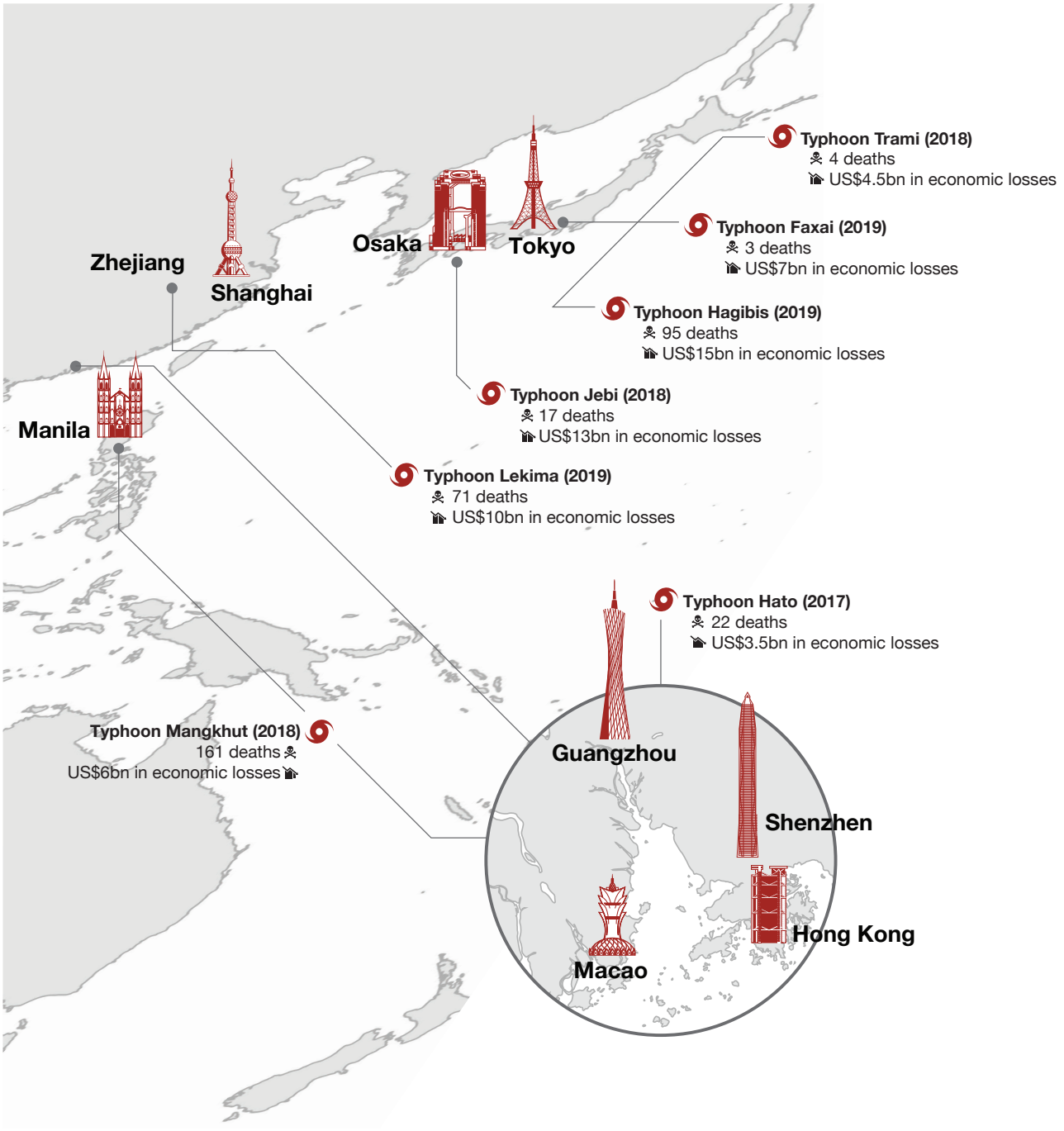


Source: CWR based on Digital Terrain Model (5m-grid) from the Lands Department of Hong Kong, ESRI

Storm surges – it's not 2050 or 2100, it's happening now

Climate change has already led to worse floods, droughts and storm surges/tides which have had devastating consequences on economies and livelihoods in APAC. The graphic below only shows the impacts of seven typhoons from the region from 2017-2019; yet the losses already amount to almost US$60bn.

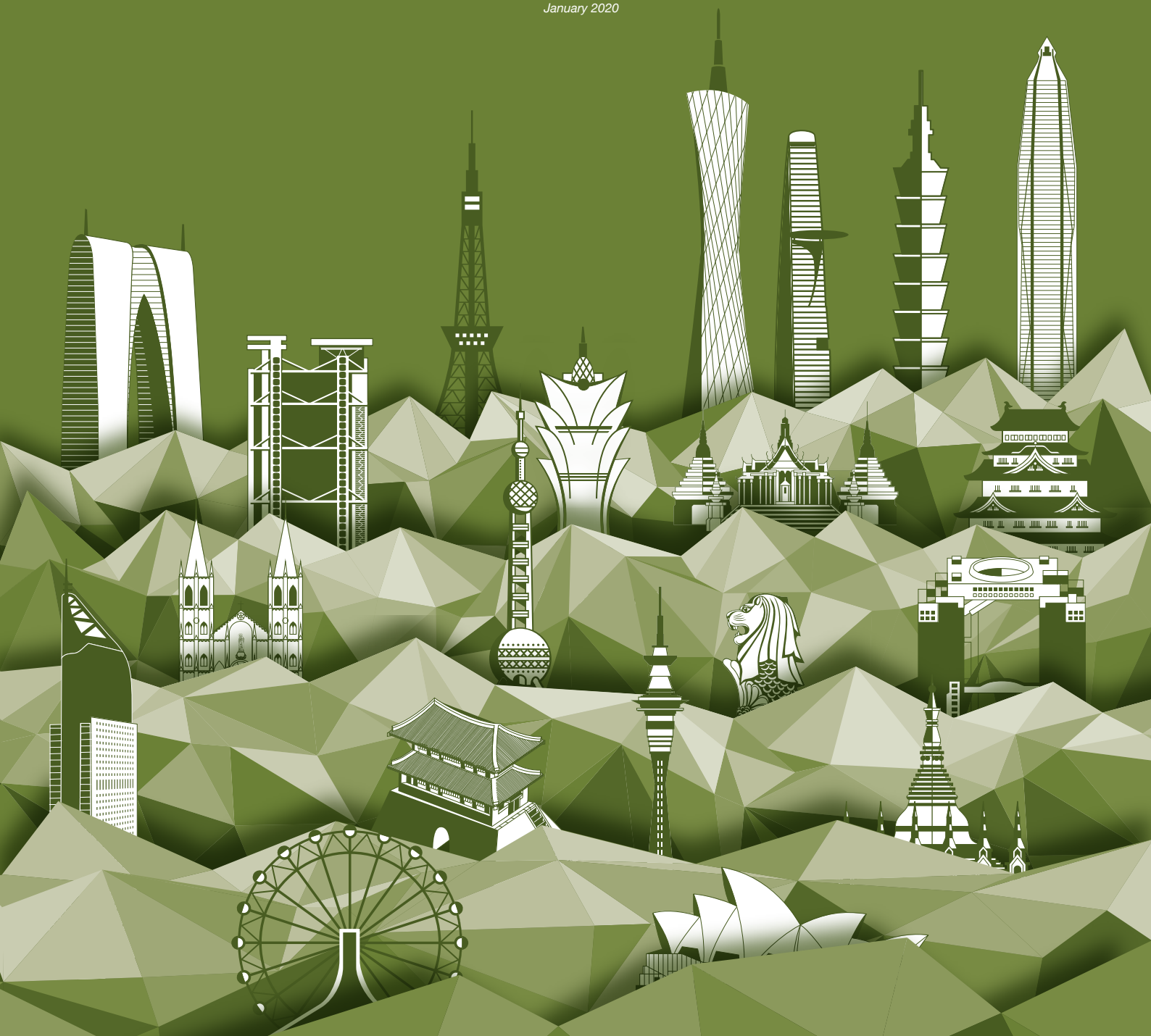
But beware, historical data may not provide insights into future events – as BlackRock warns in their 2019 "Getting Physical" report: *"New climate patterns mean long-dated historical data are a poor guide to the future. Investors using models overly reliant on the past are missing the big picture"*. Remember that new research points to higher vulnerability to future storms.



Source: CWR, AON Global Catastrophe Recap Reports in 2017, 2018 and 2019

"I believe we are on the edge of a fundamental reshaping of finance… In the near future – and sooner than most anticipate – there will be a significant reallocation of capital."

CEO of BlackRock, Larry Fink
January 2020



"You can't wish away systemic risk. In the end, a small investment up front can save tremendous cost down the road … We have a situation with climate change, which will involve the entire world, and from which we can't self-isolate, and is predicted not just to be a risk tomorrow, but the central scenario."

The former governor of the Bank of England, Mark Carney
May 2020

Recalibrating finance
For tail risks

Section 2

Three central bank governors
in an open letter on climate related financial risks, April 2019…

"The catastrophic effects of climate change are already visible around the world… This requires a massive reallocation of capital. If some companies and industries fail to adjust to this new world, they will fail to exist."

The Chair of the NGFS Frank Elderson, Governor of Banque de France François Villeroy de Galhau & the then Governor of Bank of England Mark Carney

Climate tail risks drive recalibration of financial risk

Finance has started to assess carbon transition risks for 3°C-4°C …

Financial 'base case' consensus is 3°C-4°C by 2100 but focus on carbon risks = forget that many APAC cities will not survive this. There is growing consensus and resignation in the financial industry that 3°C-4°C should be used as the base case to assess climate impacts given the stasis around global decarbonisation efforts and the Paris Agreement. As the Task Force on Climate-related Financial Disclosures (TCFD) scenarios have largely focused on carbon transition risks, the accompanied chronic and significant SLR tail risks that come with this scenario are overlooked.

…but chronic & huge physical tail risks from SLR and storm surges are not factored in

At 4°C, stranded assets/ abandoned cities will trigger shocks to the financial system if not prepared

Chronic tail risks rise as temperatures rise = stranded cities + shocks to financial system. Unfortunately, sea levels will not stop rising and tipping points are being passed, guaranteeing us significant tail risks. As discussed in the previous section, such tail risks are severe, even at 1.5°C. These risks rise with each degree of temperature as per the charts on the following page. Our analysis across four climate scenarios (1.5°C, 2°C, 3°C and 4°C) show that SLR risks stack up for the 20 APAC cities as temperatures rise across all key indicators of land area, population, airports, ports, CBDs and stock exchanges. At 4°C, exposure is significant pointing to stranded assets/abandoned cities and the upgrade/relocation of large infrastructure projects will become a reality. These will trigger shocks to the financial system if it is not prepared; ripple effects will be felt globally.

2100 timeframe focus amplifies this risk of being blindsided

Focus on 2100 timeframe + carbon transition risks = locked-in SLR impacts overlooked. The financial sector has overlooked such grave impact from locked-in SLR as their climate projections/scenarios are usually limited to a 2100 timeline. Moreover, the sector has prioritised assessing carbon transition risks rather than long term physical impacts, reflected by TCFD scenarios which have so far been largely carbon transition scenarios. While some have factored in acute (event-driven) storm surge risks, most have not explored chronic locked-in SLR scenarios, which will definitely strand swathes of assets, even those that are not carbon intensive. Unfortunately, sea levels will not stop rising as tipping points are passed.

Magnitude of chronic tail risks = "going concern" assumption MUST be changed

= downward revision of terminal values + replacement costs in all valuation models

Significant chronic tail risks question going concern assumptions + valuation models. That the risks are a "timeframe beyond our lifetime" is not a valid argument as the assumption of infinite going concern is a concept that underpins all valuation models in the financial industry. Once we pass tipping points, SLR will be guaranteed; surely, this certainty warrants adjustments to underlying assumptions in all financial valuations. Chronic tail risks must be recalibrated today to ensure financial system resiliency through repricing and reallocation of capital. New valuation methods need not be invented; current models can accommodate the adjustment – more in **"Locked-in tail risks force re-calculation of terminal values"**.

Recalibration of chronic tail risks will also impact sovereign/ municipal credit ratings

Implications for cost of capital, sovereign risk/credit ratings, equity & project valuations. Recalibrating to reflect real tail risks means that at a minimum, sovereigns should be re-rated and the cost of capital adjusted; terminal values in valuation models should also face downward revision. It's not just us saying this, almost all finance professionals surveyed agreed with us - see their feedback on the following pages. Also, recently published reports – Moody's' ***"Sea level rise poses long-term credit threat to a number of sovereigns"*** (Jan 2020) as well as BlackRock's ***"Getting Physical: Scenario Analysis For Assessing Climate-Related Risks"*** (Apr 2019) – both delve into how physical risks from climate change can impact sovereign and municipal bond issuers. A recalibration of valuations and risks across the financial industry is inevitable – more on APAC sovereigns in ***"Sovereigns at Risk: APAC Capital Threats"***. Indeed, BlackRock recently launched a climate risk-adjusted sovereign bond ETF; evidently there is demand for such products.

Valuation/cost of capital adjustments are inevitable…

…NGFS, a group of 68+ central banks are taking action to address this structural change in the global financial system

Central banks globally are also acting to recalibrate financial systems. A group of 68+ (and growing) central banks under the NGFS has also acknowledged that climate change is a source of structural change in the financial system and is calling for action. They warn that *"catastrophic impacts of climate change are already visible"* and *"if companies and industries fail to adjust to this new reality, they will fail to exist"*.[14] Set up in 2017, the group is fast growing and active in developing global environment and climate risk management in the financial sector to reduce the risks facing the financial system. In 2020 alone, they have so far released seven reports pertaining to these risks.[27] The financial sector is evolving and preparing for systemic shocks ahead – don't be blindsided by regulations, get up to speed with the timeline and latest reports in ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

APAC 20 SLR Stranded Assets Snapshot for 1.5°C, 2°C, 3°C and 4°C

People, land, trade & finance materially affected across all scenarios. It is clear from the charts below that people, land and trade will be materially affected. At 4°C, almost half the population of the 20 cities at over 100 million people will be displaced as 43% of cities' land area will be permanently submerged. Trade is vulnerable with 92% of airports and 100% of ports hit as is business with over half of the CBDs and a quarter of the 16 stock exchanges located in the 20 cities affected. Some cities will face more issues: *"thinking about how densely populated HK and SG are and how there is no "hinterland", as the largest financial cities"*

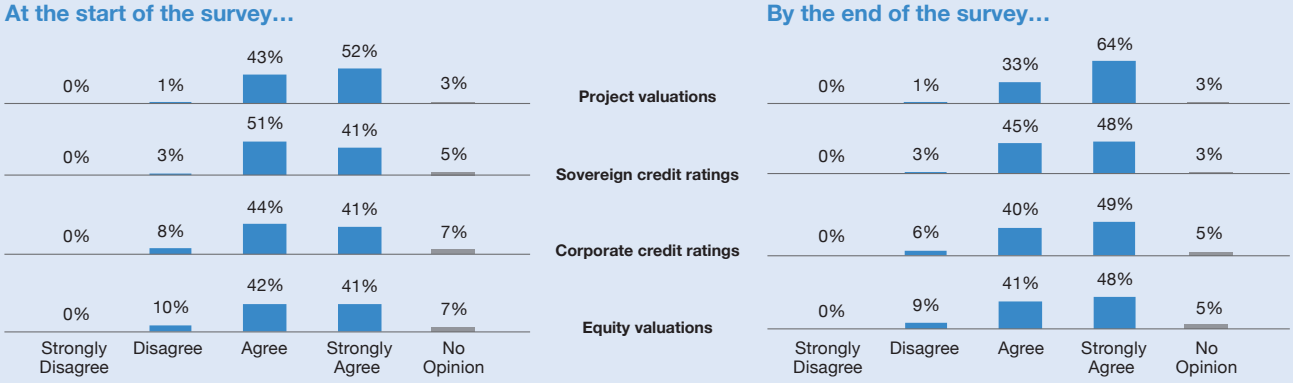
Ports are the most vulnerable: 87% hit at 1.5°C to 100% at 4°C. Aside from trade impacts, this level of vulnerability will impact energy security as many of the cities as well as countries/territories are reliant on imports of fuels for energy via ports. Adaptation planning for key ports need to start now - please see **"Granularity matters: Deep dives on HK, Taipei & Tokyo"** in the section on **"5 Key Challenges"** for more on port adaptation costs. For finance sector feedback on the key indicators below, please see **"Physical threat factors & proxy indictors – which ones to use?"** set out later in this section.

Source: CWR APACCT 20 Index

Finance says tail risks should be factored in valuations

Strong agreement that locked-in SLR & storm surge be factored into valuations. We asked the same question regarding impact on valuations before and after the survey. It is clear that views shifted towards "Strongly Agree" after the survey across the four types of valuations per the chart below. Note that zero percent "Strongly Disagree" with the inclusion of such risks in valuations; project valuations and sovereign credit ratings carried the least "Disagree" votes for inclusion at 1% and 3% respectively.

Inclusion in valuations - Do you agree that long term sea level rise (SLR) and storm surge risks should be taken into consideration when valuing the following?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Whilst agreeing that locked-in tail risks should be factored in, timeframe issues were highlighted: *"Timeframe is too long for Corp bonds and equity valuations"* and *"SLR considerations in corporate credit (and even equity) is difficult because the tenor of the instrument may not match the timeline of sea level ris e. Corporates also have the ability to move their facilities inland which can have lower cost over this time horizon than models projecting a 100% loss to value"*. We note this concern and recommend the terminal value to be discounted, rather than wiped out – see the following page for more on this.

Material exposure of cities warrant sovereign risk adjustments. The financial industry can also gauge the resilience of the city together with the governments /corporates' plans to move their cities/assets inland and adjust sovereign risk. Such adjustments to sovereign risk ratings for locked-in tail risks will have wide implications as all valuations will be recalibrated as cash flows will be discounted with a new cost of capital. Clearly, this will only be the case if the city represents a material share of the country/ territories' GDP. As one surveyed pointed out *"On sovereign risk ratings – countries are big so risks will be more spread – hence why Agree only"*. Our analyses have found that **GDP is clustered in these 20 APAC cities - 11 of the 20 cities account for over a fifth of national/territorial GDP**. More on this in our report ***"Sovereigns at Risk: APAC Capital Threats"***.

Recommended Reading

NGFS, *"A call for action: Climate change as a source of financial risk"*

April 2019

"Climate-related risks are a source of financial risk and it therefore falls squarely within the mandates of central banks and supervisors to ensure the financial system is resilient to these risks...

We need to take action and we cannot and will not do this alone. We will globally cooperate with policy makers, the financial sector, academia and other stakeholders to distill best practices in addressing climaterelated risks."

https://www.ngfs.net/sites/default/files/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf

Moody's, *"Sea level rise poses longterm credit threat to a number of sovereigns"*

January 2020

"Sea levels several decades from now will be largely determined by past greenhouse gas emissions and temperatures.

Sea level rise is gradual, but manifests abruptly, by intensifying the frequency and severity of storm surges, flooding and tropical cyclones, which have credit implications for sovereigns.

Sovereigns in Asia, Middle East and North Africa (MENA) and small islands are most exposed to rising sea levels"

https://www.moodys.com/research/Moodys-reporton-global-sea-level-rise-says-Vietnam-Egypt--PR_417214

BlackRock, *"Getting Physical: Scenario Analysis For Assessing Climate-Related Risks"*

April 2019

"Extreme weather events pose growing risks for the credit worthiness of state and local issuers in the $3.8 trillion U.S. municipal bond market…

a rising share of muni bond issuance over time will likely come from regions facing economic losses from rising average temperatures and related events. Some 58% of metropolitan areas face climate-related GDP hits of 1% or more by 2060–2080 under a "no climate action" scenario."

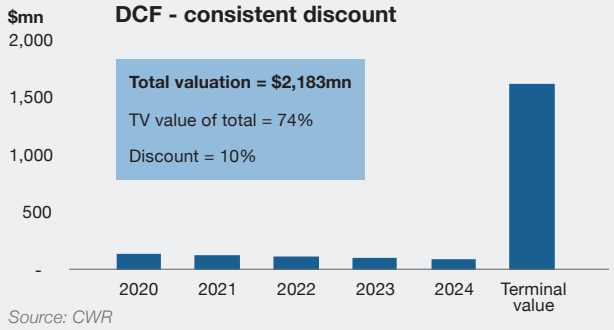
https://www.blackrock.com/ch/individual/en/insights/physical-climate-risks

Locked-in tail risks force re-calculation of terminal values

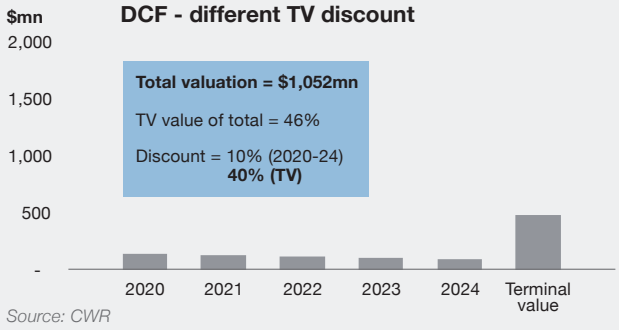
Discounted cash flow models (DCF) are widely used to value companies or projects by forecasting cash flows and discounting these to arrive at a current, present value. Typically, detailed forecasting is carried out for 3 -5 years and then the remainder of the project/company's value is calculated by making assumptions about cash flows beyond the final explicit forecast year, which is called the terminal value (TV). According to 2° Investing Initiative and The Generation Foundation this TV accounts for over 82% of a company's fair value.[28] Depending on which TV method is used, it either assumes a company/project generates cash flow indefinitel y (perpetual growth method) or the business model and operations are still a going concern and c an be sold at that point (exit multiple method). However, using the same discount rate for the TV as for the detailed short-term forecasting does not account for potential disruptions in the future.

We argue that coastal threats should be factored into valuations as tail risks because we are locking-in SLR, storm surges and subsidence risks with our actions today. Valuations clearly need to be adjusted for assets located in cities which will certainly be permanently submerged by SLR in the future as this will definitely impact the "going concern status" of a company/project/asset. Subsidence which can bring forward such inundation risks should also be taken into account when assessing tail risks. Storm surges brought by typhoons are typically assessed as acute (event-driven) risks – however, we argue that when they become more intense and start occurring annually, they should be accounted for as chronic tail risks as well because insurers may no longer cover such risks. Action taken to adapt for all these threats can reduce tail risks. For example, if a project is based in a location highly susceptible to coastal threats but neither the project nor the government has invested to reduce their exposure, the operations in this location may not be viable/profitable in the future. In this instance, the TV should be discounted accordingly. To incorporate realistic adjustments and understand the potential impact on valuations, sensitivity analysis can be carried out:

- *Perpetual growth*: reduce the cash flow perpetual growth rate;
- *Exit multiple*: reduce the expected exit multiple (for the chosen financial statistic) below the current average market rate; and
- *Either method*: Use two different discount rates for the TV and initial forecasted period with the TV discount being higher due to the uncertainty of the value of the company/project beyond the forecasted period. The discount rate is the WACC (weighted average cost of capital) which would be expected to be much higher in the event of continuous climatic disruptions to business operations. The charts below illustrate how valuations could be dramatically changed if different discounts were to be used for the TV to incorporate climate uncertainties; changing the TV discount rate from 10% to 40% reduces the DCF fair value by 52% from US$2.2bn to US$1.1bn.



Source: CWR



Source: CWR

The adjustments made to the calculations will depend on the location and sector of the assets. Thus, multiple discussions internally will ensue about the vulnerability of particular locations and drive analysis of what actions are being taken by the company/project as well as the government in those areas to adapt to and reduce the severity of the risks. Banks and investors will have to carry out robust engagements with management to ascertain this information and could lead to companies carrying out mapping exercises of their assets and supply chains to disclose this information. Thus, shareholders will be better informed about how risky their investments potentially are.

Recalibrating valuations for tail risks from, coastal threats could also lead to changes in lending poli cies:

1) Reduce loan book/equity portfolio risks by divesting from risky locations and sectors;
2) Raise capital adequacy to rebalance for imminent loss in insurance cover;
3) Spread risks by investing in new locations that are less exposed; and
4) Provide momentum to diversify away from carbon intensive sectors as these diminish the quality of the rest of the portfolio.

Existing indices & tools – how useful are they?

Finance experts surveyed wanted to assess coastal threats to cities…

66% were mainstream

There are indices & tools to evaluate coastal threats, yet most have "never heard of it". It is clear from the survey responses, despite being 66% mainstream, the financial industry understands that coastal threats impact valuations and would like an index that helps them gauge such risks. Indeed, a few indices and free tools exist already to help assess coastal threats but they do not address finance needs – of those we surveyed 52% and 79% had "never heard of" free products such as "CDP Cities A List"[29] and "Climate Central Surging Seas - sea level rise analysis"[30] respectively; "World Bank - impact of sea level rise on developing countries"[31] had the highest recognition as only 35% had "never heard of it".

34% said they were working in "Sustainable Finance /ESG"…

…so we infer that existing tools do not meet their needs

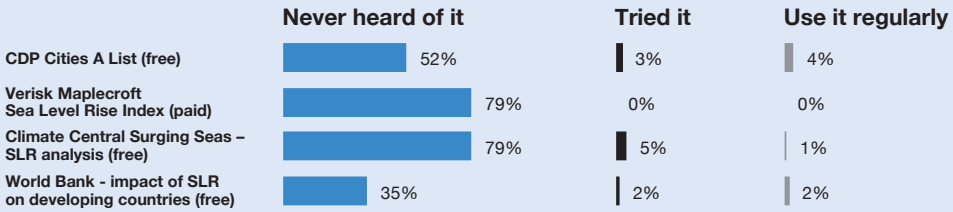
Existing indices do not meet sector needs; at most 4% use CDP Cities A List regularly. Yet despite acknowledging the risks, between 0%-5% said they have "tried it". Note that while Climate Central fared the best, it scored lower on "use it regularly" at only 1%. CDP Cities A List came out top with "use it regularly" at a mere 4%. Consulting firm, Verisk Maplecroft fared the worse – none surveyed have even tried it.[32] However, this could be because it is a new product launch in February 2020. Given that 34% marked themselves as working in "Sustainable Finance /ESG", we infer that these products are not useful for them as opposed to them not doing their jobs. We therefore sought to build a more practical/useful and open index.

Only 4% admitted to using one of the tools regularly

Up to 79% had "never heard of" products that can help them gauge city exposure

79% say they have "never heard of" some tools; only 4% "use it regularly"

Before we start the survey, coastal threat and climate change data sets and research already exist. Have you heard of or know any of the following?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

All 4 tools provide some aspect of cities' exposure to coastal threats …

… but none of them provided an overview of real physical threats faced & government action to address these

Upon closer look, tools are very different although they all strive to assess coastal risks. As can been seen from the box below, while all four indices and tools can help evaluate coastal threats/cities resilience, they are very different. World Bank and Climate Central tools allow you to see the impacts of SLR at various scenarios, they do not provide analysis of key infrastructure/ assets that are impacted nor the relative rankings of cities. Verisk Maplecroft Sea Level Rise Index does not include government action reflecting only physical risk of sea level rise and the CDP Cities A List is a combined/blended index which ranks cities into categories A, B and so on based on both their adaptation and mitigation actions. We have issues with all these approaches as we believe further analysis can be done to make them more useful for the financial industry to gauge actual tail risks ahead – we expand on how and why in this section.

Note: there are more than 4 tools available to assess SLR risks – we simply selected the most appropriate tools that matched our aim of assessing real threats ahead

CDP Cities A List CDP scores cities who report to CDP each year on their transparency and action on climate change – only those that are in the A category are publicly disclosed. This is combination of adaptation and mitigation efforts on climate change. https://www.cdp.net/en/cities/cities-scores	**Climate Central Surging Seas - sea level rise analysis** An interactive map to assess coastal flood risk and sea level rise projections for anywhere in the world, and under multiple pollution scenarios. https://sealevel.climatecentral.org/maps/
Verisk Maplecroft Sea Level Rise Index Examines the impact of SLR on urban areas as well as rail, road and industrial assets. The organisation also has a Climate Change Vulnerability Index which evaluates extreme climate events and changes in climate over the next 30 years to a spatial resolution of 22km². https://www.maplecroft.com/insights/analysis/chinasmanufacturing-heartland-most-at-risk-from-rising-seas/	**World Bank - impact of sea level rise on developing countries** Assesses the consequences of continued SLR for 84 developing countries. 1-5m SLR is mapped with its impacts on critical elements (land, population, agriculture, urban extent, wetlands, and GDP). http://documents.worldbank.org/curated/en/156401468136816684/The-impact-of-sea-level-rise-on-developingcountries-a-comparative-analysis

Building consensus on an index that reflects real risks

Existing indices and tools do not allow for easy assessment of risks and require the financial industry to do more work to see real threats ahead. Indices blending mitigation and adaptation scores also hide physical threats. So an index that actually reflects real risks ahead remains elusive. We thus sought feedback from the financial sector to see if consensus can be reached on the type of index to build: 1) Physical threat factors & proxy indictors – which ones to use? 2) Should the cities index reflect impacts across various scenarios? and 3) To include / not include government action – if yes, what type? These are discussed in greater detail below:

We thus sought finance feedback to see if consensus can be reached on the type of index to build...

1. Physical threat factors & proxy indictors – which ones to use?

Maps of climate scenarios are useful, but a basic assessment of their physical impact is better. The financial industry doesn't just want to see maps of sea level rise, they want to know what is impacted. Doing this analysis is time consuming for them. So an index that reflects such impacts would be more useful than just the maps alone. However, before we delve into which indicators to use, it is worth taking a step back to think about what we are trying to assess. In this sense, there are two broad categories of factors and as discussed below, there are multiple challenges for each of these categories.

Which physical threats to include?

SLR map visuals are useful but exactly what is impacted is more useful…

… an index that reflects the impacts is thus more useful than maps alone

1) **What is doing the impacting** – there are different types of coastal threats. For the index, do we just include SLR like Verisk Maplecroft? Or do we also factor in storm surge risks as SLR compounds these risks? Are we more concerned about the magnitude of the storms or their increasing frequency? What about subsidence like in the case of Jakarta, should we include this?

2) **What is impacted** – many APAC cities are not only a country's capital but they are also the financial, manufacturing and logistical hubs, thus playing an important economic role. Aside from land area and population impacted, to gauge impact on trade, an important component of APAC countries, should we also include key infrastructure like ports and airports? What about impact on financial hubs for the region – can CBDs and stock exchanges be used as proxies?

But what is doing the impacting? and what is impacted?

Concern over SLR is high + interlinked storm surge risks = combined assessment. When asked to rank their preference on types of physical risk to assess, results reveal that everyone was concerned over SLR and almost all were concerned over imminent storm surge risks (both magnitude and frequency). Feedback also showed an understanding of interlinked risks between SLR & storm surges. One pointed out that *"Extreme weather events contemplate frequency, severity and timing (e.g., is the typhoon occurring in the 'typical' typhoon season or outside the typhoon season)? The coincidence of SLR, high tides, windstorms will exacerbate extreme weather events."* Another astutely noted *"No difference in thinking about the different risks in isolation, it's the combination that accumulates in the total financial impact."* More on finance feedback in the next page.

Survey results revealed that everyone was concerned over SLR

+ almost all were concerned over storm surge risks – both magnitude & frequency

…their interlinked nature was also recognised

On impacts, finance feedback on proxy indicators informed their weighting in the index. We sought feedback from the industry on various proxy indicators and factored their feedback into the CWR APACCT 20 Index. Regarding their concern over what is impacted, we asked them the same question before and after the survey, answers have clearly shifted toward increasing concern. Deeper understanding of threats and impacts upon seeing some results led them to reweight their preferences across indicators. We therefore weighted the index to reflect the "after the survey" results and have changed the weightings of all indicators following their comments – see charts in the next page.

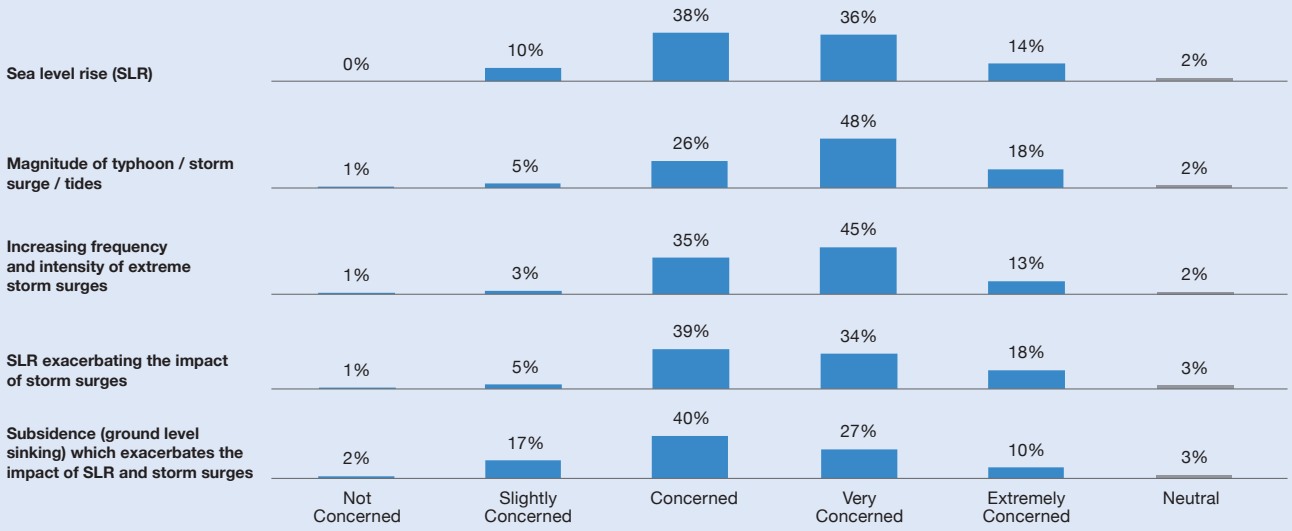
Views on impact proxy indicators (what was impacted) changed before & after survey… weightings reflect postsurvey consensus view

The CWR APACCT 20 Index includes SLR & storm surge risks, but what we want and what we can do differ due to research gaps + money spent. Coastal threats are complicated and interlinked - one noted *"There are also project specific risks, particularly those based on land reclamation where SLR forecasts aren't sufficiently prudent"* while another highlighted concerns over delta impacts of *"salinity, inland flooding, river flows."* A few others wanted the inclusion of *"manufacturing hubs due to operational risks. CBD etc not a problem due to working from home."* While we would like to factor in everything, we cannot as there are data gaps, plus funding issues. Read on to see how we tackled these issues.

CWR APACCT 20 Index thus assesses impact of SLR on proxy indicators, storm surge as well as subsidence

Everyone is concerned over SLR, but storm surges are more worrying. No one was "not concerned" over SLR; given that 2% remained neutral, everyone who opined was worried about SLR. However, the magnitude and frequency of storm surge/tides garnered more votes than SLR in the "very concerned" and "extremely concerned" categories, reflecting their shorter time frame impacts versus SLR. Feedback also clearly shows that those surveyed were also concerned about interlinked SLR & storm surge risks.

Different types of physical coastal risks - How concerned are you about the financial impacts of the following?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Both SLR and storm surge risks are thus included in the CWR APACCT 20 Index. SLR risks are assessed via impacts on various key indicators across climate scenarios – these indicators are discussed on the following page. Storm surge risks are more complicated due to their interlinked nature with SLR and due to limited funding, we have created a set of indicators to assess the risks from storm surge instead of running storm surge scenarios for each city – these are discussed in more detail in **"Storm surge projections – simple metrics vs. expensive modelling?"** in section titled **"5 Key Challenges"**.

94% expressed varying levels of concern over subsidence exacerbating SLR & storm surge. Given such concern, we have also factored in subsidence by scoring cities that on average are sinking by 1cm or more per year. Subsidence is not a major issue for some cities but for others it can be dire – please see the box below for more on subsidence. For greater detail on varying impacts on cities and mapped examples of impact on Jakarta, please see ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***, another report in this series. The maps there clearly show that subsidence will bring forward the timeline of SLR impacts.

Subsidence shifts SLR impact timelines forward

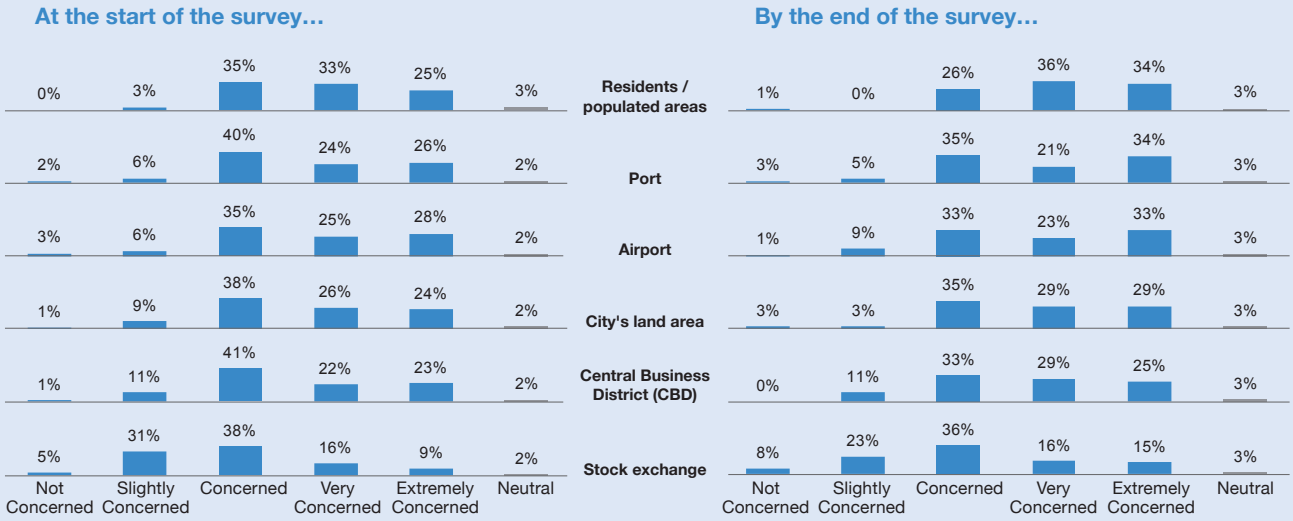
Subsidence is the sudden or gradual sinking of the ground's surface. It can occur naturally but is accelerated by human activities such as groundwater extraction and urbanisation with heavy/large buildings which can compress the earth. Clearly, subsidence can exacerbate the impact of SLR. We were unable to map subsidence for the CWR APACCT 20 Index as only some parts of cities face this and the data is not complete. But as we believe it is important to include subsidence in the index, cities that are sinking more than 1 cm per year were given a score for this; the three cities of the 20 that fit this are Jakarta, Bangkok and Manila.

However, some cities are more at risk than others; for example, since the early 1970's major parts of Jakarta have sunk by 2m-4m. This is similar to expected locked-in SLR at 1.5°C of 1.6m-4.2m. North Jakarta is most at risk – it has sunk 2.5m in 10 years and is continuing to sink by as much as 25cm/year in some parts, which is >2x the global average for coastal megacities. If this rate of sinking continues in North Jakarta in another 40 years it would have sunk by 10 meters which is the same as locked-in SLR at 4°C (6.9m-10.8m). Parts of Jakarta could disappear before the end of the century, which may explain why the government is attempting to take drastic action to not only move the administrative centre out of Jakarta but to also build a giant sea wall and artificial islands to protect it even though it will cost billions of dollars – please see the selection of case studies for various cities in ***"Sovereigns at Risk: APAC Capital Threats"***.

Source: CWR, Henk Kooi and Angga Trysa Yuherdha. 2018. Updated subsidence scenarios Jakarta; BBC News article. Jakarta, the fastestsinking city in the world. Mayuri Mei Lin & Rafki Hidayat, 13 Aug 2018; WEF article "Jakarta is slowing sinking into the Earth", Sean Fleming, 15 Aug 2018

Impact indicators – levels of concern vary across indicators; concern increased after survey. We selected a set of proxy indicators to assess impacts from SLR – see the box below on why they were chosen. After the survey, 95-98% said they were concerned about impact across all these indicators except for the stock exchange. Although there was only slight movement in the total level of concern over each indicator before and after the survey, views clearly shifted toward higher levels of concern after the survey as can be seen from the charts below. After the survey, when asked to rank their concern over what was impacted, residents of the cities came out top with 70% saying they were very & extremely concerned compared to 58% before the survey. This was followed by ports and airports and then city land area and CBDs. One clearly summed this up with *"The CBD and stock exchange functions can continue to operate given disaster recovery plans, remote working etc. Whereas you can't move residential buildings and transport infrastructure"*.

How concerned would you be of the long term financial and economic impact if the following was to be affected by SLR and storm surges?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Less concerned over the Stock Exchange. Those surveyed were least concerned over the stock exchange with one explaining *"I would assume that Stock Exchanges would have their data centres in other places than the actual physical Stock Exchange building, often in more rural areas. Therefore, I would be more concerned by the BCP plan of such data centres than the city buildings. Likewise, I think that whilst the CBDs will have an impact to the brain of large companies, the majority of such companies would/should have online working capabilities for such functions. The bigger damage would be expected in the manufacturing locations."* We thus applied a lower weighting towards the stock exchange but note that key data centres and power generation assets that supply electricity to the cities should be assessed. We hope that the index can be expanded to include these in its next iteration.

Why these proxy indicators were selected to gauge impact

- **Percentage of people affected:** flooding could lead to mass migration of populations away from coastal cities, disrupt social stability and cause labour shortages;
- **Ports and airports:** if key logistics infrastructure is flooded this would cause disruptions to food and energy security as well as the economy as trade plays a significant role in APAC economies;
- **Percentage of land affected:** as key property will be exposed and could damage economic activity. As highlighted in the CWR, Manulife Asset Management and AIGCC report "Are Asian Pension Funds Ready for Climate Change?" this will also affect the financial sector as mortgage and corporate loan books could be left exposed especially as more expensive real estate is typically found by the coast. Sea wall data is not included even though they can reduce flood risks as it is currently not possible to find all sea wall data for the 20 cities;
- **Central Business District (CBD):** as the economic and financial centre of a city, its flooding could lead to large disruptions; and
- **Stock exchange:** Not all cities have a stock exchange as they're not a financial hub. But if a city is home to a stock exchange, its flooding could force a halt to trading and cause the financial system to be at risk as typically a large percentage of financial institutions will be located by the exchange.

2. Should the cities index reflect impacts across various scenarios?

1.5°C is our best-case as there is high certainty that we will reach this by 2030

4°C is our base case as this is the current path

Running scenarios can help gauge and plan for risks ahead. Both TCFD and NGFS recommend running scenarios. So far, these have focused on carbon transition risk and acute (event-driven) climate risks but are starting to shift towards assessing all physical impacts including underlying environmental risks. As discussed earlier, exposure to lockedin SLR rises for all key indicators across all four climate scenarios. For the index, 1.5°C is our best-case as there is a high certainty that we will reach this by 2030;[3] as for the base case, we have selected 4°C as our current path is at least 3°C-5°C[1].

Storm surge scenarios are expensive & may not be useful …

"New climate patterns mean long-dated historical data are a poor guide to the future. Investors using models overly reliant on the past are missing the big picture"
BlackRock, Getting physical, 2019

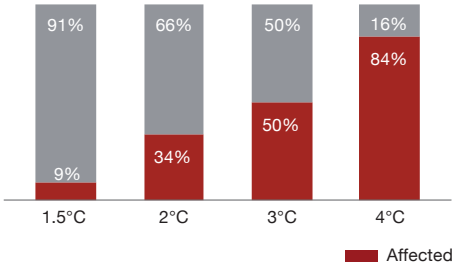
Given costs, data availability, consistency & reliability, we mapped stacked risks for SLR but not storm surges. Running scenarios is expensive, so it is important to choose scenarios wisely. Climate models predicting storm surge frequency and magnitude can be expensive to run and their accuracy debatable as they rely on historic data, which we know are no longer valid. Also, it is important to preserve consistency in the approach to ensure that the results are comparable across cities. Yet, it transpires that typhoons/ hurricanes/ tropical cyclones are not measured on the same scale in APAC; each county/ territory/ region has its own scale and measurements. Therefore, we decided that it was more pressing to map and reflect stacked risks for locked-in SLR than for storm surges. For more details on storm surge challenges, please see **"5 Key Challenges"**.

Unique city locations & elevations mean that cities are impacted differently across climate scenarios…

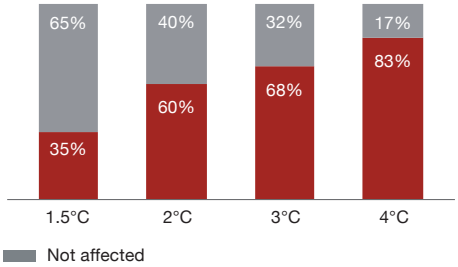
Stacked SLR risk exposure varies across climate scenarios. Cities are impacted differently at each degree of warming due to their unique geographical location and elevation characteristics, plus the location of key infrastructure differ from city to city. Impacts for each degree of warming therefore differ significantly and we feel that a stacked risk SLR exposure allows more colour on the risk exposure profile of the city. Take for example Bangkok and Tianjin – the charts below show the land area affected by locked-in SLR in Bangkok (LHS) and Tianjin (RHS). At 4°C they have a similar percentage of land at risk (83%-84%), but at 1.5°C Tianjin has 35% at risk whereas it's only 9% in Bangkok. It is clear from the charts that each city faces different impacts at each temperature scenario (1.5°C, 2°C, 3°C, 4°C). This means the exposure profile differs between the two cities as the risks "stack-up" differently once all climate scenarios are considered.

eg. Bangkok & Tianjin's risk profiles differ although at 4°C exposure is similar

Bangkok land affected by locked-in SLR



Tianjin land affected by locked-in SLR



Source: CWR APACCT 20 Index

Our index thus takes into account SLR stacked risk exposure measured using impact proxy indicators across 4 climate scenarios…

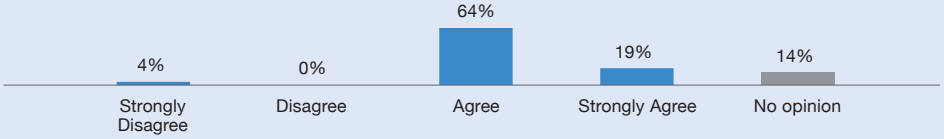
The CWR APACCT 20 Index reflects stacked risk exposure for each of the 20 cities across 4 climate scenarios. Taking into account such stacked risks would mean that the CWR APACCT 20 Index scoring would reflect Tianjin as more at risk to SLR than Bangkok. Since finance feedback overwhelmingly agreed that stacked risk exposure provided a better idea of exposure of SLR threats (see below), we assessed SLR impacts of four climate scenarios on all key indicators for each city and included the results in our index.

…this was analysed for each of the 20 APAC cities

…Finance feedback showed that they overwhelmingly agree with the approach

83% say they want index to include stacked risks ….

Should the index reflect this "stacked risk" where Tianjin would be shown as facing a relatively higher risk compared to Bangkok?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

3. To include / not include government action – if yes, what type – adaptation vs. mitigation?

An index that reflects real risks ahead should factor in government action/inaction. We believe that government action should be factored in to reflect the real risk as they can alleviate storm surge and SLR threats. For example, the Verisk Maplecroft Sea Level Rise Index highlights that from 500 cities evaluated Guangzhou is one of the most at -risk cities to SLR.[32] However, government action has been significant and includes building 600km of sea walls to protect the region and turning the city into a "sponge city" to reduce flooding risks.[33] As can be seen from the chart below, an overwhelming 90% agree with us with 50% indicating "strongly agree".

Government action should be factored in as they can alleviate storm surge & SLR threats…

…an overwhelming 90% agree with us

But blended approach including mitigation & adaptation in the same index hides risks. When it comes to tackling climate change governments can 1) push for a reduction in carbon emissions so that the worst risks are avoided (mitigation) and 2) invest in protecting people and assets from the expected physical threats due to a warming planet (adaptation). The CDP Cities A List is a combined/blended index which ranks cities based on both their adaptation and mitigation actions.[29] This is a good first step as we should reward cities for decarbonising, but we think this blended approach could hide the fact that the city could still be exposed due to a lack of adaptation efforts locally. This is because for mitigation to be effective it needs to be carried out globally; but for adaptation to be effective it needs to be carried out locally. Indices should thus reflect results separately. Half of those surveyed agreed with us and a further 11% wanted an adaptation only index compared to 1% who wanted a mitigation only index. Meanwhile 38% said a blended index was still useful. For more please see the box on the next page on **"Blended mitigation-adaptation index dilemma"**.

What about mitigation, should that be included?

But blended approach (mitigation & adaptation) will hide risks…

…because mitigation efforts are global but adaptation efforts are local

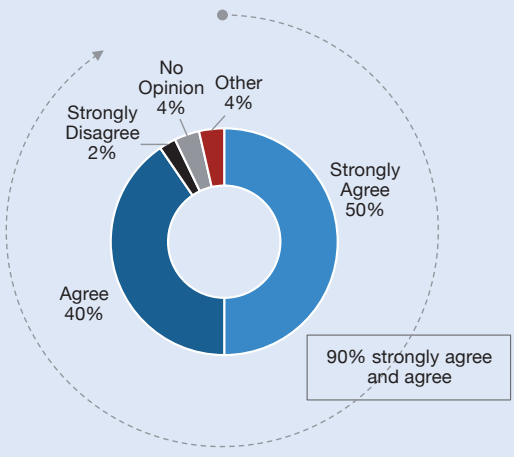
The CWR APACCT 20 Index thus includes government adaptation actions, not mitigation. Since we would like to reflect actual physical threats ahead, the CWR APACCT 20 Index only factors in government adaptation actions, not mitigation. We believe this is the right choice especially given the slew of comments from those surveyed weighing in on the matter – see next page. That said, benchmarking government action is difficult as actions differ for each city. To reduce subjectivity, we identified some proxy indicators to score adaptation action. What these are and finance sector input on them are set out in **"Government actions are inconsistent and unique – what proxy indicators to use?"** in the section titled **"5 Key Challenges"**

Finance wanted adaptation-only index … so we obliged

…they also inputted into govt adaptation proxy indicators used to gauge action

90% agree; 50% "strongly agree" to include government action

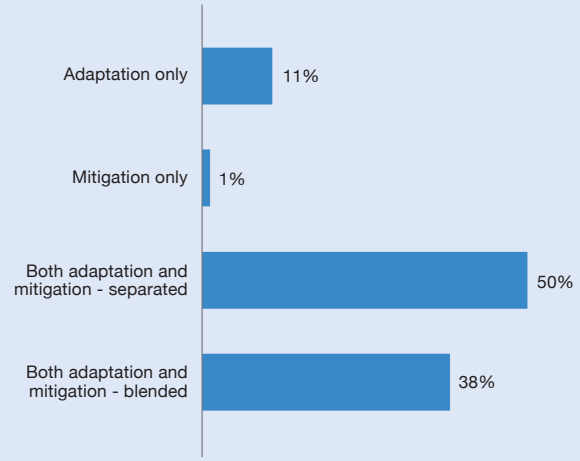
We believe that government actions should be included in a cities coastal threat index to reflect the real risk exposure. What do you think?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

99% say adaptation matters; 61% want a separate adaptation index

For a cities coastal threat index, should government actions by each city include?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Mitigation will only alter future climate risks if efforts are carried out globally …

…so mitigation needs macro analysis & must be evaluated in the global context

But physical risks are felt at a local level…

…so micro analysis of local adaptation actions is key to know how risky a city really is

Blending scores biases the results…
eg. Singapore is not in CDP's A List as it needs to do more on mitigation but its adaptation efforts are ahead of the region

So be careful when using blended indices to assess physical risk…

…looking at government case studies can help

Blended mitigation-adaptation index dilemma

When it comes to tackling climate change governments can push for a reduction in carbon emissions so that the worst risks are avoided (mitigation) and invest in protecting people and assets from the expected physical threats due to a warming planet (adaptation). However, mitigation will only alter future climate risks if efforts are carried out globally with multi-government co-operation.

For example, even if a country/city is stepping up and doing more than its peers to reduce emissions, if its peers are not doing the same or if it is a very small percentage of global emissions, the physical risks it faces do not change markedly as overall carbon emissions continue unabated. Mitigation requires a macro analysis and must be evaluated in the global context. Physical risks on the other hand are felt at a local level. Thus, micro analysis of adaptation actions being taken locally is paramount to comprehend how risky a city really is. Different researchers have attempted to quantify such adaptation actions - we have summarised these in **"The value of adaptation"** in the following page.

The CDP Cities A List Index gives cities an overall score dependent on the actions taken on both mitigation and adaptation and these scores are not split out, which makes it harder to use the index as a risk management tool. We believe blending the scores biases the results as a city vulnerable to the impacts of climate change could be perceived to be taking a lot of action to mitigate and nominal action to adapt and still receive a good score even though technically it is still at risk as globally we are heading for 3°C-5°C. For example, Singapore is not in its A List, which we assume is because it needs to do more on mitigation. However, Singapore's adaptation efforts are ahead of the region thus reducing physical risks faced.

We should celebrate cities that are taking steps to mitigate and criticise those that are doing less, but by blending the scores it is difficult to do this. CDP has a wealth of data. Therefore, we hope it separates and discloses adaptation and mitigation scores per city so that we can input these scores into the CWR APACCT 20 Index in the future. Until then, please be aware of the drawbacks of blended indexes as the real risks to your investments could be hidden.

In the meantime we urge you to heed the advice of fellow finance professionals below. Separately, we have also set out some government adaptation action case studies so that you can decide for yourself which cities are addressing coastal threats and which need to do more – access these in ***"Sovereigns at Risk: APAC Capital Threats"***.

Comments on whether to include adaptation/mitigation in the CWR APACCT 20 Index:

"Mitigation efforts focus on reducing carbon emissions, while adaptation focuses on activity that manages / avoids the physical damage of the impact. These are quite different things."

"Adaptation capacity is the most important measure."

"Surely it must be adaptation only at a city level? A country's carbon emissions policy has de minimis direct relation to each individual city's risk, relative to the world at large."

"Preference is for adaptation 90%, but do also want to know mitigation if possible."

"A good mitigation score has no link to the physical exposure at a city level."

"Adaptation is directly correlated to how much action the city is taking. For small countries/states like Sg and HK, the amount of mitigation effort on their part is insignificant in the grand scheme of things."

"Actionable global efforts difficult to enforce. Local efforts are m ore outcome driven/ measurable."

"I was going to select agree and add a comment) Like what is often done to corporate ESG evaluation, I think it would be best to have two measures, a) the level of potential risk, and b) the level of action taken to address such risk. That way, you do not provide the wrong incentive of continuing to contribute to the risk whilst putting in adaptation measure in place."

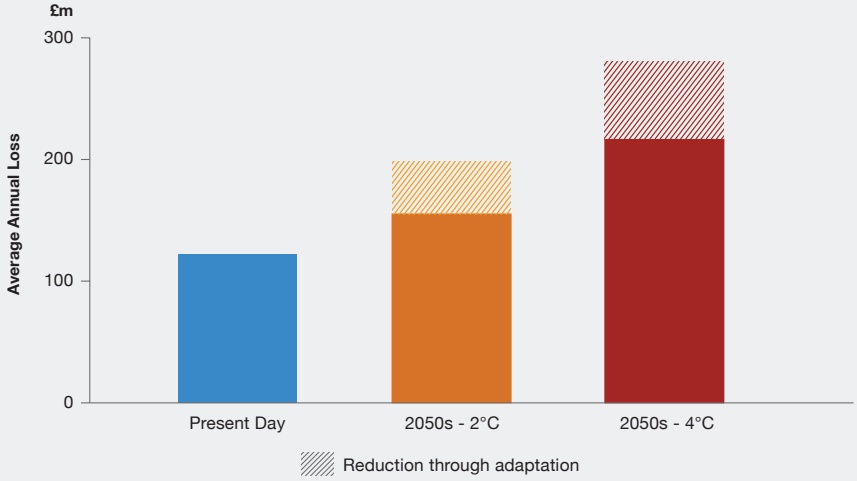
The value of adaptation

Even though the impacts of climate change are already here, adaptation investments have lagged over uncertainties of the benefits given the costs. Several recent reports have attempted to plug this gap by calculating the value of adapting for climate change in different scenarios which show **that benefits of adaptation outweigh the costs, and opportunities abound.** Some of these reports have been summarised below:

- **Vousdoukas, M.I., Mentaschi, L., Hinkel, J. et al. (2020) Economic motivation for raising coastal flood defenses in Europe. Nat Commun 11, 2119.** Annual coastal flood losses in Europe currently amount to €1.4bn and about 100,000 EU citizens are affected every year. Without any coastal adaptation annual coastal flood losses for Europe by the end of the century are projected to grow to between €209.8bn – €1268.4bn, depending on the climate scenario. However, **83% of flood damages in Europe could be avoided by elevating dykes and benefits tend to outweigh the costs in more valuable and densely populated areas.** With moderate mitigation, 95% of these impacts could be avoided.

- **Cambridge Institute for Sustainability Leadership (CISL) (2019) Physical risk framework: Understanding the impacts of climate change on real estate lending and investment portfolios.** According to the report under a 2°C scenario **around two thirds of additional average annual losses (AAL) for insurers could be offset** in the UK if half of at-risk households installed flood protection measures as the chart below shows. **With tropical cyclones, roof upgrades to properties at risk could offset around half** of the increase in AAL.

Reduction in AAL from floods to properties in UK mortgage portfolios



Source: CISL (2019) Physical risk framework: Understanding the impacts of climate change on real estate lending and investment portfolios

- **IMF (2020) Global Financial Stability Report: Markets in the Time of COVID-19.** One of the five chapters is titled "Climate Change: Physical Risk and Equity Prices" as the IMF acknowledges that the impacts of climate change could threaten financial stability. The report recognises the importance of adaptation as it highlights a study of expected flood losses in 136 coastal cities which est imates that **global annual losses could be reduced to US$60bn with adaptation versus US$1 trillion without it by 2050.** However, public equity valuations currently do not reflect the severity of climate change even though these could cost US$1 trillion annually.

- **Global Commission on Adaptation (2019) Adapt now: A global call for leadership on climate resilience.** The study found that the overall rate of return on adaptation is extremely high, with cost - benefit ratios ranging from 1:2 to 1:10, and in some cases even higher. In addition, **US$1.8 trillion of adaptation investments globally in five areas from 2020 to 2030 could generate US$7.1 trillion in total net benefits.** These five areas are early warning systems, climate-resilient infrastructure, improved dryland agriculture crop production, global mangrove protection, and investments in making water resources more resilient.

Consensus toward benchmarking coastal threats

Benchmark index can help avoid sinking long term capital into a future Atlantis…

…plus drive cohesive instead of mismatched climate strategies

Valuation is an art, not a science: tail risks must be factored in, valuations adjusted + capital reallocated. The NGFS has already recognised that fundamental changes must be made to account for systemic risks ahead.[14] Chronic SLR tail risks, often overlooked and ignored are an integral part of such assessment. We can prevent systemic shocks by re-rating further capital investments in vulnerable cities (literally avoiding sinking long term capital into a future Atlantis) and we can use this index to engage with various stakeholders on their resilience plans. Currently, many of these make no sense – many cities/ governments/ corporates/ banks have decarbonising strategies that head for 3°C-4°C, but physical adaptation strategies for 1.5°C-2°C. Such mismatched climate strategies are clearly doomed from the start.

Recalibrating for chronic tail risks will break vicious cycle…

…costly carbon transition pathways + no/low return adaptation action will then be investment worthy

Recalibrating tail risks can break current negative finance feedback loop + fast track decarbonisation. Not mapping and assessing how locked-in tail risks will disrupt and reshape APAC, makes the region complacent towards decarbonising. The Top 30 per capita GHG emitters are Australia (#10), New Zealand (#21) and South Korea (#27).[10] By recalibrating tail risks, costly carbon transition pathways, risky business unusual start-ups and no/low return adaptation projects will likely be reconsidered investment worthy. We hope that all stakeholders (governments, central banks, investors & corporates) will use the index to gauge absolute and relative tail risks and rethink APAC capital allocation. Remember, there's nine years left to avoid locked-in SLR of 1.6m-4.2m at 1.5°C;[11] already extreme storm tides of over 5m are happening today.[8] Start with ***"Waterproofing APAC to Avoid Atlantis: Executive Summary & Next Steps"***.

CWR APACCT 20 Index reflects the best-case (1.5°C) + base case (4°C) of APAC coastal threats…

…but it can be adapted to benchmark worst-case SLR scenarios

We created the CWR APACCT 20 Index to close real threat assessment gaps in APAC. With input from the finance sector through the survey, one-on-ones and countless Zoom calls, we created the CWR APACCT 20 Index to close the knowledge gap in the region. The index reflects mapped stacked SLR risks for four climate scenarios (1.5°C, 2°C, 3°C and 4°C) for 20 APAC cities across key indicators of population, land area, ports, airports, CBD and stock exchanges. Storm surge threats from typhoons/tropical cyclones/hurricanes plus government adaptation actions to reduce physical risks have also been assessed and included. We intend our index to reflect the best-case (1.5°C) and base case (4°C) of APAC coastal threats but it can be adapted to benchmark worst-case SLR scenarios – for more, please see Section 3.

Despite technical issues & data gaps, finance input led to consensus way forward…

We also built consensus on which methodology to use to overcome technical issues encountered. While we have discussed the key components of the index in this section, finance professionals also provided feedback on more technical issues. For example, the global underlying elevation data currently available has multiple inaccuracies; and multiple data gaps exist in valuing storm surges; moreover, the data is not consistent across the region, making benchmarking difficult. Finance sector input on each of these issues helped build consensus towards which methodology/data set to use – they span which SLR levels to use, flooding models, map granularity, storm surge indicators as well as proxies used to measure government action. We encourage you to dive into these nitty gritty issues to better understand the methodology behind the CWR APACCT 20 Index – see **"5 Key Challenges"** in this report.

…talking to local experts + reviewing latest ice science helped understand fast-changing SLR risk landscape

We need to understand the latest science and risks ahead if we are to come up with effective strategies. Therefore, besides the finance sector, we also reached out to regional scientists for latest research in the region. We are also grateful to them for their input and guidance of our work – for more on the latest science and how to build SLR and storm surge scenarios, please see ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

All these influenced underlying methodologies & index weightings

Index is far from perfect but it's a starting place for future collaborations. This is a first attempt to unpack complex interlinked coastal water risks for the APAC region. It is far from perfect as can be seen from the challenges we faced. However, we must start somewhere because the risks are significant. On this front, we are grateful to have had quality input from 100+ finance professionals ranging from chairs/directors of bank boards to research analysts and financial regulators. Their input has been invaluable in helping building consensus on underlying methodologies used as well as when considering weightings. We will continue to work with them to perfect the index and we welcome others to participate and collaborate.

This is our first attempt; it's not perfect but results alarm

CWR APACCT 20 Index results alarm + show importance of government action. The results & rankings that provide a first glance at the absolute and relative risk are alarming. More importantly, it shows that government action can make a difference. Read on for results.

CWR APACCT 20 Index

Results & rankings

Section 3

CWR APACCT 20 Index: benchmarking chronic tail risks & adaptation actions to avoid Atlantis

We developed the index with finance sector input through a survey, one-on-ones and countless Zoom calls…

…we hope you find it useful!

Despite global efforts, we may have to face the harsh reality that we will reach 1.5°C, potentially as early as 2030.[3] Hence, we must already start factoring associated tail risks from 1.5°C locked-in SLR today. With input from the finance sector through a survey, one-on-ones and countless Zoom calls, we developed the CWR APACCT 20 Index to close the knowledge gap in the region. We hope it kick starts a conversation on tail risks, fast-tracks decarbonisation and catalyses action to waterproof Asia. We hope you find it useful and wish you luck in your own journey to waterproof assets/ portfolios/ cities/ territory/ country/ region against capital threats and systemic shocks triggered by climate risks.

Below are the key considerations in this index:

- **20 APAC cities were chosen** that are the capitals and economic hubs of the leading countries in the APAC and are also located in coastal regions. They are: Aichi/Nagoya, Auckland, Bangkok, Guangzhou, Ho Chi Minh, Hong Kong, Jakarta, Macao, Manila, Osaka, Seoul, Shanghai, Shenzhen, Singapore, Suzhou, Sydney, Taipei, Tianjin, Tokyo and Yangon. However, there is no clear-cut definition of what constitutes a city as the definition could vary by country. For example, Shanghai is a city and a provincial-level municipality, while Tokyo is the capital of Japan as well as a prefecture. For comparative reasons, this report measures the 20 cities based on their best available official administrative references. Please see the table below for the official administrative references we used for each city.

20 cities selected for the index are coastal capitals & economic hubs in APAC…

Aichi/Nagoya = Aichi Prefecture	Macao = Macao SAR	Suzhou = Suzhou
Auckland = Auckland Region	Manila = Metro Manila	Sydney = Greater Sydney
Bangkok = Bangkok	Osaka = Osaka Prefecture	Taipei = Greater Taipei
Guangzhou = Guangzhou	Seoul = Seoul Capital Area	Tianjin = Tianjin
HCMC = Ho Chi Minh City	Shanghai = Shanghai	Tokyo = Tokyo To
Hong Kong = Hong Kong SAR	Shenzhen = Shenzhen	Yangon = Greater Yangon
Jakarta = Jakarta	Singapore = Singapore	

An at-a-glance assessment of absolute and relative risks from coastal threats for each city can be found in **"Appendix 1: CWR APACCT 20 Index City Factsheets"**.

Population stats used are 2020 estimates; future changes are not factored in

- **Population growth is not factored in**: Because we are dealing with long timelines and assessing SLR impacts requires the geo-spatial spread of the population per city, we decided to use population data today. Figures we used are based on estimates for 2020 and do not include any further population growth and increases/decreases in urbanisation. They are from the Center for International Earth Science Information Network (CIESEN) at Columbia University based on national census data between 2010-2014 and the United Nation's 2015 World Population Prospects report.[34]

We developed 2 indices:
• 1.5°C as the best-case
• 4°C as the base case

- **Impacts from 1.5°C to 4°C were evaluated**: Despite global efforts, we will likely reach 1.5°C by 2030 – 70 years ahead of schedule;[3] our current path is at least 3°C-5°C[1] as discussed previously in Section 1. To gauge risks, we have thus developed two indices:
  - **The best-case: 1.5°C CWR APACCT 20 Index** reflecting the coastal threat landscape we will likely lock-in by 2030; and
  - **The base case: 4°C CWR APACCT 20 Index** reflecting the risk landscape locked-in under the current climate pathway of 4°C by 2100.

Sea levels continue rising beyond 2100… so index uses locked-in SLR to gauge chronic locked-in tail risks

- **Locked-in SLR rather than SLR at 2100 was used to gauge chronic locked-in tail risks.** Sea levels do not stop rising in 2100, yet many financial scenarios have only taken SLR risks until then. The CWR APACCT 20 Index thus uses locked-in SLR to ensure that such guaranteed tail risks are factored in – more on why in **"Appendix 2: Locked-in SLR used in the CWR APACCT 20 Index"**. Note that we used GMSL, not local SLR. Local tide adjustments were not made.

- **Locked-in SLR impacts on key indicators are analysed and factored in.** Scoring depends on the degree of exposure of each key indicator to locked-in SLR at every temperature scenario (1.5°C, 2°C, 3°C and 4°C). These key indicators include land area and population affected as well as key infrastructure such as ports, airports, the stock exchange and the CBD as they act as proxies for the impact on GDP due to trade and economic activity disruptions. Finance sector input discussed previously in **"Physical threat factors & proxy indictors – which ones to use?"** helped us decide weightings across these indicators. The flooding methodology to determine impacts on these key indicators was the GIS-based bathtub approach – please see **"Flooding methodology – bathtub or hydrological?"** in the next section for why we opted for this instead of hydrological models.

Locked-in SLR impacts analysed for:
- land & population
- ports & airports
- CBD & exchanges

…weightings finalised with input from finance

- **The 4°C CWR APACCT 20 Index accounts for stacked SLR risk** as cities are impacted differently at each degree of warming due to their unique geographical location and elevation characteristics. Furthermore, the locations of key infrastructure differ from city to city. Impacts at each degree of warming therefore differ significantly. A city that is already vulnerable at 1.5°C will be even more vulnerable at 4°C, and thus the scoring will compound to show the increased risk. The 4°C CWR APACCT 20 Index takes into account this locked-in SLR stacked risk exposure at 1.5°C, 2°C, 3°C and 4°C across key indicators described above to provide more colour on the risk exposure profile of the city. Finance sector input discussed previously in **"Should the cities index reflect impacts across various scenarios?"** helped us decide on the approach of a climate scenario adjusted stacked SLR risk index.

Stacked SLR risks evaluated to reflect unique risk profiles of 20 APAC cities at each degree of warming

- **The median level of locked-in SLR was used for each climate scenario** as this received the highest votes from our finance survey – please see **"Determining SLR exposure – which level of locked-in SLR to use?"** for more on why we went with median SLR. That said, it is worth noting here that impacts could be worse at the high-end of the range for each climate scenario as the range is wide – 1.6m-4.2m (median = 2.9m) for 1.5°C and 6.9m-10.8m (median = 8.9m) for 4°C. Therefore, for more in-depth analysis of potential tail risks of vulnerable cities, we recommend analysing impact at the higher end of locked-in SLR range at each climate scenario. The differences are significantly material – we have provided a comparative case study of the impacts between the low, median and the high-end of the range for your reference in the next section in **"The impact on Hong Kong at different levels in the locked-in SLR range".**

Median locked-in SLR used as it received the highest survey votes…

…but recommend in-depth analysis at higher end of SLR range for hotspots

- **The 30m-grid NASA SRTM (SRTM-30m) elevation data was used to map SLR risks for regional consistency** in modelling SLR flooding. Although there are more granular (5m) topographical maps for certain cities, they are made based on different methodologies and not all cities have this level of granularity. We were thus unable to use these as the index results would not have been comparable. We do however recommend (if they are available) the use of granular data for in-depth analysis of risks. A more detailed discussion on mapping granularity, case studies showing the differences between 30m vs. 5m grid maps as well as finance sector input are set out in the next section **"Mapping granularities – trade-off granularity for consistency?"**.

Global elevation data used for benchmarking consistency…

…but recommend high granularity analysis of hotspots

- **Physical risks from storm surges are also assessed.** Typhoons/tropical cyclones already cause billions of dollars of economic losses annually and are set to get worse. Although not all cities are affected, those that are in the path of these extreme events will be more vulnerable. Note that whilst we did not map storm surge risks as the data is not widely available regarding exact storm surge levels, we instead assessed each city's exposure through past, current and expected magnitude and frequency of storm surges faced. Challenges we faced in factoring these in as well as finance sector input have been set out in the next section in **"Storm surge projections – simple metrics vs. expensive modelling?"**.

Already costly typhoons/ storms will get worse…

…so index accounts for their chronic nature through key indicators; weightings decided via finance sector input

Accounted for subsidence as it brings forward coastal threats

- **As subsidence brings forward coastal threats, it is taken into account.** Subsidence of land naturally occurs but some cities are sinking due to over-extraction of ground water and the weight of buildings. The index takes into account cities that on average are sinking by 1cm or more per year as this exacerbates SLR risk by bringing forward impacts – to see maps of subsidence impacts see ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

Govt adaptation action included to give a better ideal of "real" threat exposure levels…

…but benchmarking was challenging; finance sector input helped finalise weightings of proxy indicators

- **Government adaptation actions to reduce coastal threats are also included.** As adaptation measures taken by governments can help reduce the impacts of coastal threats various actions were taken into consideration to better gauge tail risks. However, government actions across cities are unique and difficult to quantify so we used proxy indicators to measure action. That said, government actions were not evaluated for their effectiveness; instead governments were evaluated for having a plan or already having invested in adaptation measures. No doubt, we faced multiple challenges in finding a consistent set of proxy indicators across the APAC cities – these challenges and finance sector input which helped us decide the weightings for these proxy measures across four categories are set out later in **"Government actions are inconsistent and unique – what proxy indicators to use?"**. Note that only publicly available data sources were used for this to ensure a consistent approach for the region. Finally, as discussed in the previous section, mitigation measures were not included as they should be analysed in the global context as a city's own actions may not change its risks unless global GHG levels reduce.

City with higher risks have higher scores…

City with:
- lowest risk ranks #1
- highest risk ranks #20

- **Index scoring – lower score reflects lower risks.** Cities that are more vulnerable to coastal threats will score higher on physical risks than those which are less vulnerable. Because government adaptation action can reduce these physical risks faced, cities' scores are reduced depending on the amount of action they take. Therefore, index scores go up with SLR, subsidence and storm surge whereas government action reduces scores. Hence, a city that is most vulnerable to threats after taking into account government adaptation action will rank at the bottom of the CWR APACCT 20 Index at #20 with the highest score. On the other hand, a city that is least vulnerable after taking into account government adaptation action will rank at the top of the index at #1 with the lowest score.

It's not perfect … feedback is welcomed!

- **It's our first attempt! We value your feedback to improve the CWR APACCT 20 Index.** The index is far from perfect and can be improved as can be seen from the box below. We value your continued support and welcome feedback to improve this work on coastal threats. Please email us at info@chinawaterrisk.org.

CWR APACCT 20 Index: Didn't include these, but would like to next time … let us know what you think?

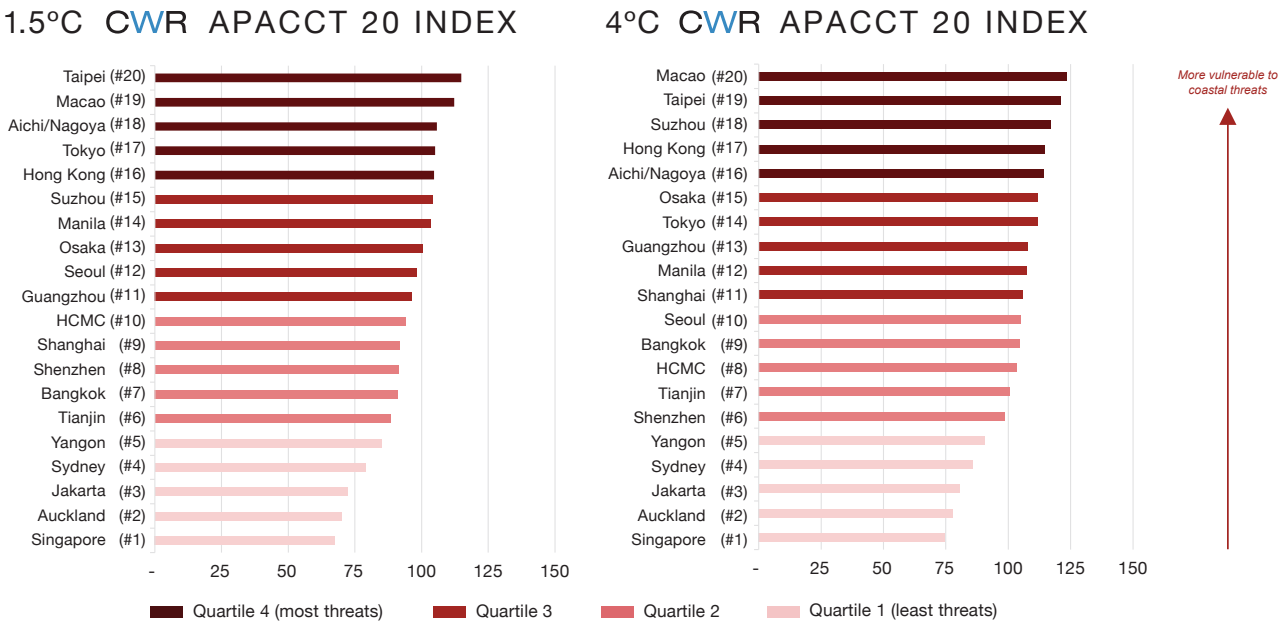
- *Additional cities and hubs*: We have had requests to expand the index as explained in **"This is a start - finance wants more…"**. In addition to cities we could also add manufacturing and logistics hubs that may not be in cities themselves but would be important for a city's/country's/territory's resilience.
- *City's importance to its country/territory GDP*: Entire countries/territories could be at risk if cities that drive economic growth are also vulnerable to coastal threats. Even though we did not include this in the index we have analysed it further in ***"Sovereigns at Risk: APAC Capital Threats"***.
- *Energy security*: Cities that rely heavily on imports for their power sector could be left extremely vulnerable from coastal threats which would impact port operations.
- *Key links such as rail and road*: Important for the transport of products domestically and if damaged could impact GDP as well as food and energy security.
- *Food security*: Exposed due to reliance on import/export of agri-products. Also, as suggested *"It could be interesting to also look at dependence on agriculture for these cities and the impact of SLR on saltwater flooding to crops"*.
- *Misalignment between government mitigation and adaptation action*: Governments taking significant action to adapt to protect its people but not to reduce emissions or vice versa could leave the city very exposed.
- *Strength of infrastructure*: Ideally, as suggested in the survey, we *"Should assess the robustness of existing infrastructure to make this fair"*. But, this is easier said than done plus costly to implement. Ideally, such stress testing should be spearheaded by governments for all key infrastructure & buildings with construction standards raised.

CWR APACCT 20 Index: Rankings at 1.5°C and 4°C

Rankings can inform allocation and/or sovereign risk ratings at both 1.5°C and 4°C. Knowing which cities are more/less exposed to coastal threats can help drive capital allocation away from more vulnerable areas. These indices can also be used to gauge/spread investment risks across APAC. The two charts below show the full CWR APACCT 20 Index at 1.5°C (best-case) and 4°C (base case). These indices rank cities for physical coastal threats of locked-in SLR, storm surge and subsidence, as well as government adaptation action to alleviate the physical risks. These rankings should be read in conjunction with the **"Appendix 1: CWR APACCT 20 Index City Factsheets"** which lays out key absolute risks and government actions for each city for a fuller picture.

Index shows which cities are more/less exposed to coastal threats…

… can inform capital allocation + sovereign risk ratings



Source: CWR APACCT 20 Index

The key points to note are:

- **Cities vulnerable to typhoons/tropical cyclones face more threats and have higher risk scores.** 13 of the 20 cities in the index are in the path of typhoons/tropical cyclones and have already experienced the strongest level of typhoon recently. They are Hong Kong, Macao, Taipei, all five cities in mainland China, all three cities in Japan, Manila and Seoul. Generally, these cities will have a higher physical score to reflect storm surge risk but government action could lower scores.

Cities in the path of typhoons will typically rank lower than those that are not

- **Our likely current locked-in path is reflected by the 1.5°C CWR APACCT 20 Index:** To recap, 28mn people will be impacted given that 15,006km^2 of land will be submerged (see **"Risks rise for all cities regardless of rankings between 1.5°C and 4°C"** infographic):

At 1.5°C…
…28mn people will be submerged by locked-in SLR

  - **The most vulnerable cities in Quartile 4 are Taipei (#20), Macao (#19), Aichi/Nagoya (#18), Tokyo (#17) & Hong Kong (#16).** All these cities are vulnerable to storm surges and some are low-lying. They also score badly as their governments are taking relatively less adaptation actions given their threat levels compared to the rest of the APAC 20 cities. Indeed, of the 20 cities, Taipei has taken the least action to adapt followed by Macao. In fact, Taipei is relatively not that exposed to coastal threats; it is its relative complacency in adaptation compared to the other cities that shifts it to last place – more on this later in this section.

…Taipei (#20) & Macao (#19) govts have taken the least action to adapt

Cities in Q1 rankings are not exposed to severe storm surge risks

- **The least vulnerable cities in Quartile 1 are Singapore (#1), Auckland (#2), Jakarta (#3), Sydney (#4) and Yangon (#5)** as they do not have significant storm surge risks. Moreover, their governments are taking adaptation actions to reduce the risks – Singapore, Auckland and Jakarta are amongst the top 5 cities that have the best scores for government adaptation action.

At 4°C…

102mn people displaced by locked-in SLR

…Rankings change as cities become relatively more/less risky vs. 1.5°C

…Macao is now the most at risk; then Taipei & Suzhou

…Q1 cities maintain their position

- **Rankings change at 4°C vs. 1.5°C - some cities become relatively more/less risky.** At 4°C, 102mn people are displaced given that 39,683km^2 of land will be submerged. City rankings for the 4°C index is different to that of 1.5°C index due to the 1) unique topography of the cities. 2) stacked SLR risk scoring across key indicators for the four climate scenarios, 3) storm surge profile and 4) existence of subsidence. Key changes between the 4°C and 1.5°C CWR APACCT 20 Index are:

  - **Quartile 4's most vulnerable cities Taipei, Macao, Aichi/Nagoya & Hong Kong remain whereas Suzhou replaces Tokyo at 4°C.** Macao becomes the most at risk city (#20) followed by Taipei (#19) and Suzhou (#18). Hong Kong falls one place to (#17) whereas Aichi/Nagoya moves up to #16.

  - **Quartile 1's least vulnerable cities stay the same.** All cities maintain their position at 4°C. Note here that despite Jakarta being more exposed to coastal threats than Sydney, it ranks ahead of Sydney due to its greater government plans and efforts to adapt – more on this later.

  - **Top movers between 1.5°C & 4°C:** Many cities moved one or two places within their Quartile between the two scenarios but some have jumped quartiles:

Top losers = Suzhou+ Shanghai drops to Q3

Top winners = Tokyo (moves from Q4 to Q3) + Seoul (moves from Q3 to Q2)

    - **Losers: rankings are worse at 4°C than 1.5°C.** Suzhou's the biggest loser sliding from #15 at 1.5°C down to #18 at 4°C; meanwhile Shanghai slips two places from #9 to #11 switching from Quartile 2 to Quartile 3. Other cities which lost two places within their quartiles are Osaka, Guangzhou and Bangkok;

    - **Winners: rankings are better at 4°C than 1.5°C:** The biggest winners are: Tokyo moving up from #17 (Quartile 4) at 1.5°C to #14 (Quartile 3) at 4°C; meanwhile Seoul also moves up from #12 (Quartile 3) to #10 (Quartile 2). Cities which gained two places within their quartiles are Aichi/Nagoya, Manila, HCMC and Shenzhen.

Jakarta scores well due to govt action but adaptation efforts are not evaluated for effectiveness

- **Jakarta is vulnerable but ranks well in this index due to government plans and efforts to adapt** from moving the city to planning to build a sea wall to protect coastal areas. But just because they say they are doing something doesn't mean that they actually are – this index does not score government adaptation action for effectiveness. Also the carbon costs of building and moving to a new city have not been factored in.

At #1, Singapore is miles ahead of HK's #17

- **Financial hubs Hong Kong & Singapore are at either end of the spectrum.** This is because Singapore is not subject to typhoons and its government is taking serious action to adapt to climate change; scoring top marks in adaptation action. Meanwhile, Hong Kong, although taking some government action is not doing much vis-à-vis the rest of the cities.

Cities may fare better relative to other cities at 4°C …

…BUT all experience a rise in absolute risks

- **Caution! City rankings may improve but risks are always rising.** Rankings can give us an idea of relative threat level across the cities. However, it is important to remember that while rankings in the benchmark may improve relative to other cities, city risk scores all rise between 1.5°C and 4°C. This can be discerned from the charts on the following page – impacts on population and land at 4°C are always higher than that at 1.5°C across all cities. It is clear that risks rise the most between 1.5°C and 4°C for Shanghai and Bangkok, followed by Suzhou, Tianjin, Guangzhou, Osaka and Macao as they have the widest difference in CWR APACCT 20 Index scores between the two scenarios. Meanwhile, on the other end of the spectrum are Manila and Yangon.

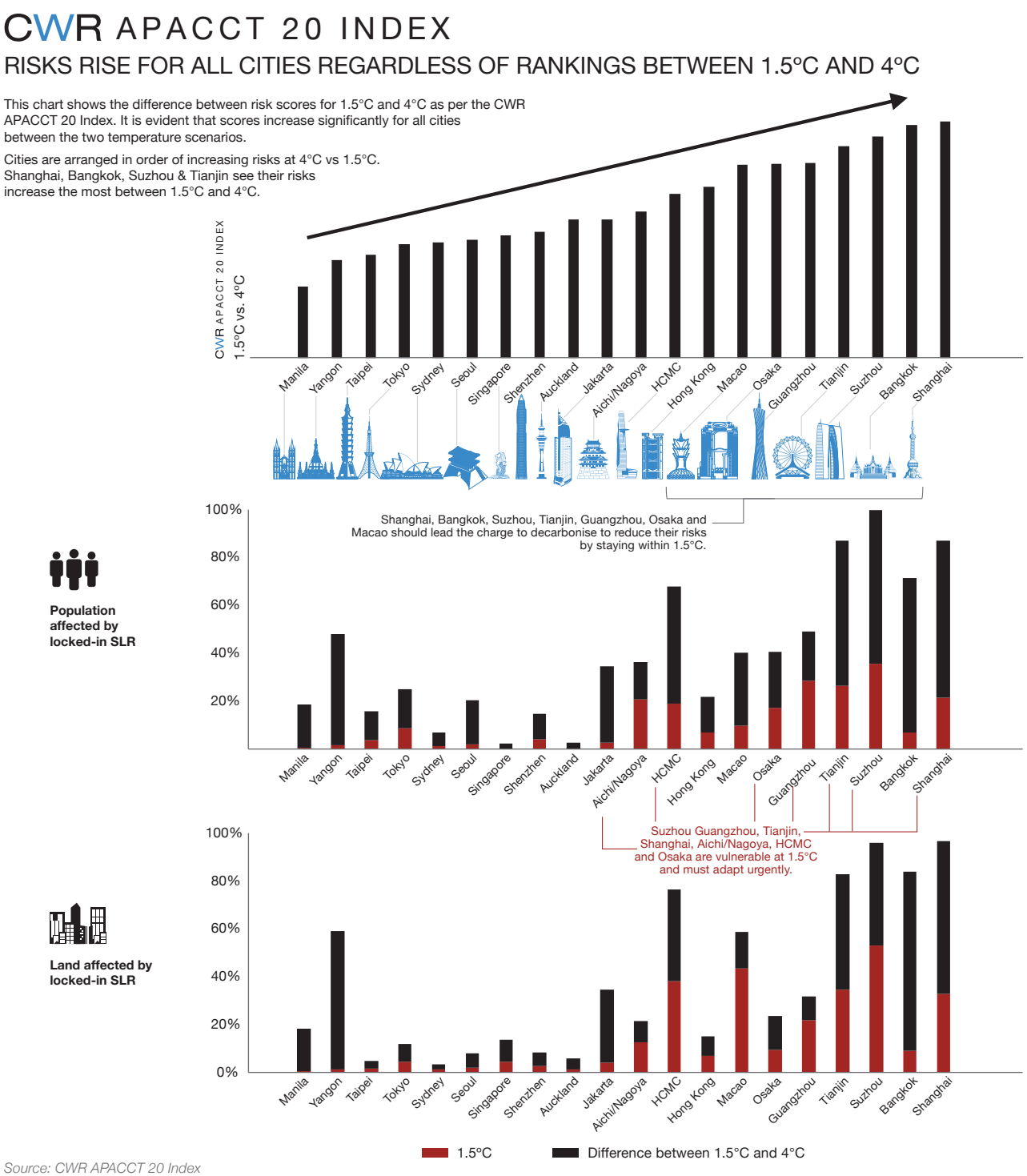
Cities with highest threats should be doing most – but not always the case

- **Most at risk cities should be doing the most.** It's common sense that cities that face the most threats should be making the most government efforts, but this is not always the case. We look at the indices at both climate scenarios with and without government adaptation action next to discern which cities are acting and which are not.

Risks rise regardless of rankings between 1.5°C and 4°C

Risks are clearly rising regardless of rankings and all cities need to fast-track decarbonisation. Here we look at the difference between risk scores for 1.5°C and 4°C as per the CWR APACCT 20 Index. We find that risks widen significantly between the two temperature scenarios for Shanghai, Bangkok, Suzhou, Tianjin, Guangzhou, Osaka and Macao. These cities should therefore be leading the charge to decarbonise to reduce their risks by staying at 1.5°C by 2100.

Also, Suzhou, Guangzhou, Tianjin, Shanghai, Aichi/Nagoya, HCMC and Osaka must start urgently tending to adaptation as a significant proportion of their land and people face flooding even at 1.5°C (best-case). The good news is that some of these cities are taking adaptation action already - see how the cities rank in the indices with/without government action on the following pages.



Source: CWR APACCT 20 Index

CWR APACCT 20 Index: With/without government action

Govt adaptation actions are key to reduce city risk…

…but private sector must have own plans & actions

Government actions matter because they can reduce impacts from physical coastal threats. Government action to tackle the risks from climate change can greatly alleviate the pressure on corporates and investors. Whether it's by implementing disaster management policies with plans to ensure food and energy security as well as building sea walls, growing mangrove forests, increasing the capacity of reservoirs, strengthening and building canals or expanding the drainage capacity of the sewer system. The private sector may still have to plan for multiple scenarios and take precautionary measures, but governments can relieve pressure.

Govt adaptation actions can change rankings…

…but unique nature means benchmarking can be improved

Their ability to change rankings means their scoring needs to be sound. Benchmarking government action was difficult as they are unique to each city, making it difficult to compare. Which indicators were used as proxies have been discussed in detail later in the next section in **"Government actions are inconsistent and unique – what proxy indicators to use?"** However, it is important to note here that since government adaptation actions were not scored for effectiveness, government adaptation action scores are the same for this iteration of the index.

Given disclosure bias, we carved out govt actions from the index so you can gauge physical threats only…

We have carved out government actions so you can better gauge threats be it from physical risks/lack of government action. Given the disclosure bias of the government actions, we have carved out government actions from the full CWR APACCT 20 Index so that you can see the physical threats faced by all cities at 1.5°C and 4°C in the charts on the following pages. The CWR APACCT 20 Index includes government action, whereas the ex-Govt Action index just scores physical impacts of coastal threats.

…this allows us to see govt performance on protecting their residents & cities

Government adaptation action can make a material difference to the rankings. The charts on the following pages show that government action/inaction on adaptation can move rankings (either up/down) for both 1.5°C and 4°C. This is not to say that cities where governments are acting are completely safe, but these plans and actions can significantly alleviate economic and social pressures in the face of climate change. However, ranking shifts are important as it allows us to gauge the relative performance of the 20 city governments in protecting their residents from coastal threats. Such ranking shifts are discussed in detail for both scenarios in the following pages.

Relative risk scores can help push governments to step up adaptation as impacts at 1.5°C are already severe…

…plus fast track decarbonisation to avoid catastrophic 4°C

CWR APACCT 20 Index with/without government action can be used to engage with government to accelerate adaptation and decarbonisation efforts. Scoring relative risk as per the CWR APACCT 20 Index at 1.5°C and 4°C (with/without government action) can be used to persuade governments to step up adaptation efforts at 1.5°C as impacts can already be severe for some cities. These indices can also be used to push governments to fast track decarbonisation to avoid 4°C. These index rankings also allow cities to see what each other is doing to adapt to such risks and whether they are ahead/behind in such efforts. As these CWR indices show inconsistencies in adaptation efforts across cities within a country, they can also be useful in helping governments manage climate strategies across cities. Please see much deeper analysis on this front in ***"Sovereigns at Risk: APAC Capital Threats"***.

City collaborations = knowledge sharing + best practice

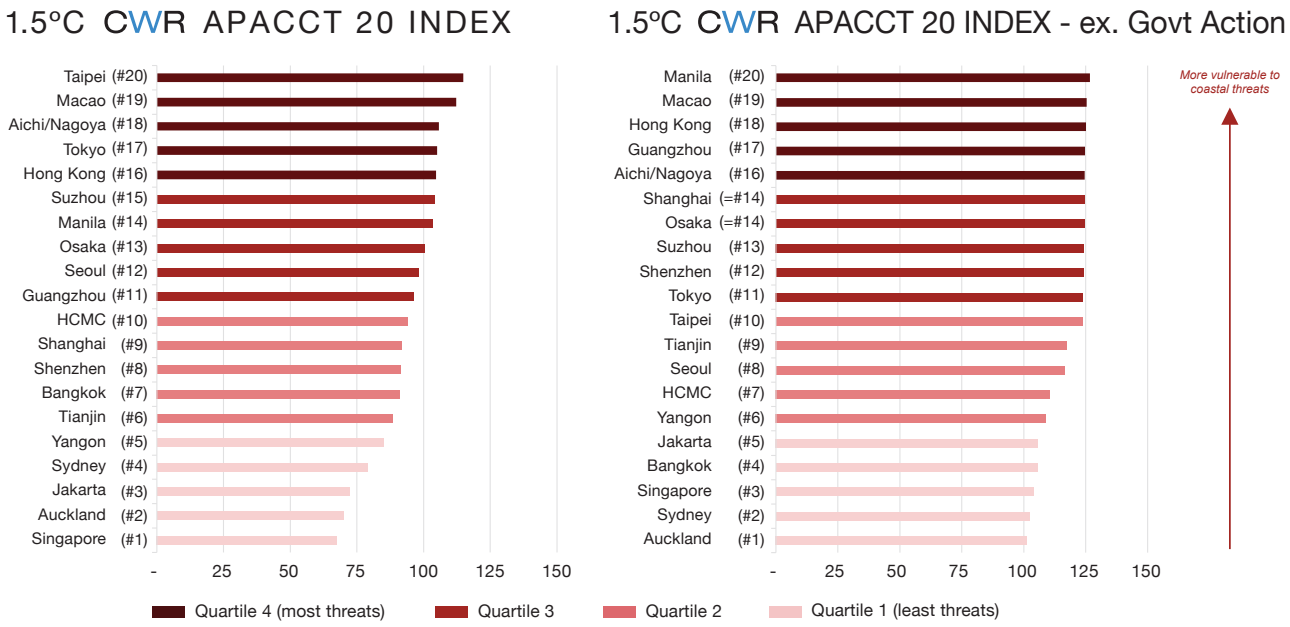
Caution: just because govts are acting, doesn't mean cities are safe!

Governments do not have to start this journey alone. Even though the action taken will need to be unique for the local context and threats faced, joining groups such as the Global Resilient Cities Network (GRCN) which aims to support cities in *"future-proofing their communities and critical infrastructure"* will help with collaborative action and to learn from best practice. It currently is made up of 98 cities.[35] Among the 20 cities in this report, only five belong to this group, which are Bangkok, Jakarta, Seoul, Sydney and Singapore. Although this does not mean that these five cities are more resilient than the remaining 15, it nevertheless gives them more opportunities and impetus to build resilience against climate change.

Index can be used as a building block to assess chronic tail risks & to inform better capital allocation decisions

Financial sector can also use these CWR indices to recalibrate for chronic tail risks. Fixating on the physical risks alone provides an incomplete analysis of threats faced. We encourage the financial sector to use these indices as a building block to help assess city/sovereign risks when considering investments; capital allocation can also be adjusted accordingly. We discuss specific actions for the financial sector to take later – for now, let's see how the 20 cities rank at 1.5°C (best-case) and 4°C (base case).

1.5°C CWR APACCT 20 Index – with & without government action



Source: CWR APACCT 20 Index

Key points of note: 1.5°C CWR APACCT 20 Index - with/without government action:

- Accounting for physical risks alone, Manila is at most at risk at #20 as it faces material subsidence as well as storm surges. However, since its government is taking action to reduce risks, it moves up six places from #20 to #14.

Govt action moves Manila from #20 in the physical index to #14

- The Greater Bay Area cities (Hong Kong, Macao, Guangzhou and Shenzhen) are all vulnerable to coastal threats. Besides Shenzhen, the other three cities fall in Quartile 4 of the ex Govt Action index. Significant action in the mainland lifts rankings for Guangzhou (#17 to #11) and Shenzhen (#12 to #8) but Hong Kong and Macao's relative complacency causes them to stay in Quartile 4 in the 1.5°C CWR APACCT 20 Index.

GBA mainland cities improve; but Macao & HK govts need to step up adaptation

- Other mainland Chinese cities of Shanghai and Tianjin also both improve their rankings due to significant government adaptation efforts. Shanghai jumps five places from #14 to #9 and Tianjin moves up from #9 to #6.

Other mainland cities all improve rankings with adaptation efforts

- Bangkok and Jakarta with a similar physical risk profile move in opposite directions – Bangkok slips down in ranking from #4 to #7 after adjusting for government action whilst Jakarta moves up from #5 to #3 with an ambitious plan to build a giant sea wall and move the administrative capital.

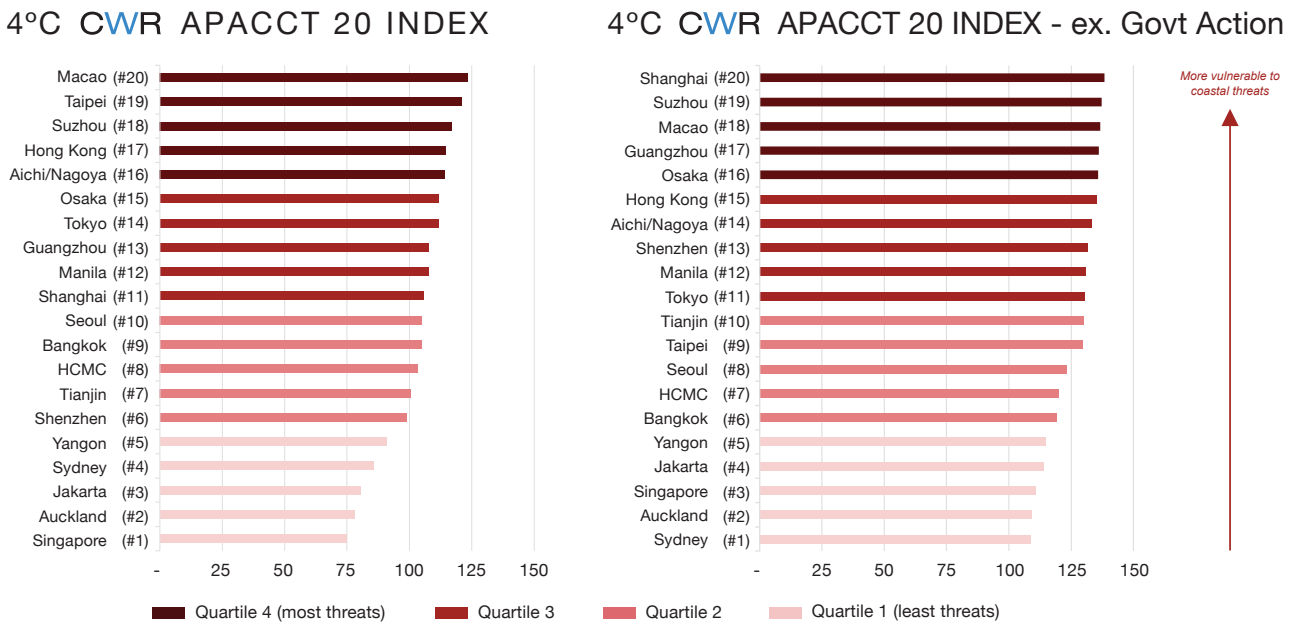
Bangkok & Jakarta face similar physical risks but govt action leads to divergent rankings

- Taipei & Tokyo are the worst performers. Taipei underperforms the most – physically, it is relatively less exposed at #10 but lagging government adaptation action means it drops 10 places and is relegated to the bottom at #20. Tokyo gives up 6 places, falling from #11 to #17, placing it in the bottom quartile as well.

Taipei underperforms the most – falling from #10 in the physical index to #20

- Seoul and HCMC also drop places post government action but not as drastically as Taipei and Tokyo.

4°C CWR APACCT 20 Index – with & without government action



Source: CWR APACCT 20 Index

Key points of note: 4°C CWR APACCT 20 Index - with/without government action:

Shanghai, Guangzhou & Osaka shift from Q4 (physical risks) to Q3 with govt action

- Ex-government action, Shanghai, Suzhou, Macao, Guangzhou and Osaka fall in Quartile 4 as they are most physically vulnerable. But after accounting for government action, Macao and Suzhou remain in Quartile 4 whereas the rest move to Quartile 3.

Govt action moves Shanghai from #20 to #11

- Shanghai is the most at-risk city at #20 accounting for physical risks alone, but it moves to #11 due to significant government action. That said, its score increases dramatically between 1.5°C and 4°C as per the previous graphic **"Risks rise regardless of rankings between 1.5°C and 4°C"**.

Shenzhen & Guangzhou govt action also substantial…

- Guangzhou is highlighted in the Verisk Maplecroft Sea Level Rise Index as the most at-risk city to SLR from 500 cities evaluated globally.[32] However, government action in the city has been significant and has already started due to the substantial typhoon risks faced. Looking at physical risks alone at 4°C, it is at #17 but improves to #13 once government action is included. The other mainland GBA city of Shenzhen also improves from #13 to #6.

…but 8 cities' (Taipei et al.) relative complacency in adaptation = fall in rankings

- Some cities are worse off in terms of the rankings when government action is included, notably Taipei (again the worst performer) dropping from #9 to #19. Others that are worse off after factoring in government action were Macao (#18 to #20), Hong Kong (#15 to #17), Aichi/Nagoya (#14 to #16), Tokyo (#11 to #14), Seoul (#8 to #10), Bangkok (#6 to #9) and Sydney (#1 to #4).

Naturally, Singapore ranks #3 but govt action makes it #1; HK moves in the opposite direction

- Financial hubs Hong Kong and Singapore move in opposite directions. Naturally, Singapore ranks #3 but its top-down, Prime Minister-led government action has moved it into pole position in the 4°C CWR APACCT 20 Index. Meanwhile, Hong Kong's complacency in adaptation has relegated it from Quartile 3 to 4.

Finance & regulations to steer us from systems collapse

Index shows dire future if we reach 4°C

The CWR APACCT 20 Indices reveal a ballpark future that is already ugly at 1.5°C but at 4°C it'll be more dire. Although far from perfect, the indices sufficiently show us a dire future ahead for APAC capitals and cities if we are not more aggressive at closing the emissions gap to steer us away from 4°C (our current base case) to reach 1.5°C by 2100 instead of 2030.

All must collaborate to close emissions gap to avoid Atlantis

At 4°C no city is safe! All hands on deck to avoid Atlantis: cities, science, finance, governments, corporates, NGOs have roles to play. We need to pay attention to science – there are a lot of papers out there with findings that have grave financial and policy implications. There has to be collaborative efforts to plug science research gaps that could inform better financial decisions. We all have a role to play; there is no room for complacency.

Systemic shocks can happen even at 1.5°C…

…so chronic tail risks warrant structural changes in financial systems

Even 1.5°C will trigger systemic shocks that put APAC banks/finance at risk of collapse. The NGFS recognised in 2019 that *"climate change is one of many sources of structural change affecting the financial system"*.[14] There is no doubt that there are tail risks from coastal threats. The unpreparedness by governments, banks and other institutions for them will trigger systemic shocks to the financial system. The problem is that these significant tail risks have so far been ignored as fundamental financial analyses have not yet changed, thus lagging the new risk landscape. While acute (event-driven) risks can be accounted for with scenarios, chronic tail risks warrant structural changes.

…hopefully the index helps the sector prepare

The financial sector thus has an important role to play. We hope they can use the CWR APACCT 20 Indices to prepare for systemic shocks ahead:

APAC savings at stake from clustered nature of coastal threats…

…not just sectoral but locational analysis needed to spread risks

- **Central banks/banks must check clustered risk spread across the 20 cities to ensure capital adequacy.** Banks must be able to survive coastal threats at 1.5°C through 4°C as APAC savings are at stake. The clustered nature of coastal threats means that tail risk impacts across the region must be well understood to ensure proper allocation of capital and spread of risk. Sectoral and company analyses are no longer the only concerns when allocating capital; locational impact analysis will need to be performed due to clustered assets facing coastal threats. Impacts on assets such as ports and airports will also have knock-on impacts across multiple sectors. Worse still, there will likely be loss of insurance coverage placing all coastal threat risks squarely on banks.

Fundamental risks are mispriced so CWR indices can be used to re-rate sovereign & corporate risks

- **Recalibrate for tail risks to ensure financial resilience: sovereigns, credit & equity valuations.** Financial mispricing of fundamentals has allowed no sense climate strategies to pervade across governments and all sectors – these must be adjusted. More specifically, we see these CWR indices used to inform credit rating agencies on their re-rating of sovereign and corporate risks as governments and companies are exposed to these 20 cities – more in ***"Sovereigns at Risk: APAC Capital Threats"***.

Use 1.5°C index to push for adaptation…

…as APAC cities already face high risks at this level of warming

- **Drive APAC governments & corporates to step up proper adaptation for 1.5°C.** The 1.5°C CWR APACCT 20 Index shows that risks are still material at this level of warming. Cities falling in the bottom quartile – Taipei, Macao, Aichi/Nagoya, Tokyo and Hong Kong must do more to lower threats. However, because almost all the 20 cities' ports and over half the airports are impacted, the financial sector should ensure trade resilience by raising rates/ withholding capital from these ports and airports unless they adapt to survive coastal threats ahead.

Use 4°C index to aggressively push for decarbonisation…

…as many cities will not survive this

- **Push APAC governments & corporates to decarbonise to avoid 4°C.** As all cities are significantly impacted at 4°C, APAC must act to avoid this at all costs. In particular, physical coastal threats rise significantly between 1.5°C and 4°C for Shanghai, Bangkok, Suzhou, Tianjin, Guangzhou, Osaka and Macao. These cities must do much more to fast track decarbonisation. They should not only be mitigating their own impact risks by cutting carbon emission in their jurisdictions but also by coordinating/ leading efforts across the region and beyond.

No-sense climate strategies should be penalised…

- **Penalise governments for mitigation strategies that head to 4°C but adapting for 1.5°C.** Currently, many cities' climate (mitigation & adaptation) strategies don't make sense including Singapore, who is leading the index. Please see case studies on no-sense climate strategies by governments and corporates in ***"Sovereigns at Risk: APAC Capital Threats"***. Governments must not only make all out efforts to fast track decarbonisation to avoid 4°C but mismatched mitigation and adaptation strategies must also be realigned. Finance should penalise those for not taking action.

…decarbonisation & adaptation must be fast-tracked concurrently

Data gaps need to be plugged – all stakeholders have roles to play

- **Work to resolve nitty gritty issues regarding data gaps through collaboration**. We had to make do with the data we have so far to create the index. Although finance sector feedback signals consensus, how coastal threats and government adaptation actions are measured can be improved. These nitty gritty issues are explored in detail in the next section. Here, science, academia, finance, corporates, investors and governments all have a role to play.

Tough trade-offs ahead to steer us away from reaching 1.5°C by 2030…

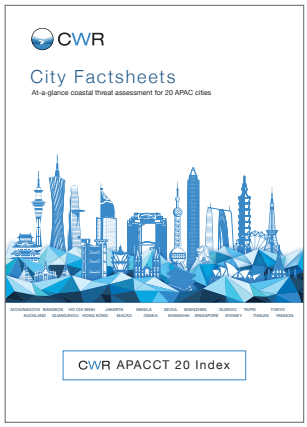
Time is running out. There is much to do and we are playing catch up. We are not ready, and we have nine years left to steer us away from reaching 1.5°C by 2030 – 70 years in advance of our target of 2100. We face a Herculean task to avoid Atlantis – there will be tough trade-offs ahead. Efforts to be made are sobering – in COVID-19 terms, we will need a decade of coronavirus to get us back on track.[15] Since no one wants that, we must act to build back better systems that are resilient.

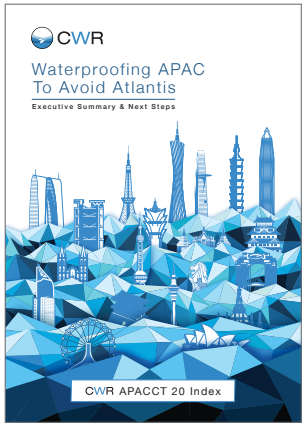
… efforts to be made are sobering: in COVID terms, we will need a decade of coronavirus to get us back on track

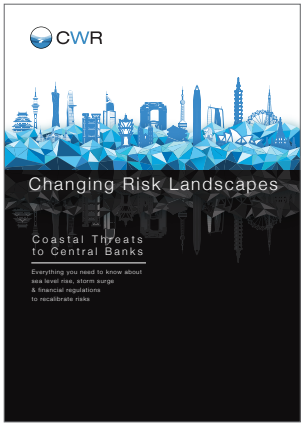
For more on what to do, check out ***"Waterproofing APAC to Avoid Atlantis: Executive Summary & Next Steps"*** – there we have set out actions for 1) asset owners and managers; 2) banks; 3) financial regulators; and 4) governments to address such imminent threats.

And the latest news from our poles looks grim…

Unfortunately, as we are writing this, there is continuous grim news from our cryosphere. Accelerated melt even at today's temperatures could result in a further collapse in impact timelines. So please read on to see how to use these indices to assess such worst-case scenarios. If you want to see how it really is, check out "8 things you must know about SLR" in our report ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.







How to use the CWR APACCT 20 Index for worst-case benchmarking

The CWR APACCT 20 Index whether at 1.5°C or 4°C is intended to be the "locked-in" best & base case but not the worst-case. However, given that we are on track for 4°C, we will likely trigger feedback loops and uncontrollable melt as discussed earlier in section 1. Deep uncertainties linked with Antarctica's marine ice cliff instabilities; permafrost thaw; and loss of Arctic sea ice could bring about rapid SLR.[18] These deep uncertainties although mentioned in the 2019 IPCC-SROCC, have yet to be included in the IPCC SLR estimates so far.

Our current path could trigger feedback loops and uncontrollable melt…

Potential rapid SLR could bring forward risks by hundreds of years. The discussion below thus explores how our indices can be used to assess these "worst-case" RCP8.5 scenarios by shifting the timelines forward:

- 1.5°C CWR APACCT 20 Index's locked-in SLR of 2.9m may be reality by 2100; and
- 4°C CWR APACCT 20 Index's locked-in SLR of 8.9m may be reality by 2200.

…so use the CWR APACCT 20 Index to assess these "worst-case" RCP8.5 scenarios

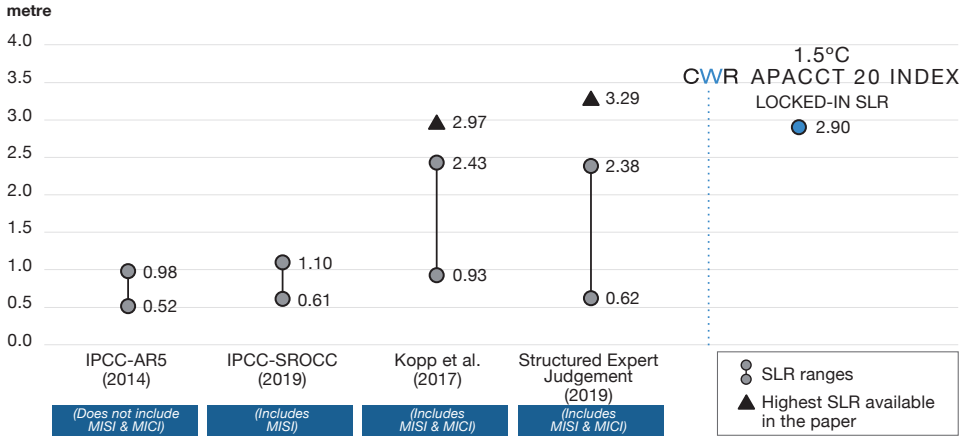
Antarctica & Greenland melting faster than we thought – collapse of ice sheets/cliffs could bring 2.9m+ of SLR by 2100. Recent observations of ice melt show alarming melt rates plus our oceans are warming faster. Moreover, we are 70 years ahead of achieving our warming target of 1.5°C by 2030 instead of 2100.[3] We may have thus brought forward SLR impacts. While the IPCC did make adjustments to the AR5 for polar marine ice sheet loss (MISI) in its 2019 IPCC-SROCC, the upward revision of estimates may not be enough as it does not include the loss of marine ice through calving and/or collapse of ice shelves/cliffs (MICI) which could cause rapid SLR. Factoring in both MISI and MICI, SLR projections change significantly[36,37] to as high as 2.43m[36] ("very likely" range) by 2100 under the RCP8.5 scenario (current climate pathway). The chart below shows the various sets of SLR ranges – note that the highest SLR estimates that include MISI & MICI are 2.97m and 3.29m (represented by the triangles). Please see the box on the next page for the differences between "likely" and "very likely" ranges.

We are 70 years ahead of our warming targets = greater SLR sooner…

…revised IPCC's SLR projections do not include MICI so SLR could be much worse than 1.1m

1.5°C CWR APACCT 20 INDEX

AT WORST; LOCKED-IN SLR OF 2.9M MAY BE PLAUSIBLE REALITY BY 2100



Source: CWR, IPCC AR5 Synthesis Report (2014), IPCC Special Report on Ocean and Cryosphere (SROCC) (2019); Kopp et al. (2017) "Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections." Earth's Future; Bamber et al. (2019) "Ice sheet contributions to future sea-level rise from structured expert judgement", PNAS; CWR report "Avoiding Atlantis – The CWR APACCT 20 Index" (2020). All SLR ranges are per RCP8.5 with the exception of the CWR APACCT 20 Index locked-in SLR of 2.9m.

Ice sheet experts project much higher ranges than the IPCC…

… their "very likely" SLR range high-end are 2.38m & 2.43m – this is 2.2x IPCC-SROCC

…their top ends of 2.97m & 3.29m are similar to the locked-in SLR used in 1.5°C CWR APACCT 20 Index of 2.9m

Use the 1.5°C CWR APACCT 20 Index to benchmark worst-case 2100 SLR coastal threats under RCP8.5. At 1.5°C the CWR APACCT 20 Index benchmarks SLR risks at the median of 2.9m. Although this locked-in SLR range was expected to occur 200 years from now, it appears that we may reach these levels by 2100 as per SLR projection ranges shown in the chart above. Evidently, the 1.5°C CWR APACCT 20 Index can thus be used to benchmark worst-case 2100 rapid SLR from ice sheet/shelf/cliff loss and collapses (MISI & MICI) in Greenland and/or Antarctica. Surely it's worth swotting up on **"8 things you must know about SLR"** and find out exactly what is MISI and MICI in ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***. Think about it - with an SLR of 2.9m just factoring in high tide (around 2m-2.5m), means we need to prepare for 5m+ of coastal flooding WITHOUT storm surges.

At best our 1.5°C index signals risks in 200 years' time…

…at worst, it can be used to benchmark risks by 2100

IPCC range estimates typically reflect a 66% confidence level or a "likely" range…

…but for adaptation & worst-case assessment use highest plausible SLR estimates to be prudent

Likely vs. very likely SLR ranges – which to use?

*This exert is taken from **"Changing Risk Landscapes: Coastal Threats to Central Banks"**, if you'd like to know more please see **"How to build scenarios for SLR tail risks & event-driven storm tides"** in that report.*

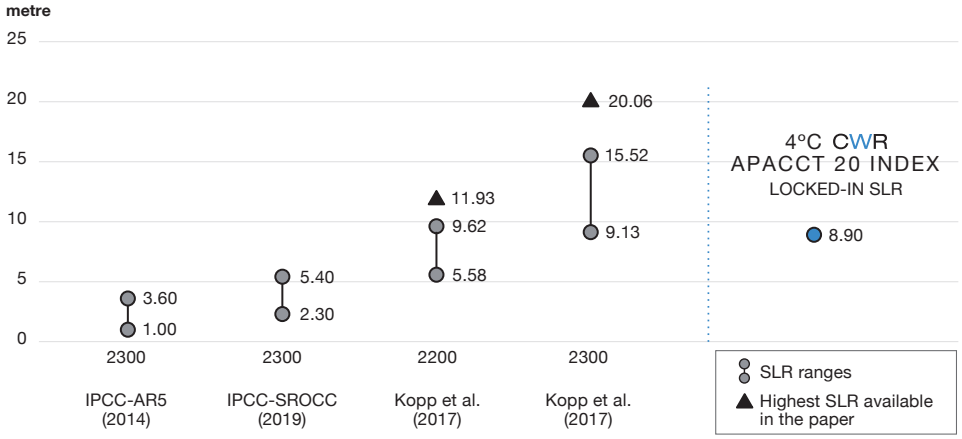
IPCC projections are used to build scenarios to assess risk, but IPCC SLR projections may not provide the full picture. IPCC range estimates typically reflect a 66% confidence level or a "likely" range. The "very likely" ranges (90% confidence interval) tend to be wider so as to garner more consensus than "likely" ranges. For adaptation and worst-case scenario building purposes, it is clear that the top end of the "very likely range" should be used as they are plausible scenarios. As Bamber et al. who led the Structured Expert Judgement (SEJ 2019) on ice sheets warned: *"limiting attention to the likely range, as was the case in the IPCC AR5 may be misleading and will lead to a poor evaluation of the true risks. We find it plausible that SLR could exceed 2m by 2100 for our high-temperature scenario, roughly equivalent to business as usual."* The high-end of their "very likely" range is 2.38m with the top end of the range at 3.29m. For Kopp et al. the high-end of the "very likely" range is 2.43m with the top end at 2.97m. So be prudent – use the high-end SLR estimates of the "very likely" range to the top end as they are plausible!

The gap widens between IPCC & ice sheet experts at 4°C…

…the 2300 range of the ice sheet experts of 9.13-15.52m is 3-4x that of IPCC-SROCC's 2.3-5.4m

Beyond 2100 impact timelines are likely brought forward, especially if we continue to head towards 4°C. As can be seen from the chart below of various RCP8.5 scenarios, the gap widens between IPCC estimates and the latest research. The locked-in SLR of 8.9m used in the 4°C CWR APACCT 20 Index now falls in the updated 2200 "very likely" SLR range based on RCP8.5 scenarios updated for polar melt (MISI and MICI) of 5.58m-9.62m.[36] The 2300 "very likely" range of 9.13m-15.52m is 3-4x that of IPCC-SROCC for the same timeframe.[36]

4°C CWR APACCT 20 INDEX
AT WORST; LOCKED-IN SLR OF 8.9M MAY BE PLAUSIBLE REALITY BY 2200



Source: CWR, IPCC AR5 Synthesis Report (2014), IPCC Special Report on Ocean and Cryosphere (SROCC) (2019); Kopp et al. (2017) "Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections." Earth's Future; CWR report "Avoiding Atlantis – The CWR APACCT 20 Index" (2020). All SLR ranges are per RCP8.5 with the exception of the CWR APACCT 20 Index locked-in SLR of 8.9m.

The locked-in SLR of 8.9m used in the 4°C CWR APACCT 20 Index falls in the updated 2200 SLR range…

…so the 4°C index can be used to benchmark the worst-case by 2200

Use the 4°C CWR APACCT 20 Index to benchmark worst-case 2200 SLR coastal threats under RCP8.5. At 4°C the CWR APACCT 20 Index benchmarks SLR risks at 8.9m. Although this locked-in SLR range is expected to occur 200 years from now; it now appears that we may reach these levels by 2200 as per SLR projection ranges shown in the chart above. Evidently, the 4°C CWR APACCT 20 Index can be used to benchmark worst-case 2200 rapid SLR from MISI & MICI in Greenland and/or Antarctica.

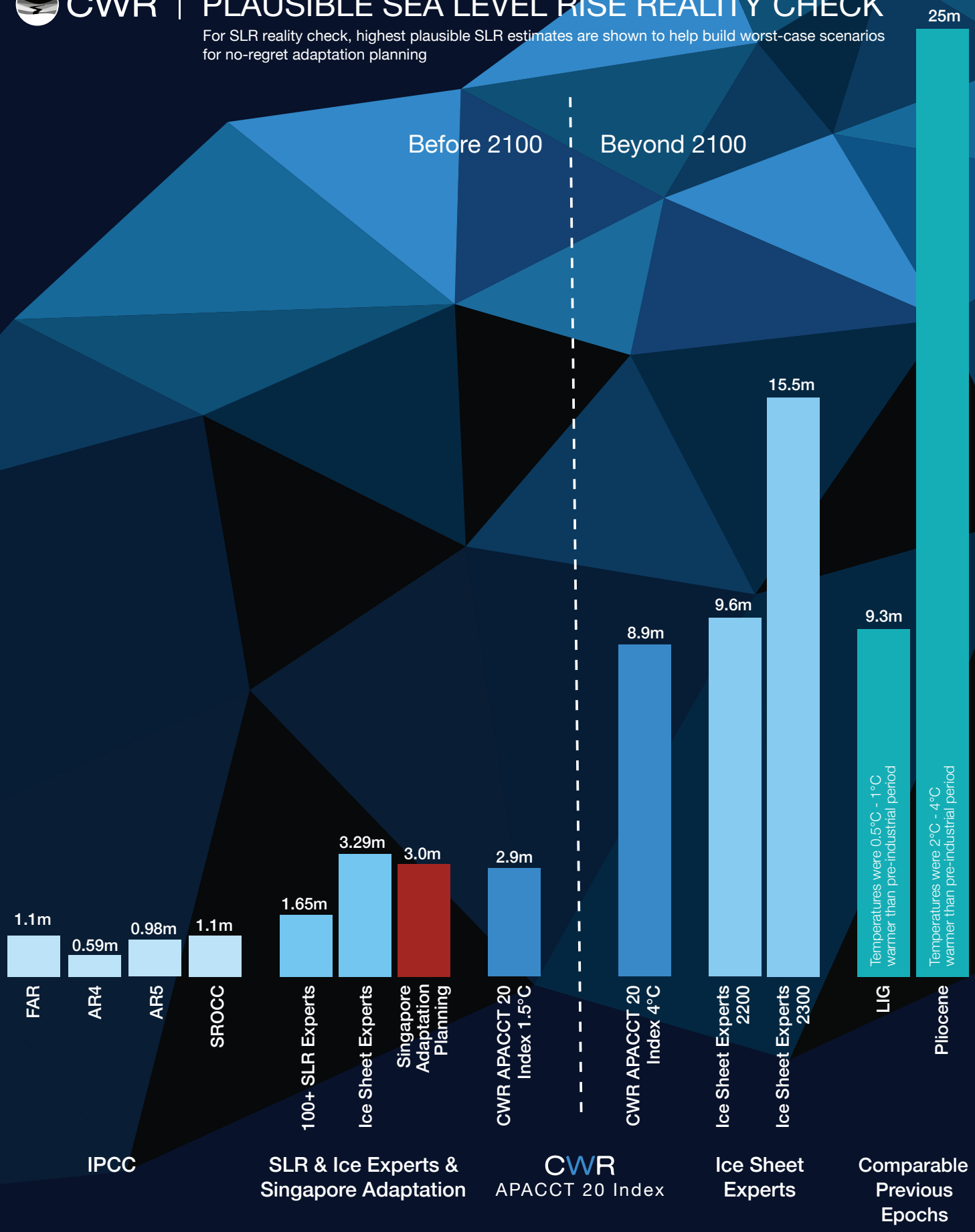
Plausible SLR estimates by 2300 of 15.52m to 20m are unsurvivable…

…we have 9 years to act to avoid tipping points which guarantees Atlantean future

Our current trajectory is collapsing our timelines and exponentially increasing our risks. SLR threats are more imminent than we think yet we still have not reached consensus on how to value them.[38] By 2300, the high-end of the plausible range of 15.52m or the top end at 20m of SLR is unsurvivable for millions that live by the coast.[36] The **financial sector must start recalibrating these chronic tail risks today and the CWR APACCT 20 Index can play an important role** to help APAC reassess its risks, reprice and reallocate capital. We have a small window of opportunity (nine years) to right the course – otherwise, we may pass other tipping points that could well end up locking-in up to 60m of SLR – please see graphic **"Tipping points & runaway melt – window to act closes by 2030"** and get on top of your SLR and storm tide scenarios in **"How to build scenarios for SLR tail risks & event-driven storm tides"** in our other report ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

CWR | PLAUSIBLE SEA LEVEL RISE REALITY CHECK

For SLR reality check, highest plausible SLR estimates are shown to help build worst-case scenarios for no-regret adaptation planning



Source: CWR reports "Changing Risk Landscapes: Coastal Threats to Central Banks" 2020; IPCC reports (1990-2019); Horton et al. (2020); Bamber et al. (2019); Meteorological Service Singapore (2015); Singapore National Day Address (2019); Kopp et al. (2017); DeConto & Pollard (2016)

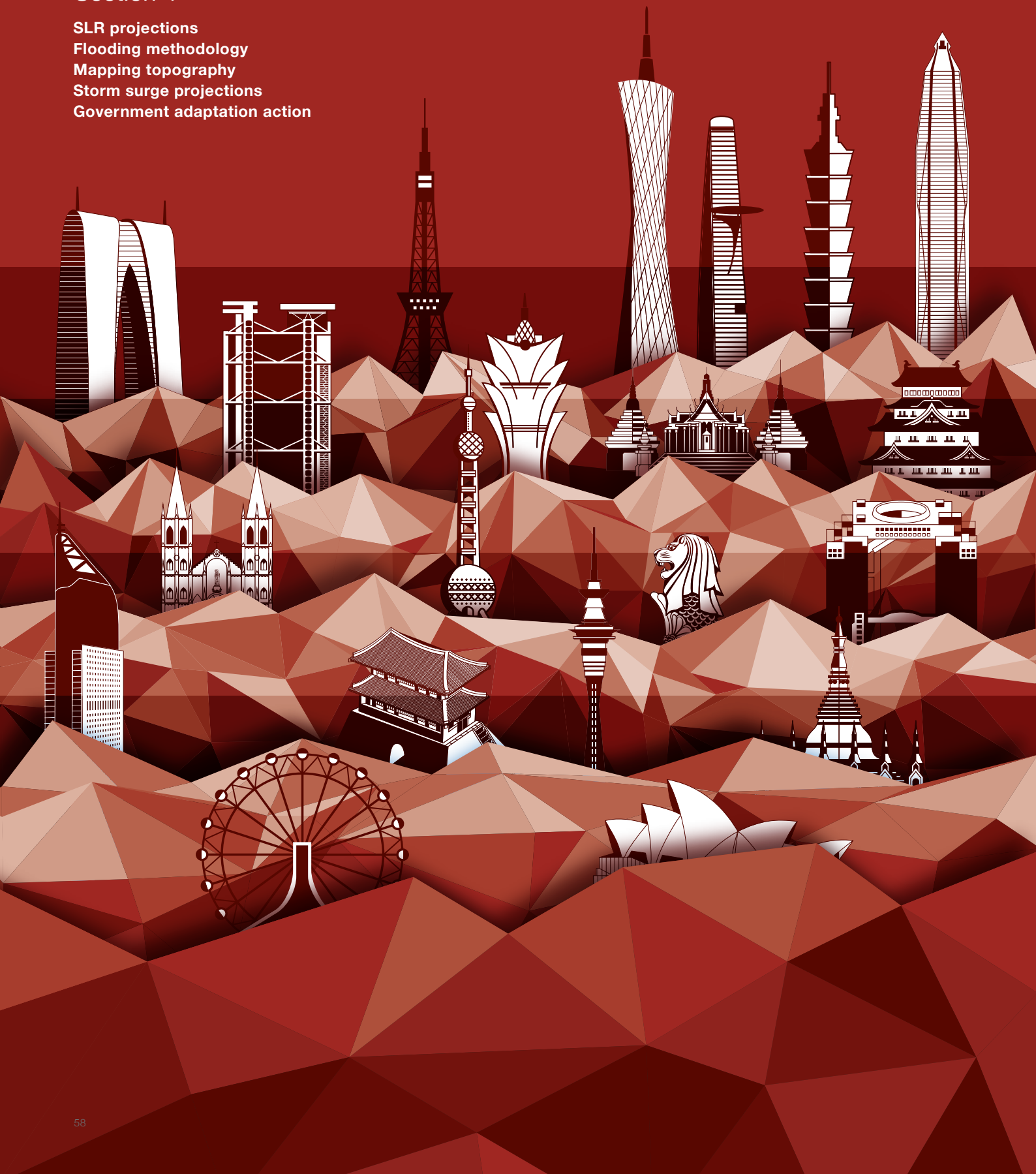
The information and graphics on this page have been extracted from the CWR report, "Avoiding Atlantis: The CWR APACCT 20 Index", 2020

CWR

5 Key challenges

Section 4

SLR projections
Flooding methodology
Mapping topography
Storm surge projections
Government adaptation action



Key challenges we faced in creating the index

Finance sector input helped us overcome 5 key challenges in creating the index…

…so that it is useful & practical + available by the end of 2020

We faced many challenges in creating the CWR APPACT 20 index. After having reached consensus with finance sector input on what type of index to create, we faced challenges in its execution. This was mainly due to research data gaps as well as timing and budget constraints. We have had to simplify various components of the index in order to ensure that it was useful, practical and available by the end of 2020. Set out in this section are the five key challenges we faced and how we overcame them, taking into account advice from the financial professionals surveyed. The five key challenges were:

1) Determining SLR exposure – which level of locked-in SLR to use?

2) Flooding methodology – bathtub or hydrological?

3) Mapping granularities – trade-off granularity for consistency?

4) Storm surge projections – simple metrics vs. expensive modelling?

5) Government actions are inconsistent and unique – what proxy indicators to use?

Data is imperfect but we need to start assessing risks now so trade-offs were made

Trade-offs were made in determining exposure as we do not have the luxury of time to wait for better data. As you will see later, we have had to make trade-offs – more granular analysis for regional consistency, scenario analysis of frequency and magnitude of storm surges for simpler indicators of these instead and so on. We believe these trade-offs were worth making, as does the finance sector. We do not have the luxury of time to wait for scientists to come up with even better storm surge models, narrower SLR projection ranges or high granularity maps for all APAC cities.

Assessing chronic SLR risks was problematic, causing 3/5 challenges

Three of the five challenges pertain to assessing SLR impacts and data gaps. To assess chronic tail risks from SLR in the index, flooding in each city from locked-in SLR has been mapped at each temperature scenario. However, the impact of this flooding in the maps and data will depend on: 1) The level of locked-in SLR used; 2) Flooding method used; and 3) The granularity/accuracy of the elevation maps used (ground-level elevation data). The multiple challenges related to each of these are discussed later.

But determining storm surge risks was also hard due to their complex nature…

Storm surge scoring threw up multiple issues from accuracy to budgets. As one surveyed pointed out *"Extreme weather events contemplate frequency, severity and timing (e.g., is the typhoon occurring in the 'typical' typhoon season or outside the typhoon season)? The coincidence of SLR, high tides, windstorms will exacerbate extreme weather events."* This makes assessing the actual impact of storm tides in the future difficult. This threw up the choice of opting for simple metrics or execute storm surge modelling across APAC. How we resolved this is covered later in this section.

…yet government action was most challenging due to their unique nature & disclosure bias

Government action was the most challenging as actions are inconsistent and unique. We tried our best to remove subjectivity to ensure consistency in scoring but still disclosure biases remain as we did not score for effectiveness of government plans/actions at this stage. That said, we believe that the challenges are sufficiently addressed at this stage taking into account finance sector input.

The index can be improved with your feedback

There is room for improvement – we need your input! There are challenges in the calculation of each of these factors, but we believe we must move past this and assess risks from coastal threats, or else assets will be mis-priced. All aspects of these five key challenges can be improved. Please contact us at info@chinawaterrisk.org if you would like to collaborate to further improve these index indicators.

We recommend you read challenges #1 to #4 relating to physical coastal threats with another report in our series ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

As for challenge #5 pertaining to scoring government adaptation, we recommend you read this part with ***"Sovereigns at Risk: APAC Capital Threats"***, another report in the CWR Coastal Capital Threat Series. Enjoy wading through the nitty gritty!

1. Determining SLR exposure – which level of locked-in SLR to use?

Climate science is imperfect, but warming projections from the 70s have been proven right

Climate science can improve but projections of the causal relationship between emissions and temperatures have been in the right ballpark so far. Although climate science is far from perfect, the science is correct and 50-year projections made in the 1970s have been proven right.[39] 14 out of 17 peer-reviewed climate models correctly predicted how much the earth would warm based on how much CO_2 is in the atmosphere today.[39]

This leads to locked-in SLR at various temps = chronic risks

Due to global warming, sea levels will continue to rise beyond 2100, and each temperature scenario (1.5°C, 2°C,3°C and 4°C) will "lock-in" a certain amount of irreversible SLR. So although far away, we have guaranteed these outcomes and thus should recalibrate terminal values for such certain chronic tail risks accordingly. Since the CWR APACCT 20 Index seeks to assess long term tail risks the SLR levels used pertain to locked-in SLR.

We picked Strauss et al.'s SLR ranges…

The locked-in SLR data we used in the CWR APACCT 20 Index is based on peer reviewed scientific research developed by Benjamin Strauss and Scott Kulp of Climate Central, in collaboration with Anders Levermann of the Postdam Institute of Climate Impact Research[4] – for why we selected this set of SLR, please see Appendix 2 of this report. For each temperature scenario, there is a range of potential SLR - for example, at 4°C the range is 6.9m-10.8m (66% confidence) as shown in the chart below.

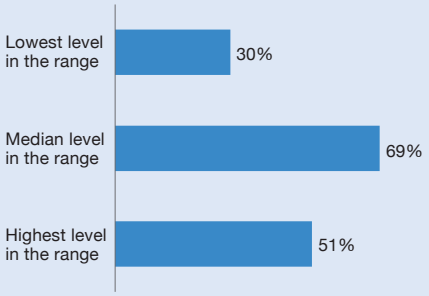
There is also wide consensus by cryosphere scientists warning of SLR of 4m-10m as previously discussed in section 1. While we are comfortable with using such research, the question is which part of the locked-in SLR range – low, median or high – should we use to map the flooding impacts for each temperature scenario (1.5°C, 2°C,3°C and 4°)?

… but the question is do we use the low/median/high SLR to assess impacts?

Finance sector feedback showed a clear preference (69%) towards using the median as per the charts below:

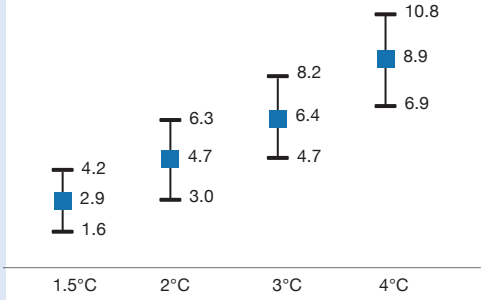
Which of the following in the locked-in SLR range should we use to map the flooding impacts for each temperature scenario (1.5 C, 2 C,3 C and 4)?

69% of finance experts surveyed wanted to use the median level of locked-in SLR



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Global locked-in SLR in metres



Note: SLR values represented in the range is the 66% confidence interval.
Source: Strauss, B. H., Kulp, S., & Levermann, A. (2015). Carbon choices determine US cities committed to futures below sea level. Proceedings of the National Academy of Sciences

… so we used the median SLR in our index

But 51% also wanted to see impacts at high-end of the range so that they can "prepare for the worst"…

However, half of those surveyed also wanted to see impacts at the high-end of the range. This was accompanied with comments that we should *"prepare for the worst"* and model the *"High SLR better to understand tail risks"*.

…we concur and recommend using the high-end to test sensitivities

A few said they wished to see a range to gauge the range of impacts – *"Median range, with the 'worst-case' scenario (highest range) also considered", "Proper range & tolerance of error"* to gauge the range of impact *"or 75th percentile - needs to be preparing for the worst but not the extreme case"*. One of them aptly surmised *"People always like seeing a range. Plus it looks cooler in charts"*.

Here we provide an example with HK…

While we used the median locked-in SLR in the index, we obliged and analysed one city as an example so that you can see the range of impacts for – low, median or high locked-in SLR. As can be seen from the box on **"The impact on Hong Kong at different levels in the locked-in SLR range"** below, impacts within one temperature scenario are wide ranging.

As per the results for Hong Kong, the flooding impact could be significantly worse if we pass tipping points and end up with the higher level of SLR. Therefore, for in-depth analysis of tail-risks and appropriate adaptation action in vulnerable cities, scenario analysis should be carried out utilising weights for the range of locked-in SLR impact on indicators at each temperature scenario.

Impacts are significantly different for the various levels in the locked-in SLR range…

The impact on Hong Kong at different levels in the locked-in SLR range

For Hong Kong…

The charts below show the impact at 1.5°C and 4°C of the low/median/high levels in the locked-in SLR range in Hong Kong using the NASA SRTM-30m elevation data. It is clear that the impacts are significantly different at the various levels in the range.

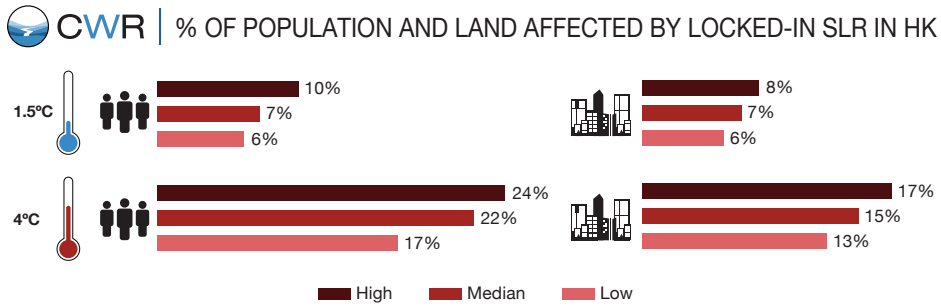
- At 1.5°C at the low level of the range 6% of the population is affected, which increases to 10% at the high level – this may seem a small change, but it is a 63% increase in the actual number of people that could be at risk. For land area, it is a 44% increase from 6% to 8%. From the median to the high-end it is a 38% increase for the population and 10% for land.

...at 1.5°C 63% more people affected at high vs. low SLR level

- At 4°C 17% of the population is affected at the low level in the locked-in SLR range and this increases by 44% (over 500,000 people) to 24%. For land area, it is a 35% increase from 13% to 17%. From the median to the high-end it is a 18% increase for the population and 14% for land.

…at 4°C there is a 44% difference in number of people affected between the low & high levels

These considerable differences in population and land affected highlights that to gauge tail risks the impacts of the entire range of locked-in SLR should be analysed.



Source: CWR APACCT 20 Index

Here, please note that sea levels do not rise evenly around the world, for the CWR APACCT 20 Index, we have used Global Mean Sea Level (GMSL) rise projections as local SLR estimates were not available for all 20 cities. However, for vulnerable hotspots we do recommend that local SLR figures are used to ascertain real tail risk exposure – more on local SLR in **"Appendix 2: Locked-in SLR used in the CWR APACCT 20 Index"**.

Note: our index used GMSL but as SLR is uneven, use local data to assess hotspots

Separately, it is important to note here that although finance wants to *"prepare for the worst"* there are more recent SLR estimates under various RCP scenarios that are worse than Strauss et al.'s estimates we used due to possible collapse of polar ice shelves and cliffs (MICI). **We did not use these latter estimates because we intend the CWR APACCT 20 Index to reflect the best-case (1.5°C) and base case (4°C) of APAC coastal threats; not the worst-case.**

Recent grim news means that ice sheets are more likely to collapse

Worse locked-in SLR estimates are produced but we did not use them…

In this case, it is important to note that Strauss et al.'s estimates do not specify an exact time of when their SLR levels will happen but rather the different post-2100 sea levels that would be locked-in this century depending on warming of 1.5°C, 2°C, 3°C and 4°C. This means that the ranges do not exactly correspond to scenarios as per the IPCC assessments. This flexible timing that is not tied to RCP scenarios but rather temperature warming allows us to adjust for the "timing" of the impacts depending on new research/level of warming, as and when they surface. Because SLR estimates are being continuously refined due to new research, we decided to stick with Strauss et al.'s set of SLR ranges because its flexible timing allows us to shift impact timelines forwards/backwards as and when necessary.

…as flexible timing of Strauss et al.'s SLR ranges allows us to adjust for worst-case impacts as and when needed

SLR impacts may be felt earlier by hundreds of years…

…due to feedback loops & other uncertainties

Since we are currently on track for 4°C, we will likely trigger feedback loops and uncontrollable melt as discussed earlier in section 1. Deep uncertainties linked with such uncontrollable melt, permafrost thaw and loss of Arctic ice could bring about systems collapses that only a Little Ice Age would resolve.[18] This could bring forward SLR risks by hundreds of years. It is thus only prudent to adjust for the latest updated SLR estimates (including MICI) in a worst-case scenario assessment.

So be prudent! Assess the worst-case

Please find these SLR comparisons as well as how to make this adjustment in **"How to use the CWR APACCT 20 Index for worst-case benchmarking"** in Section 3.

The science is complex but must be understood when building scenarios – see CWR's how-to guide

We realise that many have just started to look at assessing these risks and have not kept abreast of the latest ice research. If you found it hard to digest the above, we have provided an overview of the latest science and what this means for SLR projections as well as how to build scenarios in ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***, another report in the CWR Coastal Capital Threat Series. Other more extreme RCP projections for SLR in 2100, 2200 and 2300 can be found there as are **"8 Things you must know about SLR"** – an indispensable guide to avoid unsurvivable SLR.

2. Flooding methodology – bathtub or hydrological?

Hydrological flooding models are expensive + not all cities have them

Now that we have decided on the levels of SLR to use, we have to figure out the flooding methodology – bathtub or hydrological. Ideally the flooding method used to map SLR would only flood areas connected to the sea or river – areas that are hydrologically connected. However, hydrodynamic modelling is expensive, hard to implement at a large scale and the data may not be available publicly for most cities.

We have used the bathtub approach, which although not ideal, is the best option for now…

The second option is to use the bathtub approach to identify the areas that are lower than the SLR projection that would be flooded. The main idea behind the bathtub method is that an area which lies under a certain height gets flooded like water overflowing from a bathtub, without considering hydrological connectivity criteria and dynamics of water motion. Slopes of a beach, surface roughness, waves, current, vegetation and land cover can have an effect on the depth and extent of flooding. Therefore, certain isolated areas in the maps might still appear to be flooded even though the land area is not connected to the sea or river so in reality would not actually be affected by coastal flooding.

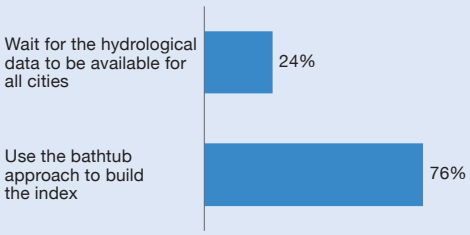
…75% of finance experts surveyed would rather use an imperfect option than wait

75% of those surveyed wanted to go ahead with the bathtub approach…

to build an indicative index to assess the absolute and relative risks between cities, rather than wait for the hydrological data to be available for all cities.

Therefore, based on the land elevation, we use the GIS-based bathtub approach to identify the areas (shaded in red in the maps) that are lower than the sea level projection and would be flooded.

To assess the absolute and relative risks between cities, should we...



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

We recommend:
- use bathtub approach to identify hotspots;
- then for hotspots, use hydrological model if available

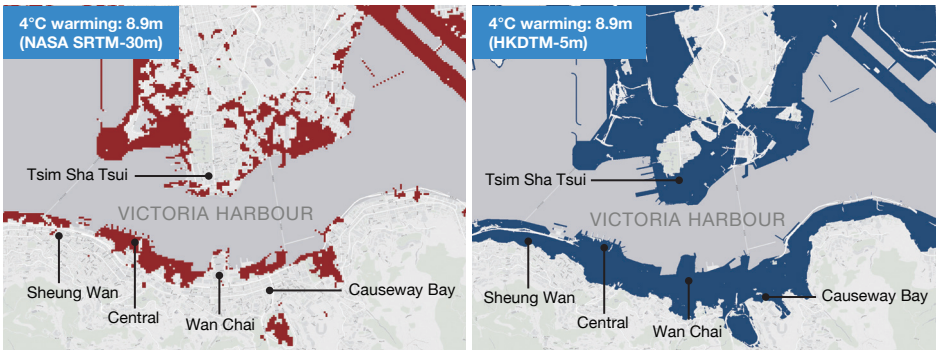
While the bathtub method used in this report provides a fast screening tool to identify highly impacted areas that warrant further investigation and a hydrological model may be worth commissioning. It is also important to note here that current sea walls which could add a degree of protection were not considered as it is currently not possible to ascertain the details of all sea walls for the 20 cities. However, in the CWR APACCT 20 Index, we reduced the scores for cities which have built sea walls and other nature-based solutions as these would reduce threats from SLR. For how these were scored, please see **"Government actions are inconsistent and unique – what proxy indicators to use?"**

3. Mapping granularities – trade-off granularity for consistency?

Some cities have developed their own elevation data that is more granular and detailed than the global elevation data sets with grids of 5m instead of 30m. The difference in granularity provides a very different picture as can be seen from the maps below. Flooding from locked-in SLR in Hong Kong at 4°C using the global elevation map - NASA's SRTM-30m is shown on the map on the left while results with Hong Kong's own Digital Terrain Model (DTM) with a 5m grid is shown on the right.

More granular local data = more accurate analysis than global dataset

CWR | THE IMPACT OF LOCKED-IN SLR AT 4°C IN HONG KONG



Source: CWR based on NASA SRTM (30m-grid), Digital Terrain Model (5m-grid) from the Lands Department of Hong Kong, ESRI. Infographic © China Water Risk 2020, all rights reserved

It is clear that HK faces much more flooding at 4°C when a 5m granular map is used vs. NASA's SRTM-30m

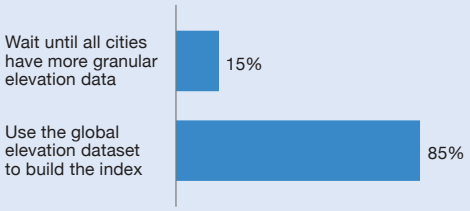
Clearly higher granularity provides a more accurate picture of the flooding. However, such granular terrain data is not available for all cities; and some cities have not made the data public. Furthermore, each city uses its own methodology to assess terrain. These data gaps and differences in methodologies made it difficult to benchmark the cities.

Unfortunately, most cities don't have this data…

Trade-offs had to be made. Should we wait until all the cities have better data to assess risks or go ahead and use the less granular maps to estimate impacts?

The finance survey results showed significant preference (85%) for the use of global elevation data to gauge impacts now instead of waiting.

To assess the absolute and relative risks between cities, should we...



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

…85% of finance sector experts surveyed would rather use a global dataset than wait

We have thus used the less granular SRTM-30m maps for land elevation data to create flooding maps at different levels of SLR across various climate scenarios. It is important to remember, that while less granular, analysis of the absolute risks with the STRM-30m maps already show significantly material impacts, let alone with more granular mapping. For mapping visuals at 1.5°C and 4°C for each city, please refer to the **"Appendix 1: CWR APACCT 20 Index City Factsheets"**. It is important to note that there is another set of global maps that were recently developed known as Coastal DEM – we did not use these maps – for why, please see the box later on **"Why we did not use CoastalDEM"**.

So our index uses SRTM-30m, which although flawed already shows significant impacts for all cities

Given the material differences in impacts with different maps, some queried *"Is it possible to roll out the index with just the cities with all the data and then add more as data improves?"* Unfortunately, too few cities have this available so the index would not have made sense. Another suggested *"Think it would be good to include case studies (or all graphs if possible?) where cities have more granular data e.g. Hong Kong so you can see the difference. This could be a key policy engagement piece to highlight the need for the granular data across all cities."* We have taken this on board and have provided case studies revealing the difference in impacts on key indicators such as land area, population, airports and ports for three cities in following two-page spread titled **"Granularity Matters: Deep dives on HK, Taipei & Tokyo"**.

Those surveyed wanted to see the difference in impacts… so we obliged for HK, Taipei & Tokyo…

Granularity matters: Deep dives on HK, Taipei & Tokyo

Benchmarking requires consistency, so SRTM-30m was used…

More granular maps = better results. To map the impact of flooding from SLR and storm surge, the underlying elevation data is important as inaccuracies could either over- or underestimate the impacts. As ranking the cities requires consistency to ensure comparability, the same globally available elevation data from NASA (SRTM-30m) was used for all cities to assess the physical flooding levels and impact on infrastructure. However, some cities have more granular and accurate underlying elevation data. To understand the difference in results, we compared the impacts of locked-in SLR at 4°C using the NASA SRTM-30m and the digital elevation data for three cities that have this granular elevation data:

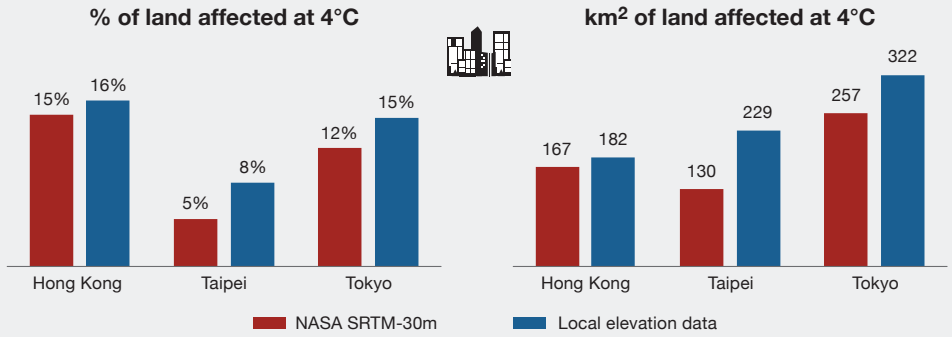
…but more granular elevation data exists for a few cities

1) **Hong Kong**: A 5m-grid DTM is released by the Lands Department of Hong Kong with an accuracy of ±5m.[40]
2) **Tokyo**: A 5m-grid Digital Elevation Data (DEM) is provided by Japan's Geographical Survey Institute (GSI-DEM) with accuracy ±0.3m-1.4m.[41]
3) **Taipei**: A 20m-grid DEM is released by Taiwan's Ministry of the Interior.[42]

Higher granularity = higher exposure…

Comparing the results below it is clear that the more granular elevation data driven maps show greater impact for all three cities; in total locked-in SLR at 4°C will flood 32% more land in these three cities together compared to the SRTM-30m. It is thus important to use the correct elevation data when mapping.

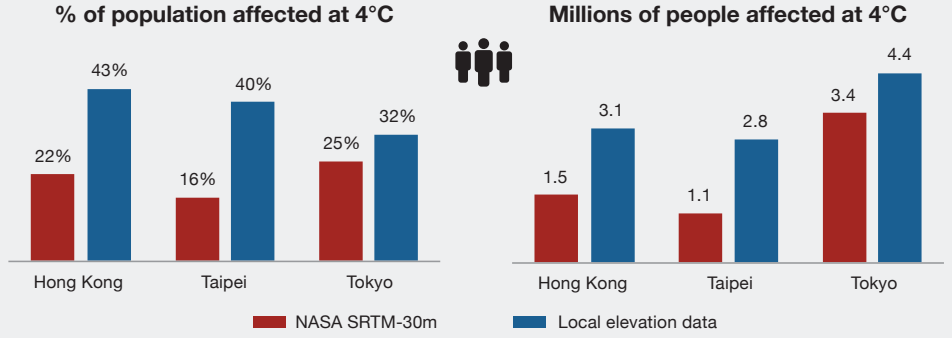
Just between HK, Taipei & Tokyo, 32% more land is flooded at 4°C using local data vs. SRTM-30m



Source: CWR, NASA SRTM (30m-grid), Digital Terrain Model (5m-grid) from the Lands Department of Hong Kong, GSI DEM (5m-grid), Taiwan's Ministry of Interior released DEM (20m-grid),ESRI, GADM administrative boundary. Population based on Gridded Population of the World, Version 4 (GPWv4) from CIESIN – Columbia University.

Dense population = high clustered risks. However, the greatest difference is in the population figures. This is especially the case in Hong Kong and Taipei where over 40% of people are in flooded zones in the local elevation map compared to ~20% in the SRTM-30m. Overall, 10.3mn people are affected in the local maps for the three cities compared to 6mn in the SRTM-30m; that's a 72% increase in impact.

It's worse for people, with a 72% increase in population affected between the three cities using local data vs. SRTM-30m



Source: CWR, NASA SRTM (30m-grid), Digital Terrain Model (5m-grid) from the Lands Department of Hong Kong, GSI DEM (5m-grid), Taiwan's Ministry of Interior released DEM (20m-grid),ESRI, GADM administrative boundary. Population based on Gridded Population of the World, Version 4 (GPWv4) from CIESIN – Columbia University.

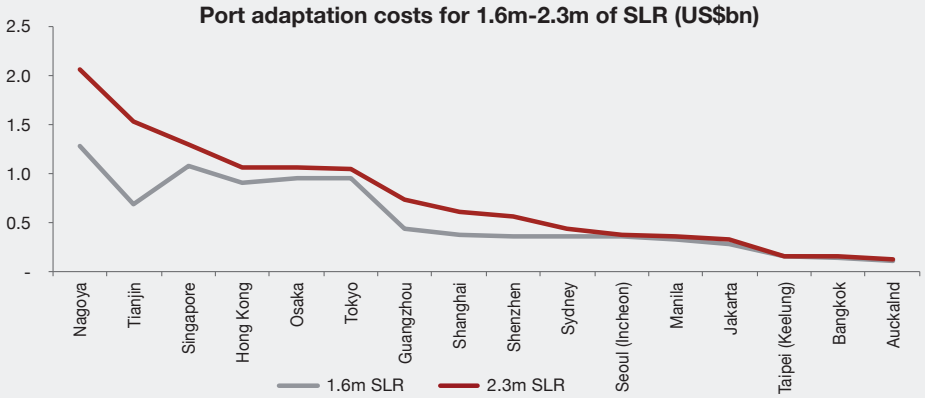
The denser the city = the more to lose = clustered risk

This highlights how densely populated these cities are especially closer to the coastal areas. This density means there is much more at risk for each metre of SLR as people and key infrastructure will all need to be moved and/or protected.

Granular elevation data = more cost-effective adaptation investments. With millions of people and acres of land affected by flooding, key infrastructure such as ports and airports are at risk as they are found by the coast. But they are also central to APAC's export oriented economic growth. A study by Asia Research & Engagement for HSBC published in 2018 estimates that just 1.6m-2.3m of SLR could result in US$9bn-US$12bn of adaptation costs in total for 16 of the 20 APAC cities as shown below; this is to protect their ports by elevating sections of buildings and warehousing.[43]

Key infrastructure by the coast will have to adapt…

Port adaptation costs for 1.6m-2.3m of SLR (US$bn)



Source: CWR, Asia Research & Engagement for HSBC (2018) Climate Costs for Asia Pacific Ports

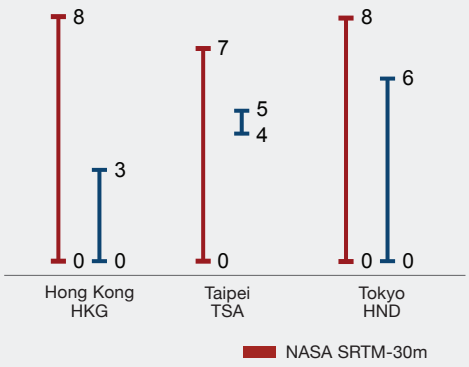
Ports - just 1.6m-2.3m of SLR could require US$9bn-US$12bn of adaptation costs for 16 of the 20 cities in our index …

Bearing in mind that 1.5°C of SLR is expected to result in 1.6m-4.2m of SLR the costs could be much higher. This is especially true when considering storm surges, which are already impacting economies today – please see infographic **"Storm surges – it's not 2050 or 2100, it's happening now"** in section 1 for more.

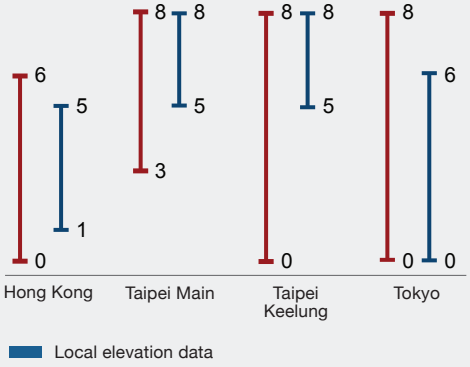
…but costs could rise significantly due to much higher SLR at 3°C-4°C

However, the degree of risk differs depending on the granularity of the elevation data used. The two charts below look at the range of flooding faced at 4°C at the airports and ports in the three cities. The local elevation maps show a much tighter range of flooding and the highest level of flooding is less in some cases.

Airports: range of flooding at 4°C (m)



Ports: range of flooding at 4°C (m)



Source: CWR, NASA SRTM (30m-grid), Digital Terrain Model (5m-grid) from the Lands Department of Hong Kong, GSI DEM (5m-grid), Taiwan's Ministry of Interior released DEM (20m-grid),ESRI, GADM administrative boundary. Population based on Gridded Population of the World, Version 4 (GPWv4) from CIESIN – Columbia University.

NOTE: Taipei TPE and Tokyo NRT airports are not included in the above charts as they do not face flooding at 4°C

High granularity of data is key to ensuring the cost effectiveness of adaptation investments as the results will be more accurate

This more accurate detail will help governments and the private sector plan for adaptation that is more cost effective because adaptation is expensive. Some governments have already started to adapt, with Singapore planning to elevate its airport and Tokyo building tunnels for floods during typhoons – to find out more please see **"Case studies of cities adapting to coastal threats"** in ***"Sovereigns at Risk: APAC Capital Threats"***.

We have set out government adaptation case studies in another report in our climate series

More funding and research needed to close data gaps. Clearly, local and granular elevation data is necessary for more accurate results. Unfortunately, this is not available for all cities and we need to invest in this research to ensure all cities can plan appropriately to ensure they are sufficiently protected. Ideally, in the future, inundation mapping analyses could be refined by using more accurate elevation data (i.e. local granular data) and integrating river networks that connect to the sea. Given significant exposure in APAC, surely investing in such research is a no-brainer?

As all cities do not have such granular data, we should fund to close gaps … clearly benefits outweigh costs

CoastalDEM is a 2019 elevation dataset created to correct the inaccuracies in SRTM-30m…

…we don't think it does for high-rise and high-density cities - so we have used SRTM-30m

Why we did not use CoastalDEM

We did not use the recently created CoastalDEM data which was supposed to correct the inaccuracies in SRTM-30m. This is because our own research and conversations from the Hong Kong Observatory (HKO) indicate that CoastalDEM maps currently appear to have inaccuracies in high-rise and high-density cities.

For example, CoastalDEM maps show flooding occurring in Hong Kong at SLR levels lower than some of the storm surges that have affected the city in the past which did not lead to flooding. In addition, the National Hydraulic Research Institute of Malaysia (NAHRIM) and Climate Change Research Institute of Vietnam's Can Tho University also warned that the CoastalDEM data should be handled cautiously, as the maps overestimated the coastal flooding in their cities as well. For more details on mapping, please see **"Which maps to use"** in ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***.

Source: CWR article. HK Submerged? Is This Map For Real? Debra Tan, Chien Tat Low and Dharisha Mirando, 18 Nov 2019 <http://www.chinawaterrisk.org/resources/analysis-reviews/hk-submerged-is-this-map-for-real/>

Until data improves, we recommend:
- use our index to find hotspots;
- then use more granular maps if available to better assess risks

As the previous two-page spread clearly shows, the granularity of elevation data makes a marked difference to the severity of the flooding impacts for all three cities. As and when elevation data improves and new data is produced, we will revisit which elevation data set to use in the next iteration of the index. In the meantime, the STRM-30m is useful in benchmarking the 20 cities as well as identifying hotspots.

However, for hotspots identified, we recommend deeper analysis and for this, more granular maps should be used (where available). This was also suggested in the survey: *"On "3. Map granularity" - the option I had in mind wasn't available i.e. relative analysis to use the global set, absolute analysis to use the one available"*.

4. Storm surge projections – simple metrics vs. expensive modelling?

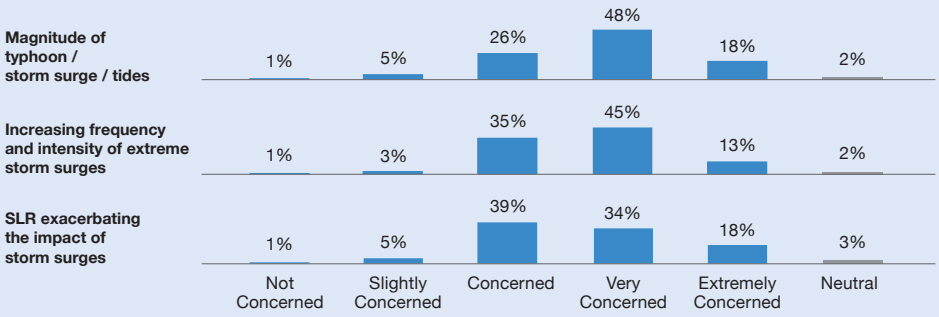
Finance sector feedback showed overwhelming concern for the magnitude and frequency of the storms as well as its interlinkages with SLR as shown below. However, assessing these aspects are easier said than done.

Finance survey results showed clear concern over storm surge impacts…

97% have varying concerns over the magnitude & frequency of storm surges

+ 96% worry over interlinkages with SLR

Different types of physical coastal risks - How concerned are you about the financial impacts of the following?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Unfortunately, storm risks are not measured on the same scale around the world…

Not all cities are affected by typhoons/ hurricanes/ tropical cyclones that bring with them destructive storm surges. However, those that are, are vulnerable as these storm surges can cause significant economic damages and losses. However, the risks are not measured on the same scale – each region has its own scale and measurements and long-term forecast models, making it difficult to treat all affected cities consistently.

A consistent regional treatment can be achieved by running storm models for the entire region to determine magnitude and frequency. However, these will be costly across four scenarios and 20 cities. Worse still, they may not be useful as storm forecasts are modelled on historical storms which no longer point to the future. As warned by BlackRock, *"New climate patterns mean long-dated historical data are a poor guide to the future. Investors using models overly reliant on the past are missing the big picture"*.[44]

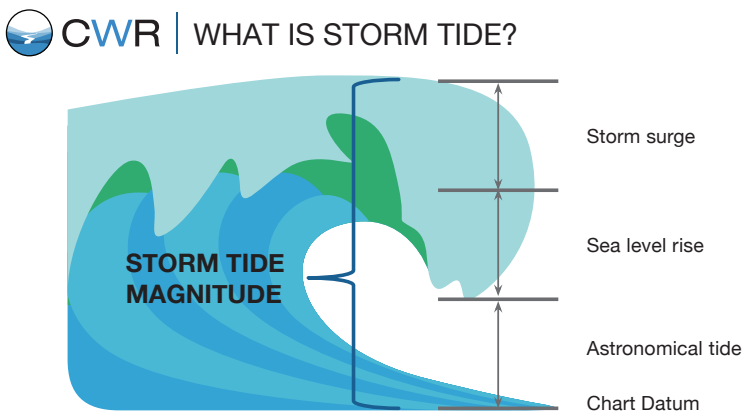
…regional modelling of storms would be ideal but costly

Also most storm models are backward looking + the angle & time of storm impact must be considered…

And that's just the storm, not the storm surge which is dependent on the angle of the storm. And then there is the time of arrival of the storm – at high tide or low tide. Arriving at high tide will bring higher storm tides than arriving at low tide. So, when projecting the impacts of storm surge, it is the storm tide that must be estimated. As shown in the graphic, the storm tide can be estimated by adding the astronomical tide at the time of the storm, sea level rise projections as well as the storm surge estimate of the storm to chart datum. Here, the chart datum is the base water level to which tide heights are referenced.

…arriving at high tide = higher storm tides than arriving at low tide

So it's about storm tide, not storm surge…



Infographic © China Water Risk 2020, all rights reserved

Storm tide =
Chart datum
+ Astronomical tide
+ Sea level rise
+ Storm surge

As the graphic above clearly shows, the combination of all the above makes the simple wish of *"Should indicate at each SLR, what is the expected storm surge levels"* near impossible. So faced with either costly modelling of consistent but "hard to predict accurately" magnitude and frequency of storms, let alone the levels of storm surge they come with, we decided to opt for the simple metrics of a set of proxy indicators for storm surge. The indicators by which physical storm surge risks were evaluated across the 20 cities were as follows:

Because of these many variables, costly models may not be able to accurately forecast impacts…

Thus we used simple metrics of a set of proxy indicators…

- **The city is in the path of typhoons/ hurricanes/ tropical cyclones** as this automatically increases all risks;
- **Increasing intensity of typhoons/ hurricanes/ tropical cyclones affecting the city** as these will become more damaging;
- **Increasing frequency of typhoons/ hurricanes/ tropical cyclones affecting the city** as there will be more periods of interrupted economic activity and damage;
- **The city has experienced one T10 in the past 5 years** (or equivalent - hurricane force wind is blowing or expected to blow with sustained speed reaching 118 km/h or above and gusts that may exceed 220 km/h) as these are the most damaging and shows how vulnerable a city is; and
- **The city has experienced more than one T10 or equivalent in past 5 years** - as the city will be even more at risk.

Storm surge risk will switch from acute to chronic when storms start occurring yearly…

Currently, storm surges are considered acute risks as they are transient but this will change going forward, when destructive storm surges start occurring yearly. In this case, storm surges may no longer be considered acute but chronic. You could say the approach that we have taken in the CWR APACCT 20 Index to assess storm surge risks (through indicators rather than modelling) reflects this chronic nature of storm surge risks.

While the indicators we used reflects this chronic nature…

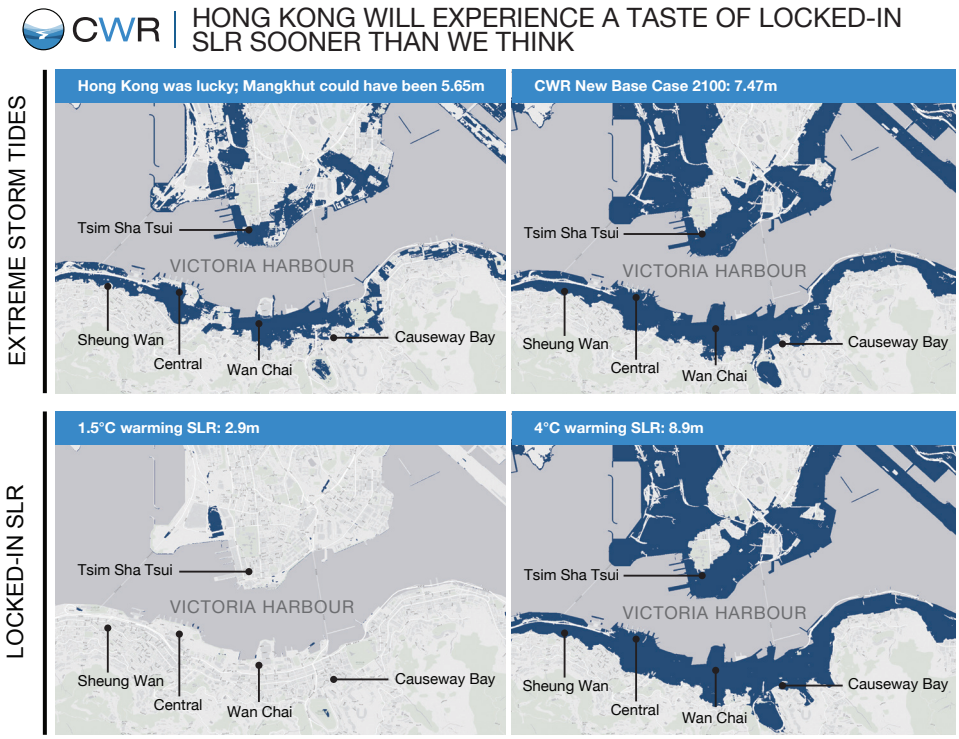
That said, although we have not assessed the acute impacts of storm surge risks by mapping storm tide impacts for our index, we recommend that this be done for cities that are in the path

…we recommend you also assess acute risks by mapping storm tides for hotspots

of extreme storms. You do not need expensive modelling to do this – we have set out a guide on **"How to build scenarios for SLR tail risks & event-driven storm tides"** in our report ***"Changing Risk Landscapes: Coastal Threats to Central Banks"*** to determine the height of extreme storm tides to assess worst-case scenarios.

Cities in the path of typhoons/ cyclones will experience locked-in SLR sooner…

Here, we use Super Typhoon Mangkhut and Hong Kong as an example. The maps below show that a storm like Mangkhut will give Hong Kong a taste of locked-in SLR tail risks sooner than we think. CWR New Base Case estimates for Hong Kong has storm tides at 7.47m by 2100 which is 2.6x that of the 1.5°C locked-in SLR of 2.9m and only 16% less than the 4°C locked-in SLR of 8.9m used in the CWR APACCT 20 Index. Note that the maps below used the more granular 5m HKDTM maps and not the 30m NASA SRTM.



HK's Mangkhut could have been 5.65m if it arrived at a different angle at high tide

By 2100, base case extreme storm tides will be 7.47m…

…this is 2.6x that of the locked-in SLR of 2.9m used in our 1.5°C index

…and only 16% less than the locked-in SLR of 8.9m used in our 4°C index

Note: All four maps are showing 5m granularity

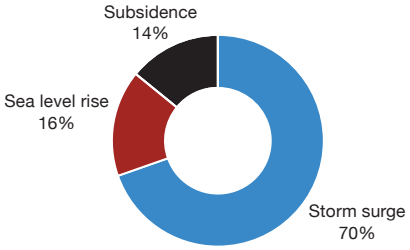
Source: CWR based on HKDTM (5m-grid) from the Lands Department of Hong Kong, ESRI
Infographic ©China Water Risk 2020, all rights reserved

There is no doubt that storm surges represent imminent threats. Therefore, given this plus consensus from the finance sector, storm surge represents the highest share of the physical risk weightings at both 1.5°C and 4°C. At 1.5°C, storm surge weightings are much greater as SLR risks are not yet as severe as at 4°C as shown in the charts below.

Due to the imminence & severity of risks from storm surges…

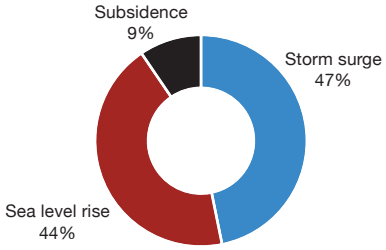
…it represents the highest share of the physical risk weightings for both our 1.5°C & 4°C indices

1.5ºC CWR APACCT 20 Index - Coastal Threat Weightings



Source: CWR APACCT 20 Index
Infographic © China Water Risk 2020, all rights reserved

4ºC CWR APACCT 20 Index - Coastal Threat Weightings



Source: CWR APACCT 20 Index
Infographic © China Water Risk 2020, all rights reserved

Subsidence plays a bigger role at 1.5°C as lower SLR is amplified

Note that subsidence share increases at 1.5°C - this is because subsidence amplifies SLR risks, making the city more prone to lower levels of SLR. At 4°C, SLR impacts are more pervasive across cities making subsidence less important.

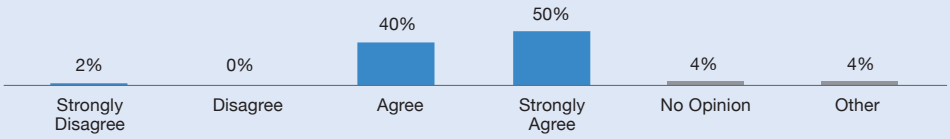
5. Government actions are inconsistent and unique – what proxy indicators to use?

Government adaptation actions can reduce the impacts of physical risks and as a result have been included in the CWR APACCT 20 Index. Indeed, 90% of those surveyed either "agreed" or "strongly agreed" with this as per the chart below.

90% of finance experts surveyed "agreed" & "strongly agreed" that …

…govt adaptation actions should be included to reflect real risk exposure

Should government adaptation action be included in a cities coastal threat index to reflect the real risk exposure?



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

As this index was created to gauge chronic tail risks facing cities, only adaptation measures are considered as they can directly reduce the risks locally. Mitigation measures were therefore not included as they should be analysed in the global context as a city's own actions may not change the risks it's facing. Indeed, consensus was reached with 61% of those surveyed either wanting an adaptation only focused index or an index that could provide both adaptation and mitigation measures separately. The rationale behind the inclusion of government adaptation action only has been discussed in detail in the section titled **"Recalibrating finance for tail risks"**.

Mitigation efforts were excluded as they should be analysed on a global context…

…plus 61% surveyed wanted a separate adaptation index

However, because each city faces its own unique climate threats, government adaptation actions are neither consistent nor standardised across the 20 APAC cities. Government action can range from disaster management policies all the way to soft and hard infrastructure to protect vulnerable areas. Adaptation plans should also take into account food and energy security as these could all be affected if logistics and agriculture are impacted. As discussed earlier, almost all the ports and airports serving the 20 APAC cities are vulnerable as they are located in low-lying areas and adaptation efforts for these can be costly – 1.6m-2.3m of SLR could cost US$9bn-US$12bn in port adaptation spend for 16 of the 20 APAC cities; – see **"Mapping granularities – trade-off granularity for consistency?"**.

Analysing government adaptation efforts was difficult…

… actions are not standardised/consistent across the 20 APAC cities

Unfortunately, most governments do not disclose all actions being taken to reduce impacts of physical risks, let alone the budget being set aside for it. Also, the exact impacts of government actions to adapt for coastal threats are difficult to quantify as they vary across cities. We have thus used several indicators as proxies within the following categories:

Disclosure must also improve

To gauge govt action, we developed proxy indicators across 4 categories

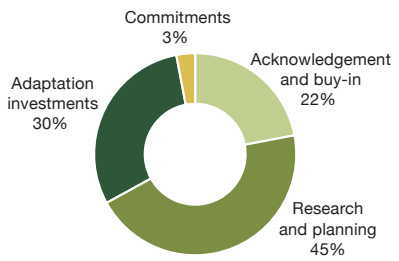
- Acknowledgement & buy-in,
- Research & planning,
- Adaptation investments, and
- Commitments.

As the chart below shows scoring is not equally weighted across the four different categories. The weightings for the four categories and indicators within them were influenced by the responses from the financial sector. The rational and finance sector preferences for proxy indicators used in the above categories are detailed in the following pages as are comments from those surveyed to provide more colour.

"Research & planning" has highest weighting … whilst "Commitments" has the lowest

Weightings were adjusted depending on finance feedback (see next page)

CWR APACCT 20 Index
Government Adaptation Action Weightings



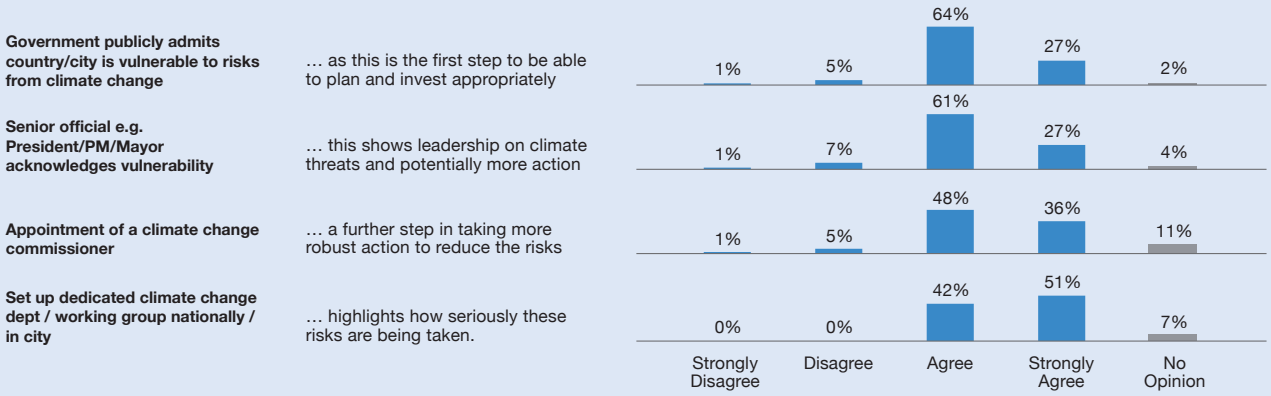
Source: CWR APACCT 20 Index

Government adaptation action: indicators used in the index

Please note that indicators below are not arranged by 'most preferred' but in the order that was presented in the survey which reflects increasing seriousness of action within each category.

Adaptation proxy indicators - The exact impact of government actions to adapt for coastal threats are difficult to quantify as they vary across APAC cities. Do you agree that the following indicators can be used as proxies for a government's adaptation efforts?

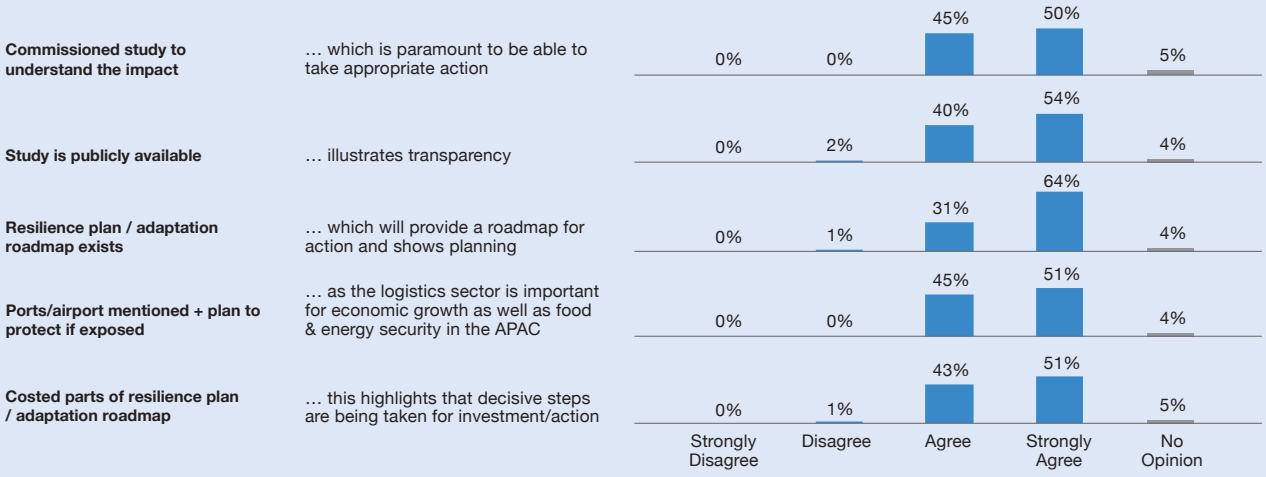
1. Acknowledgement and buy-in



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

It is clear here that finance experts preferred a dedicated climate change team as 93% "strongly agree" and "agree" with zero percent "strongly disagree" and "disagree" compared to the other options. *"Got to be a working group, no? The others are just media soundbites"* sums it up. Another comment was: *"Whether coastal threats are featured in a Ministry's agenda, whether it's the ministry in charge of infrastructure, economy, or environment (to avoid "climate change" looking at mitigation only but not adaptation). Local adaptation being featured in the media e.g. documentary, interviews, newspapers."*

2. Research and planning



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

Here, finance experts surveyed indicated clear consensus over having a resilience plan/adaptation roadmap. One would think that this was a no-brainer but it is surprising that some cities (that one would expect to have these plans) do not – for example, Hong Kong is still "commissioning a study". Elsewhere, one commented that *"In Japan municipalities have to carry out studies to understand the impact of climate change"*.

However, it was interesting to see that costed parts of resilience plan receive lower votes despite *"Strongest preference for costed parts of resilience plan / adaptation roadmap"*. Overall, the highest total consensus vote goes towards ports/airports resilience which received 96% "strongly agree" and "agree" votes, reflecting their importance to trade/growth in APAC.

3. Adaptation investments

Started to invest in adaptation - no detail disclosed

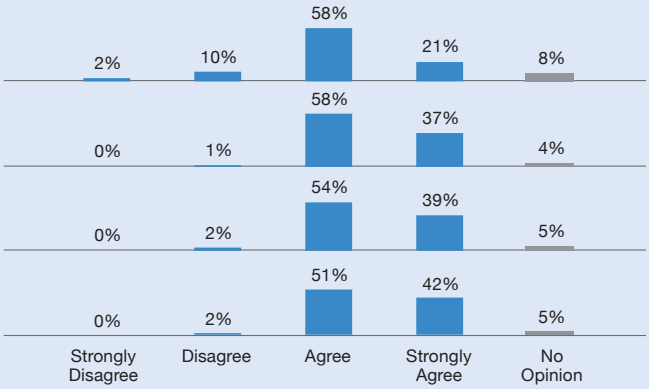
Disclosed for: Sea walls and/or elevation of coastal areas

Disclosed for: Nature Based Solutions e.g. mangroves

Disclosed for: Storm / flood drainage

… starting is an important step

… all these adaptation measures can protect city areas to different degrees from the physical impacts of coastal threats. They were not evaluated for their effectiveness, instead points were given if details were disclosed for current adaptation investments in each of the three indicators



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

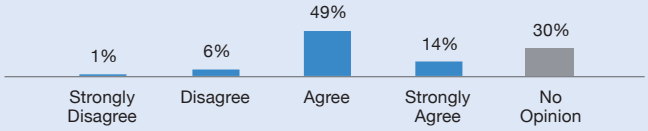
In this category, financial consensus veered towards disclosed action – in particular sea walls and/or elevation of coastal areas received the highest total votes with 95% saying that they "strongly agree" and "agree". The highest "strongly agree" vote for storm/flood drainage disclosure reflects the view that *"Contingency planning is important. And so is planning with the private sector"* and the *"Need to see outcome/output/impact"*.

Even nature based solutions received high votes with some commenting that *"Focus on nature based solutions where possible should be highlighted and given more prominence"*.

4. Commitments

Joined the Global Resilient Cities Network (GRCN)

… as it shows steps being taken to learn from best practice in other cities and for collaborative action



Source: CWR APACCT 20 Index - Finance Survey, May-July 2020

This category saw the least consensus with the lowest rates of agreement with only 63% "strongly agree" and "agree" votes and as much as 30% sitting out with "no opinion". One commented that *"100 resilient cities is great, but the new GRCN is expected to limit membership to 110 so it may not be the best proxy"*. Another was more blunt: *"Lots of cities around the world doing climate-related impact stuff for their citizens. I don't see why joining a club gets any extra points!"*.

We note that GRCN is not perfect, but it is so far one of the only collaborative global city adaptation networks. We hope that more collaborative platforms will spring up as cities turn toward dealing with/preparing for risks ahead. That said, we recognize that any group joined *"Has to be outcomes driven with deliverables to be used as a proxy"*.

Clearly those who took part in our survey agreed more with some of these indicators than others, so we took on board their comments for the weightings. Note that the last category "commitments" was given the lowest weighting as it had materially lower scores.

What is also clear is that more can be done to improve this section but as we mentioned budget and time constraints means this was the best we could do for now for the index.

Benchmarking govt adaptation action was very challenging = many flaws…

We had to rely on what's available to the public as transparency is important

Word of caution: assessing and trying to benchmark government action was the most challenging aspect of developing the CWR APACCT 20 Index and we recognise that a lot of detail is absent in this first attempt. Certain aspects unfortunately could not be included at this time. Please note the following:

- **Publicly disclosed information only.** All data gathered was from publicly available sources for each city to ensure consistency and transparency. We did not engage directly with each of the governments of the cities regarding their adaptation actions. As per a comment from our survey, *"Must disclose and provide details"*, we hope the index incentivises governments to disclose much more about their adaptation plans in the future as they can clearly make a marked difference to physical risks. This will then give corporates as well as individuals the opportunity to decide for themselves if a city will be safe in the future and lobby for more adaptation investment if not.

Govts must up disclosure as residents should know if cities are resilient & take action if not

Another comment was that *"Public education also important"* especially as governments may need to spend larger portions of the budget on mitigation and adaptation and will only be able to do this if the public understands the risks and are on board with government action. But residents should also be able to use this to hold the government accountable.

What govts say they will do and what they end up doing differ…

- **Actions were not evaluated for their effectiveness.** Instead governments were evaluated for having a plan or already having invested in adaptation measures. We know that this is far from ideal as one succulently surmised *"Public announcements are great (the alcoholic's first act is admission of the problem): however, key indicator of seriousness will be budget allocation."*

…adaptation action was not evaluated for its effectiveness in our index

We also agree with: *"I think that having a "resilience plan" or building new "resilient infrastructure" would be an indication of their adaptation efforts, as many of the large infrastructure projects are government owned. Also, whilst I have selected the above, I am not entirely sure that acknowledgement of climate change necessarily directly links to the governmental recognizing "coastal threats" specifically."*

The asset specific nature of this type of assessment makes this very costly & time consuming…

…however, we did set out case studies to provide more colour

Adaptation evaluated for effectiveness would require in-depth analysis of assessments to be made by locations within a city. While this will be more accurate, it would also be costly and time consuming for one city let alone 20. So, we did not do this for the index, but we do recommend that this be done for hotspots, especially if there are a number of high value assets located there. In lieu of this, another way to gauge effectiveness is to look at whether governments are using realistic scenarios for adaptation planning as opposed to optimistic ones. Although we did not score for these in the CWR APACCT 20 Index, we have provided case studies in ***"Sovereigns at Risk: APAC Capital Threats"*** (another report in this series).

Govts with misaligned mitigation & adaptation strategies were not punished in the index

- **Adaptation and mitigation strategies should be aligned.** Ideally these climate strategies should be aligned - if decarbonisation plans are in line with a 3°C-4°C pathway, then adaptation should be planned for this scenario also. Unfortunately, they are not – many have decarbonisation strategies for 3°C-4°C but adaptation plans for 1.5°C. Technically, such cities should receive a punitive score, but evaluating this information for all 20 cities was not possible given the current funding and timeframe for this first iteration of the index.

Govt action/inaction impacts sovereign risk ratings – we explore this in another report in our climate series

As government action is so crucial to the risk exposure of the cities to coastal threats, their action/inaction will impact on sovereign credit ratings in the long term, especially for cities which make up a significant part of their country/territory's GDP. We explore this in depth in ***"Sovereigns at Risk: APAC Capital Threats"*** along with mismatched government strategies in **"No sense climate strategies - governments"** in that report.

See "Waterproofing APAC to Avoid Atlantis" for next steps

Finally, if you are now rearing to take action to waterproof your assets/ portfolios/ cities/ territory/ country/ region against capital threats and systemic shocks triggered by climate risks, please see ***"Waterproofing APAC to Avoid Atlantis: Executive Summary & Next Steps"***.

Appendix 1:
CWR APACCT 20 Index City Factsheets

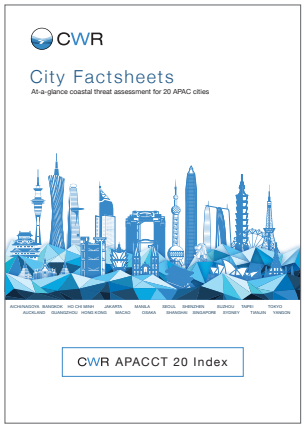
This appendix includes city factsheets for each of the 20 cities that comprise the CWR APACCT 20 Index and should be read alongside **Section 3: "CWR APACCT 20 Index Results & Rankings"** of this report. The 20 city factsheets are contained in a separate document and can be accessed together or separately by clicking on the respective links below.

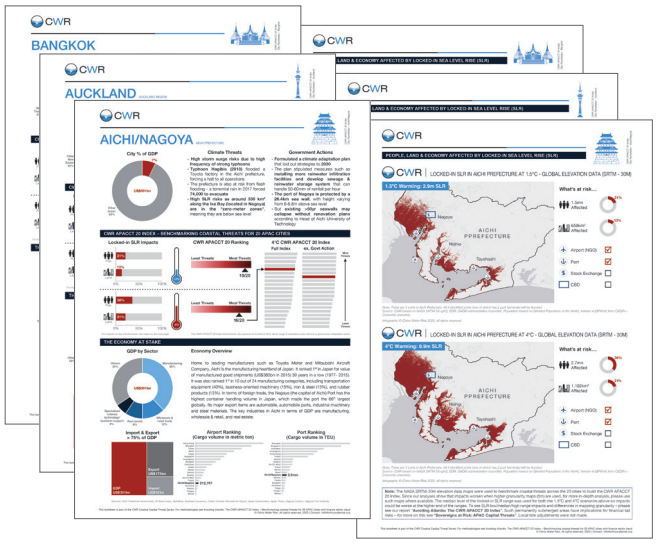
Each factsheet includes:

- At-a-glance city GDP share
- Overview of climate threats
- Overview of government actions
- City rankings in CWR APACCT 20 Index at 1.5°C & 4°C
- Overview of the economy at stake including trade exposure
- Maps of locked-in SLR at 1.5°C & 4°C showing people, land & key infrastructure affected

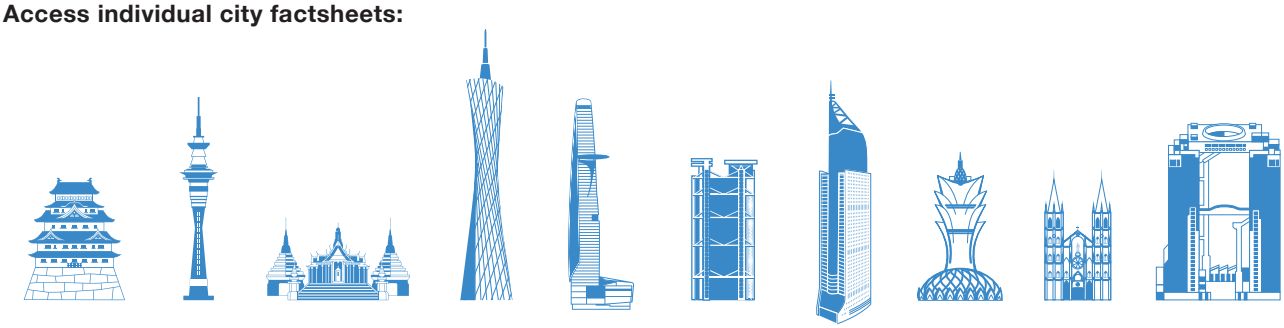
Access all 20 city factsheets:

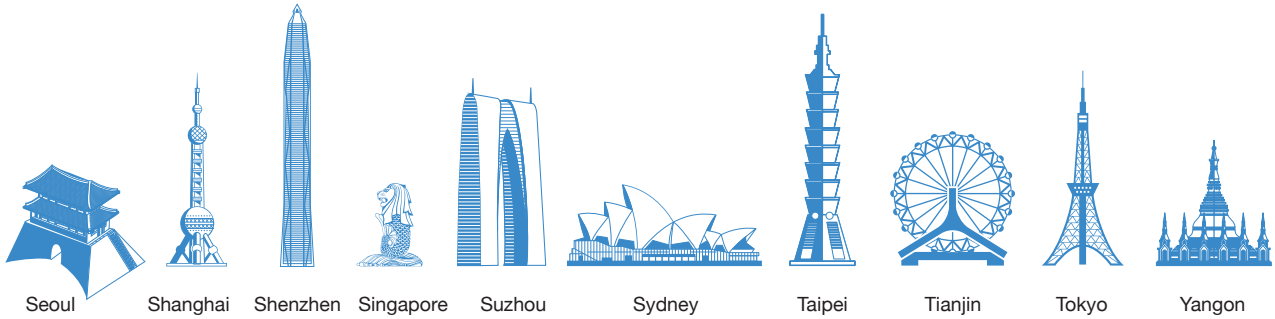
http://www.chinawaterrisk.org/notices/avoiding-atlantis-cwr-apacct-20-index





Access individual city factsheets:





Appendix 2:
Locked-in SLR used in the CWR APACCT 20 Index

We used locked-in SLR rather than SLR at 2100 to gauge real locked-in tail risks. Sea levels do not stop rising in 2100, yet many financial scenarios have only taken SLR risks until then. The CWR APACCT 20 Index thus uses locked-in SLR estimates so that such guaranteed chronic tail risks can be factored in. There are many sets of SLR projections beyond 2100 but we decided to use the projections for locked-in SLR developed by Benjamin Strauss and Scott Kulp of Climate Central, in collaboration with Anders Levermann of the Postdam Institute of Climate Impact Research in 2015 (Strauss et al.).[4]

Impact horizon: Beyond 2100 but no exact year specified so that the index can be adjusted for new research indicating accelerating SLR. Strauss et al. do not forecast what sea levels may unfold this century but rather they indicate the different post-2100 sea levels that we could lock-in in this century, depending on the temperature scenarios that result from cumulative emissions. In their 2015 paper they expected that their projections could possibly (but with low probability) occur sooner than 200 years from now or be reached as far as 2,000 years in the future. However, as can be seen below, new research on rapid polar melt can bring forward SLR impact horizons. That said, we still stuck with Strauss et al. as it allows us flexibility to "adjust" for worst-case scenarios by shifting the impact timelines – read on.

Temperature scenarios vs. RCP scenarios. The model from Strauss et al. (2015) uses temperature scenarios (1.5°C, 2°C, 3°C and 4°C) to demonstrate locked-in SLR as they are more aligned to the proposed international target and the widely understood goal of 1.5°C and 2°C warming and the business-as-usual scenario of 4°C. Note that this differs from models which use RCP scenarios (eg. RCP2.5/ RCP4.6/ RCP8.5 etc.) as per the IPCC. The IPCC only started providing scenarios beyond 2100 in 2014 in its AR5. Also, IPCC SLR estimates have a conservative bias (see box).

Conservative IPCC SLR estimates for RCP scenarios may impede risk management

Please see charts comparing different sets of SLR estimates for 2100 and beyond 2100 in **"How to build scenarios for SLR tail risks & event-driven storm tides"** in ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***, another report in the CWR Coastal Capital Threat Series. RCP scenarios are also explained in more detail there.

Rapid SLR from the collapse of parts of the West Antarctica Ice Sheet (WAIS) is not included. The global sea level projections consider four separate models including thermal expansion, melting glaciers, and the decays of Greenland and Antarctic ice sheets. Collapse of parts of WAIS (MICI) was not included by Strauss et al. because at that time in 2015, the evidence of such collapse was far from conclusive. However, since then there has been new research observing runaway melt and supporting accelerated MICI – **ice sheet experts estimate plausible scenarios of around 2.4m and as high as 3.29m of SLR by 2100**. The IPCC, while adjusting for marine ice sheet instability (MISI) in 2019, has yet to revise its estimates to include MICI.

CWR APACCT 20 Index = best-case (1.5°C) & base case (4°C) assessment of "locked-in" SLR coastal threat impacts. As we intend our index to be used as the best & base case (and not the worst-case) to gauge chronic tail risks ahead, we used Strauss et al.'s set of SLR projections. **Adjustment for rapid SLR from MICI in a worst-case scenario can be made by shifting the timeline of impact forward**. In such cases, the 1.5°C CWR APACCT 20 Index's locked-in SLR of 2.9m may be reality by 2100; and 4°C CWR APACCT 20 Index's locked-in SLR of 8.9m may well be reality by 2200. More on why the timeline for these base case indices shift in **"How to use the CWR APACCT 20 Index for worst-case benchmarking"** in Section 3.

Local SLR vs. global SLR. Sea levels do not rise evenly and in 2015, Strauss et al. used them to estimate impacts in their seminal report *"Mapping choices: carbon, climate, and rising seas, our global legacy"* released by Climate Central. However, for the CWR APACCT 20 Index, we have used Global Mean Sea Level (GMSL) rise projections as local SLR estimates were not available for all 20 cities. The differences between global and local SLR grows as temperatures rise: at 1.5°C the difference is -0.2m/+0.3m from the GMSL median of 2.9m, but at 4°C, it is -0.5m/+0.9m from the GMSL median of 8.9m. We recommend that once hotspots are identified that more analyses be performed with more granular maps and local SLR impact as well as local tide estimates.

We recommend you read **"8 things you must know about SLR"** for more on the latest research on Antarctica & Greenland, MISI & MICI, new estimates of SLR vs. IPCC as well as impacts of uneven SLR. This section can be found in ***"Changing Risk Landscapes: Coastal Threats to Central Banks"***, another report in the CWR Coastal Capital Threat Series. This report also includes an entire section on how to build base and worst-case SLR scenarios as well as base and worst-case extreme storm tide scenarios.

Abbreviations

AAL	Average Annual Losses
AIGCC	Asia Investor Group on Climate Change
APAC	Asia Pacific
AR5	IPCC 5th Assessment Report (2014)
BCP	Business Continuity Planning
CBD	Central Business District
CIESEN	Center for International Earth Science Information Network
CO_2	Carbon Dioxide
CWR APACCT 20 Index	CWR APAC 20 Cities Coastal Threat Index
DCF	Discounted Cash Flow model
DEM	Digital Elevation Data
DTM	Digital Terrain Model
ESG	Environmental, Social and Corporate Governance
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GMSL	Global Mean Sea Level
GRCN	Global Resilient Cities Network
GSI	Geospatial Information Authority of Japan
$GtCO_2e$	Gigatonnes of equivalent carbon dioxide
HCMC	Ho Chi Minh City
HKDTM - 5m	Hong Kong 5m-grid Digital Terrain Model
HKO	Hong Kong Observatory
IGCC	Investor Group for Climate Change
IPCC	Intergovernmental Panel on Climate Change
IPCC-SROCC	IPCC's Special Report on the Ocean and Cryosphere in a Changing Climate
MICI	Marine Ice Cliff Instability
MISI	Marine Ice Sheet Instability
NDC	Nationally Determined Contributions
NGFS	The Network of Central Banks and Supervisors for Greening the Financial System
RCP	Representative Concentration Pathway
SEJ	Structured Expert Judgement
SLR	Sea Level Rise
SRTM-30m	30m-grid Shuttle Radar Topography Mission elevation data by NASA
TCFD	Task Force on Climate-related Financial Disclosures
TV	Terminal Value
UNEP	United Nations Environment Programme
WACC	Weighted Average Cost of Capital
WAIS	West Antarctica Ice Sheet
WMO	World Meteorological Organization
WRI	World Resources Institute

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The cut-off date for all research referenced in this report is 9th October 2020

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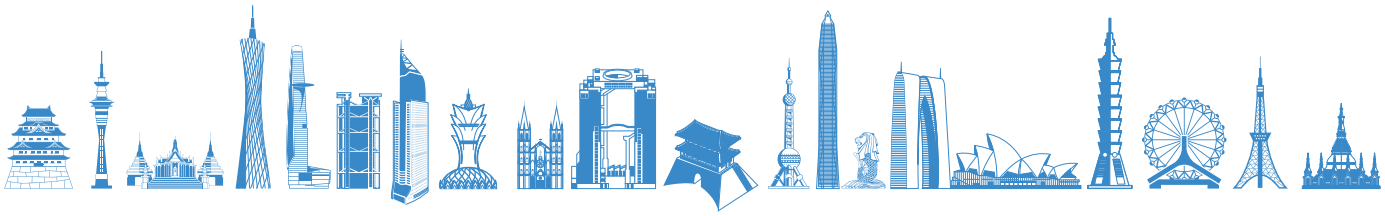

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