HONG KONG MONETARY AUTHORITY
香 港 金 融 管 理 局

Pilot Banking Sector Climate Risk Stress Test

December 2021

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Executive summary

Introduction

Climate change is posing increasing threats to the financial sector. Financial institutions should take early actions to manage climate-related risks. They should develop adequate capabilities to measure their exposures to climate risks in order to assess their resilience to potential shocks brought about by climate change. Considering scenario analysis and stress testing are widely recognised as effective tools for measuring climate risks, the Hong Kong Monetary Authority (HKMA) launched a pilot climate risk stress test (CRST) exercise in January 2021 to assess the potential impact of climate change on the Hong Kong banking sector. This first-ever, sector-wide pilot exercise seeks to achieve two main objectives, namely to assess the climate resilience of the Hong Kong banking sector as a whole and to facilitate the capability building of participating banks with respect to climate risk management.

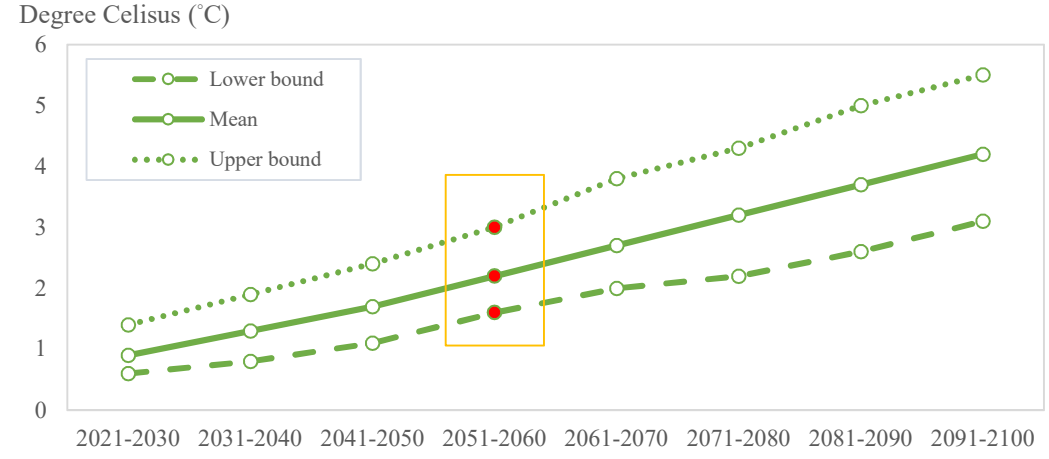
The industry was supportive of the exercise. Twenty-seven banks, including 20 major retail banks and seven branches of international banking groups participated in the exercise. They together accounted for 80% of the sector's total lending, forming a good basis for the HKMA to gain useful insights into the climate risk profile of the banking sector.

Scenarios covered

The CRST comprises three scenarios, namely a physical risk scenario of worsening climate situation and two transition risk scenarios representing different pathways (i.e. disorderly and orderly) to a low-emission economy. Physical risk and transition risk are assessed separately under these scenarios, allowing for a better understanding of the impact of each of these risks on the banking sector.

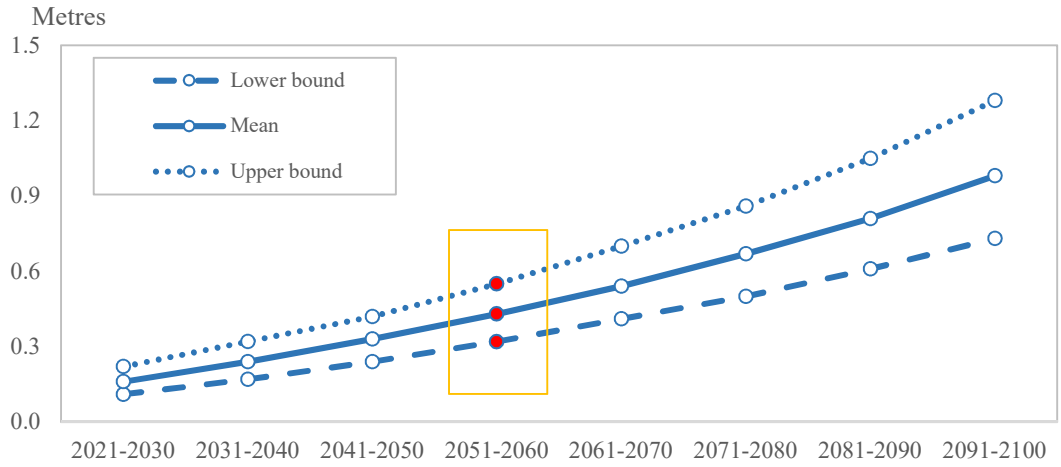
The physical risk scenario focuses on the projected climate situation of Hong Kong in the middle of the 21st century, with assumptions around potential increases in temperature and rises in sea level. This scenario is developed based on the climate projections of the Hong Kong Observatory (HKO) under a scenario of high greenhouse gas (GHG) concentration (see Chart 1 and Chart 2 below).

Chart 1: Projected changes in the annual temperature of Hong Kong relative to the average of 1986-2005 under high GHG concentration



Source: HKO

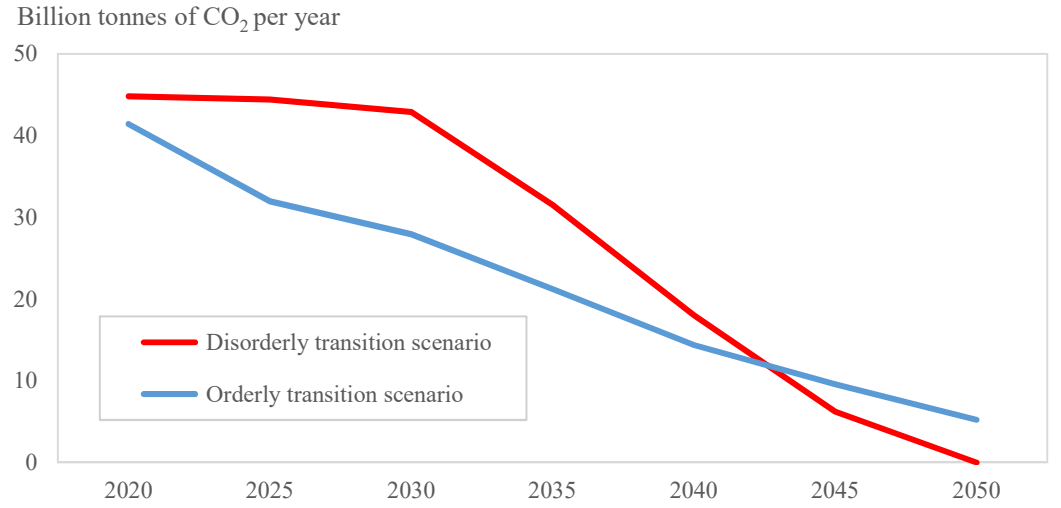
Chart 2: Projected changes in the mean sea level in Hong Kong and its adjacent waters relative to the average of 1986-2005 under high GHG concentration



Source: HKO

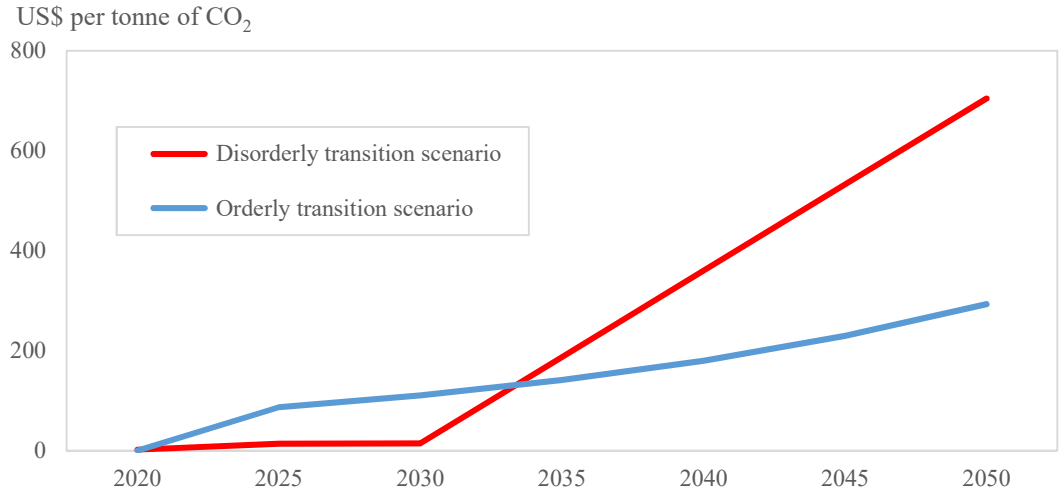
As regards the transition risk scenarios, the disorderly transition pathway assumes abrupt changes in climate policies of authorities, while the orderly transition pathway assumes early and progressive actions to achieve the climate goals of the Paris Agreement. Both transition risk scenarios are represented by trajectories of global carbon dioxide (CO_2) emission amount and carbon price projected by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) (see Chart 3 and Chart 4 below).

Chart 3: CO_2 emission under different transition pathways



Source: NGFS

Chart 4: Carbon price under different transition pathways



Source: NGFS

It is assumed in both the physical risk and transition risk scenarios that the participating banks will not change their business strategies over the horizon of assessment.

Assessment results

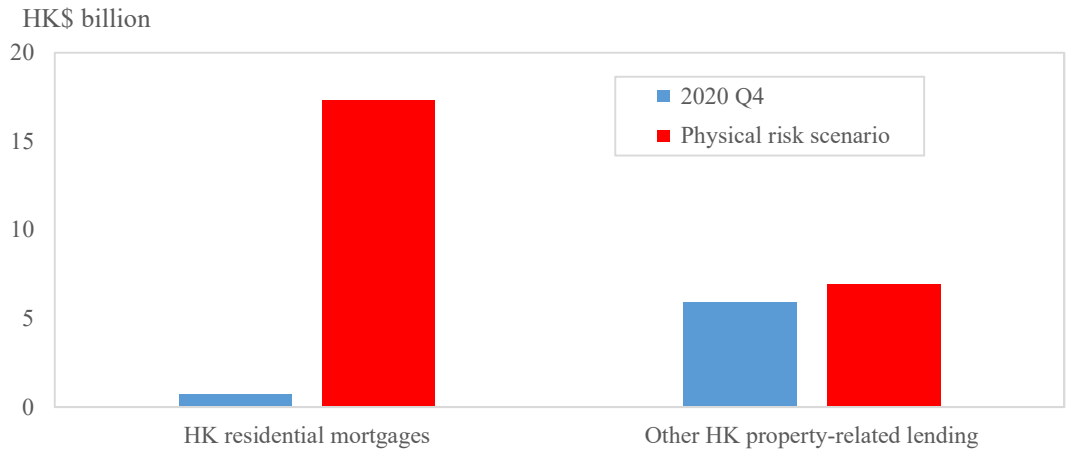
Climate risks can give rise to significant adverse impacts on the banks' profitability, capital positions and operations. Notwithstanding the significant potential impacts of climate change, the Hong Kong banking sector remains resilient to climate-related shocks given the strong capital buffers built up over the years.

Physical risk assessment

The results show that physical risks will be manifested in Hong Kong through two major types of climate hazards, namely typhoons and floods, causing devaluation of properties and business disruptions. Emphases of the assessment are therefore placed on the vulnerabilities of residential mortgages and other property-related lending in Hong Kong, which amounts to HK$2.9 trillion or 28% of the participating banks' total lending, and the potential operational losses associated with climate events.

The participating banks project that the expected credit losses (ECLs) of their property-related lending in Hong Kong will rise sharply under the physical risk scenario. The 1-year ECLs of the banks' Hong Kong residential mortgages are projected to surge 25 times from HK$0.7 billion to HK$17.3 billion under the scenario, indicating a substantial increase in the risks faced by the banks in this area (see Chart 5 below). The banks also anticipate a higher level of operational losses arising from damages to office premises and disruptions to business operations.

Chart 5: ECLs of Hong Kong property-related lending



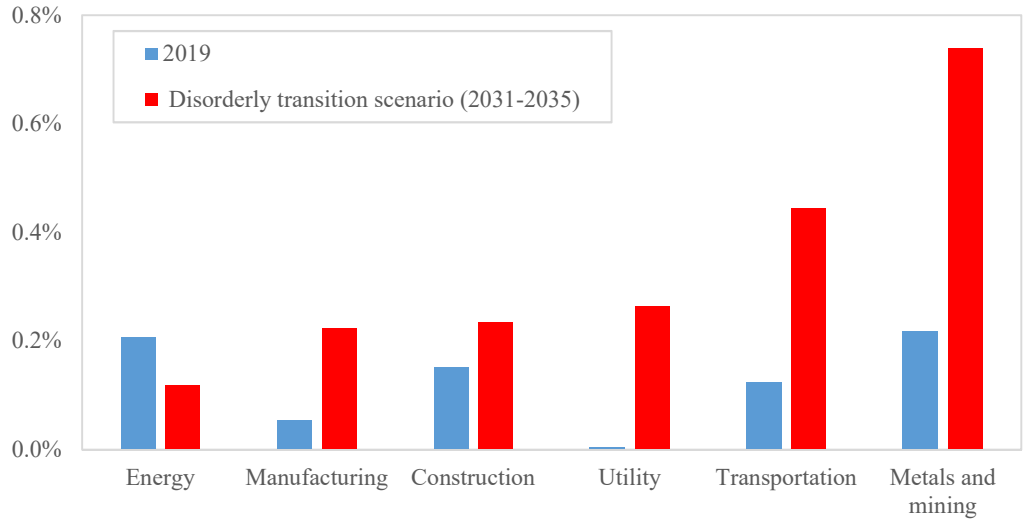
Source: HKMA

Transition risk assessment

All the participating banks have assessed the 5-year impact between 2031 and 2035 under the disorderly transition scenario while the domestic systemically important authorized institutions (D-SIBs) have additionally conducted a 30-year assessment between 2021 and 2050 for the orderly transition scenario. Under both scenarios, the participating banks have assessed the potential transition impact on their exposures to the property development sector and six high-emitting industries, including energy, utility, metals and mining, transportation, construction and manufacturing. The aggregate exposures to these sectors amount to HK$3.2 trillion or 31% of the banks' total lending. About half of these exposures are those to the six high-emitting industries.

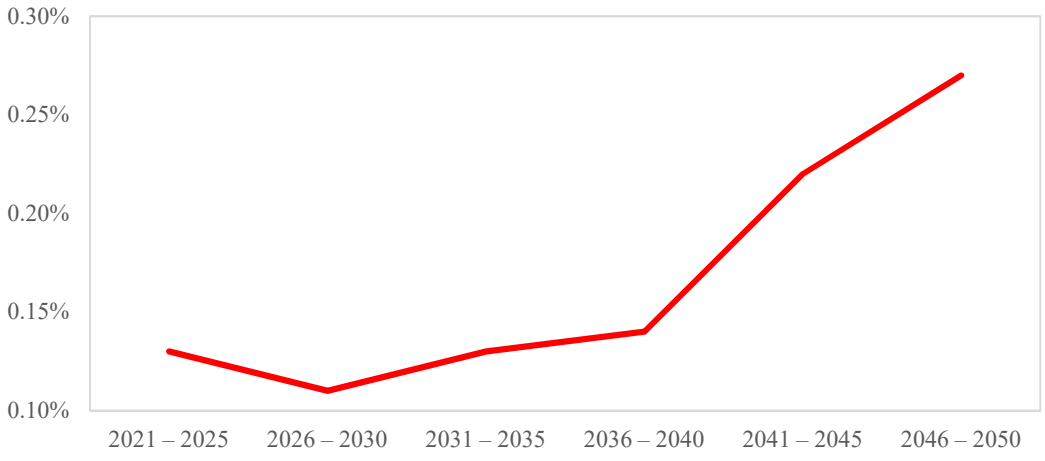
The results indicate that transition risk will manifest itself in terms of increased credit risk exposures of the banks. The impact is particularly conspicuous under the disorderly transition scenario. The annualised credit cost of lending to the high-emitting industries under this scenario will rise by three times to reach 0.3% as compared to the level in 2019. Exposures to the metals and mining and the transportation sectors are most severely affected (see Chart 6 and Chart 7 below). Higher credit cost, together with a significant increase in credit risk-weighted assets (RWA) of the assessed exposures, will lead to a notable deterioration in the banks' capital positions. D-SIBs' capital adequacy ratios (CARs), for instance, will on average drop by 3 percentage points over the 5-year horizon under the disorderly transition scenario. Even under the orderly transition scenario, it is assessed that the annualised credit cost of lending to the high-emitting industries will move higher steadily throughout the 30-year horizon.

Chart 6: Annualised credit cost of lending to the high-emitting industries in 2019 and 2031-2035 under the disorderly transition scenario



Source: HKMA

Chart 7: Annualised credit cost of lending to the high-emitting industries under the orderly transition scenario



Source: HKMA

Limitations of the assessments

As this is a pilot stress testing exercise, the participating banks are provided with the flexibility of adopting some simplified assumptions in their analyses. In the physical risk assessment, for instance, the banks have not been asked to take the full account of the broader economic impact of the intensified climate hazards on borrowers' repayment ability. In the transition risk assessment, the banks have mainly focused on the direct impact on their exposures to the high-emitting industries, while the second-order impacts, such as the spill-over effects on the non-high-emitting industries, have not been fully evaluated in some of their analyses. The projected impact of climate

change on the banks may not have been fully captured in the assessment due to these simplified assumptions.

Overall assessment

The assessment results indicate that climate risks can give rise to significant adverse impacts on the banks' profitability, capital positions and operations. Notwithstanding the significant potential impacts of climate change, the Hong Kong banking sector should remain resilient to climate-related shocks given the strong capital buffers built up by the banks over the years.

Capability building of banks

The banks have substantially enhanced their capabilities for measuring climate risks through active participation in this pilot exercise. Major gaps revealed by the exercise, particularly those concerning data availability and assessment methodologies, will need to be addressed to improve on the robustness of future assessments.

Enhanced capabilities and risk awareness

During the course of the CRST, the participating banks endeavoured to enhance their capabilities in measuring climate risks as they went through the risk identification and assessment processes. Some of the participating banks benefited more by making extra efforts to conduct more granular and in-depth analyses beyond the HKMA's requirements. A discussion forum organised by the HKMA also facilitated the banks' capability building by providing a knowledge-sharing platform for the banks to learn good practices from each other. However, some major gaps revealed by the exercise, especially those concerning data availability and assessment methodologies, remain, owing to limitations such as the lack of widely accepted standards for risk identification and insufficient modelling expertise for this new subject.

Although the participating banks are at different stages of the journey of developing their climate risk management capabilities, the exercise has given them a good opportunity to deepen the understanding of their risk levels, areas of vulnerabilities and transmission channels of climate risks. As required by the HKMA, the CRST results have been reported to the banks' senior management, thereby raising the institutions' firm-wide awareness of climate risks.

Major challenges ahead

The participating banks highlight that the inadequacy of granular and reliable data is the biggest challenge for modelling and assessing climate risks. This challenge is exacerbated by the lack of widely accepted standards for classifying and identifying climate risk exposures. The uncertain timing of materialisation of climate risks and the lack of historical events have also made development and validation of models for assessing climate risks more challenging.

Actions to address climate risks

Riding on the vulnerabilities and gaps identified in the CRST, the participating banks have developed plans to strengthen their climate strategies and risk governance frameworks in order to ensure their ongoing resilience against climate change.

Although the resilience of the banking sector against climate-related shocks is well supported by the banks' strong capital buffers, the impacts brought about by climate change can be long-lasting and grow in severity over time due to irreversible changes in climate patterns. The more frequent and rapid shifts in climate policies in response to climate change can also pose additional transition risks to the banking sector. As required by the CRST, the participating banks have provided information on their plans to mitigate climate risks and address the vulnerabilities revealed by the exercise. These plans include strategic allocation of additional resources to climate resilient activities, such as green financing and providing transition finance to support their customers to transition to low-emission business models, and the incorporation of a broader range of climate risk factors into their risk assessment frameworks. They have also undertaken to keep abreast of market developments and put in continuous efforts to enhance their capabilities on climate risk management.

Way forward

The HKMA will continue to engage the industry to support their capability building and enhance the CRST framework in order to assess the banking sector's climate resilience more comprehensively.

The HKMA will reach out to the industry to share the lessons learnt from the pilot CRST, and follow up with individual banks on their progress in closing the gaps identified in the exercise. In addition, the HKMA will explore possible solutions to tackle the challenges identified in the exercise, especially those requiring concerted efforts of banks and conducive to improving the climate resilience of the whole industry. The scenario specifications and reporting requirements will be refined, with a view to developing a more comprehensive framework for future exercises. The current intention is to undertake another CRST in two years' time.

To avoid duplicated efforts in meeting different jurisdictional regulatory requirements on CRST, the HKMA will actively explore opportunities to collaborate with overseas authorities to promote greater consistency in CRST practices.

1. Introduction

Climate change is posing increasing risks to the financial sector. Financial institutions should take early actions to manage climate-related risks. They should develop adequate capabilities to measure their exposures to climate risks in order to assess their resilience to potential shocks brought about by climate change. Considering scenario analysis and stress testing are widely recognised as effective tools for measuring climate risks, the Hong Kong Monetary Authority (HKMA) launched a pilot climate risk stress test (CRST) exercise in January 2021 to assess the potential impact of climate change on the Hong Kong banking sector. This first-ever, sector-wide pilot exercise seeks to achieve two main objectives:

- **Climate resilience assessment**: The exercise aims to assess the climate resilience of the banking sector as a whole under various climate change scenarios.
- **Capability building**: The HKMA expects banks to build their capabilities with respect to climate risk management through their participation.

Below are the salient features of the pilot CRST:

- The exercise covers two major types of climate risks, namely physical risk and transition risk.
- Distinct scenarios are established for assessing physical risk and transition risk. Participating banks are required to perform separate assessments for these scenarios to allow for a better understanding of the impact of each of these risks on the banking sector.
- The CRST scenarios cover different time horizons for capturing both the short-term impact of abrupt changes in climate patterns and transition policies, and the long-term impact of early and progressive actions.
- It is assumed that the banks will not change their business strategies over the horizon of assessment and will maintain a static balance sheet.
- Participating banks are required to evaluate the model risks associated with their assessment and to identify gaps in measuring climate risks for future enhancement.

The use of CRST in measuring climate risks is a relatively new development and banks have different levels of sophistication in their approaches to measuring and assessing climate risks. In light of this, the HKMA has adopted a pragmatic approach and has provided flexibilities to banks to promote participation in the pilot exercise. These include, for instance, allowing the adoption of simplified assumptions and a narrower portfolio coverage in performing the assessment.

The industry was supportive of the exercise. Twenty-seven banks, including 20 major retail banks and seven branches of international banking groups participated in the exercise. They together accounted for 80% of the sector's total lending, forming a good basis for the HKMA to gain useful insights into the climate risk profile of the banking

sector. The lessons learnt from the exercise have also laid a good foundation for both the HKMA and the industry to formulate strategies to enhance climate risk management.

The remaining part of this report is organised as follows: chapter 2 and chapter 3 present the detailed results of the CRST in relation to climate resilience assessment and capability building respectively. Chapter 4 outlines the participating banks' actions to address climate risks having regard to the CRST results. Chapter 5 discusses the way forward of the HKMA in pursuing similar exercises in the future. The annexes outline some useful practices adopted by the participating banks in performing the CRST.

Since the pilot exercise is exploratory in nature with various limitations on data and assessment methodologies, readers are advised to interpret the CRST results with caution.

2. Climate resilience of the banking sector

Physical risk and transition risk are two major but different types of climates risks, and they affect financial institutions through distinct transmission channels. Physical risk arises from changes in climate patterns while transition risk concerns the societal and economic shifts towards a low-carbon economy resulting mainly from evolvements in climate policies of authorities and technology. In light of this, distinct scenarios have been specifically designed to capture the unique nature of these risks. The participating banks are required to assess the two risks separately under the respective scenarios in order to allow for a better understanding of the impact of each of these risks on the banking sector.

2.1 Physical risk assessment

Physical risk arises from climate and weather-related events, such as droughts, floods, storms and sea-level rises, as well as from progressive shifts in climate and weather patterns, such as increasing temperature. It comprises impacts resulting directly from such events and shifts (e.g. damages to properties), and those ensuing indirectly from subsequent events (e.g. disruptions to global supply chains). The participating banks are required to assess these impacts which will potentially crystallise under a prescribed scenario of the climate situation of Hong Kong in the middle of the 21st century (i.e. 2051 to 2060).

2.1.1 Scenario assumptions

The CRST scenario for physical risk assessment is developed based on the projection of the Hong Kong Observatory (HKO) under the assumption of high greenhouse gas (GHG) concentration. This scenario is consistent with the Representative Concentration Pathway (RCP) 8.5 adopted by the Intergovernmental Panel on Climate Change (IPCC).

RCPs and climate change projections for Hong Kong

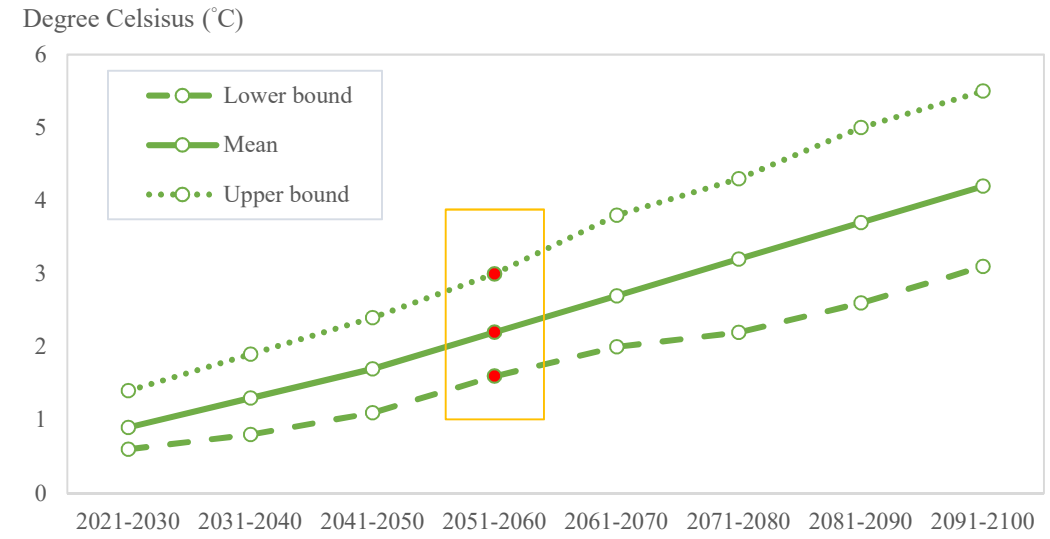
RCPs are projections of climate change pathways based on GHG emission levels having regard to population size, economic activities, lifestyle, patterns of energy use and land use, technology and climate policies. There are four major pathways projected for the 21st century, namely the stringent emission pathway (RCP 2.6), two intermediate stabilisation pathways (RCP 4.5 and RCP 6.0) and the high emission pathway (RCP 8.5).

For the climate situation of Hong Kong in the 21st century, the HKO has made projections under the assumptions of low, medium-low, medium-high and high GHG concentration which correspond to RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 respectively.

Under this scenario, Hong Kong will be affected by the acute impacts of extreme weather events, including increasing temperature, rising sea level and more intense

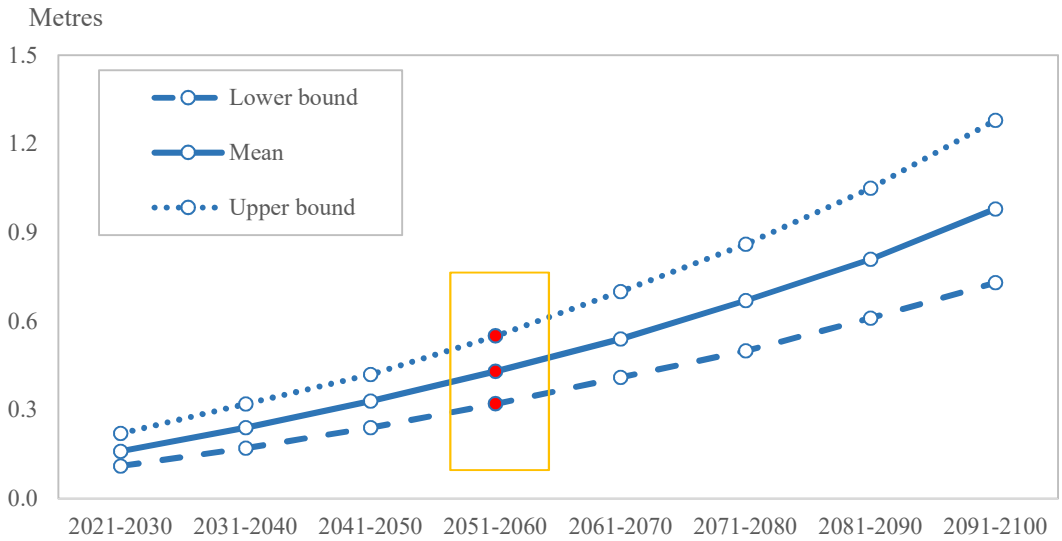
tropical cyclones. Chart 1 and Chart 2 show the HKO projections of the climate situation of Hong Kong over the 21st century based on RCP 8.5 (i.e. high GHG concentration).

Chart 1: Projected changes in the annual temperature of Hong Kong relative to the average of 1986-2005 under high GHG concentration



Source: HKO

Chart 2: Projected changes in the mean sea level in Hong Kong and its adjacent waters relative to the average of 1986-2005 under high GHG concentration



Source: HKO

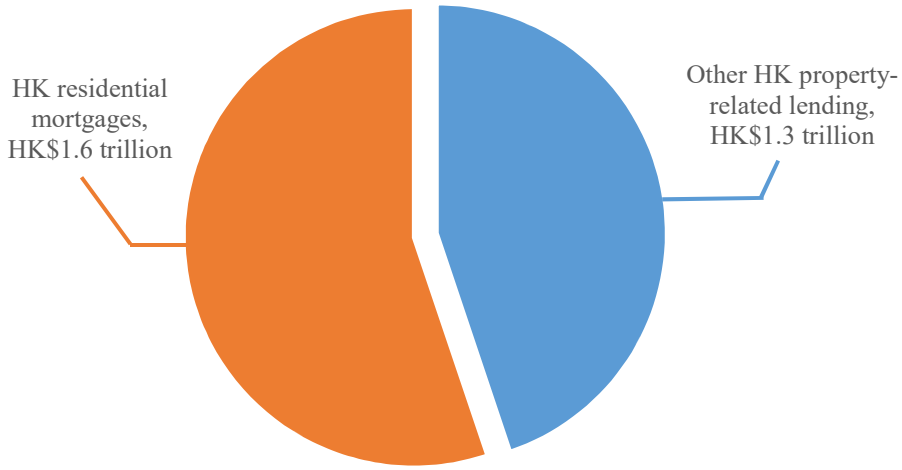
While the participating banks are encouraged to evaluate the impact of climate hazards on all relevant exposures under the scenario, emphases are placed on the credit losses

of residential mortgages and other property-related lending in Hong Kong, and operational losses associated with climate events in Hong Kong.

2.1.2 Risk identification

The participating banks have in aggregate evaluated the physical risk impact on HK$2.9 trillion of Hong Kong property-related loans, accounting for 28% of their total lending (see Chart 3 below). Fifty-five percent of these property-related loans are residential mortgages.

Chart 3: Composition of Hong Kong property-related lending covered in CRST



Source: HKMA

A majority of the participating banks assess that the physical risk impact on Hong Kong property-related lending will come from climate hazards linked to tropical cyclones, i.e., typhoons and floods. In particular, inundation or floods caused by tropical cyclones can potentially lead to severe damages to properties and infrastructure in Hong Kong, especially those in coastal and low-lying areas.

As such, the magnitude of potential damages to properties arising from climate hazards and hence the physical risk impact on the banks is location-specific. A major area of work in the risk identification process for the physical risk assessment is therefore to identify the precise location of the properties used as collateral in the banks' lending. Given the large number of loans with properties as collateral, some of the participating banks have developed technology solutions to automate the identification process. Some details of these solutions can be found in Annex A.

Based on the location information of the property collateral, the participating banks identify that 32% of their Hong Kong property-related lending is pledged with collateral located in vulnerable areas and thus exposed to material physical risk.

By applying the same approach, the participating banks identify their own premises located in vulnerable areas and assess the potential operational losses accordingly.

2.1.3 Assessment results

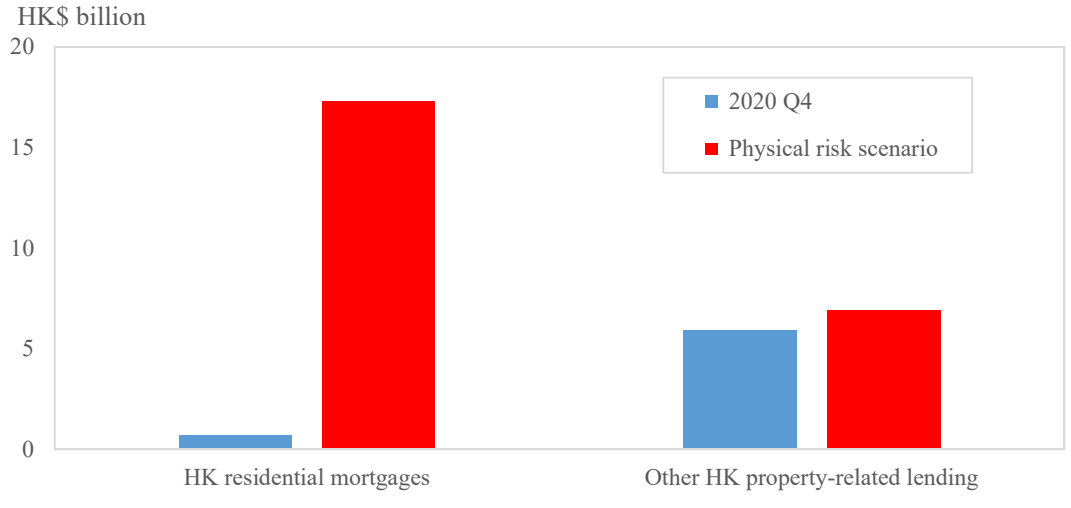
Most of the participating banks assess the physical risk impact over a 1-year horizon by assuming an instant switch from the current climate situation of Hong Kong to that in the middle of the 21st century. Some banks with more advanced capabilities have performed the analyses over a longer horizon in an attempt to understand the trend and dynamics of the physical risk impact. The results reported below represent the aggregate of the worst annual impact of the participating banks under the prescribed scenario.

Credit risk of Hong Kong property-related lending

As climate hazards become more intense, direct physical damages to properties and changes in market perception of properties' vulnerability to extreme climate events will both lead to a devaluation of the properties. This in turn will cause loss given default and hence credit risk of a bank's property-related lending to increase. In practice, the participating banks utilise historical data or results of academic research in the physical risk assessment. Insurance recovery for physical damages is not considered in aggregating the banks' assessment results given the uncertainties around the availability and the required premiums for obtaining the insurance coverage for vulnerable properties under the scenario.

The banks' assessment shows that, under the extreme scenario assumed in the exercise, devaluation ensuing from physical damages could be more than 50% for some properties in vulnerable areas. As a result, the banks need to set aside additional provisions for the loans concerned. The total expected credit losses (ECLs) of the banks' property-related lending in Hong Kong under the physical risk scenario are estimated to be three times more than those in Q4 2020. A major portion of the increase comes from residential mortgages, with respect to which the ECLs are projected to surge 25 times from HK$0.7 billion to HK$17.3 billion (see Chart 4 below). The significant increase suggests that the banks' residential mortgage loan portfolios will become much riskier than today and this will have material implications on the banks' profitability.

Chart 4: ECLs of Hong Kong property-related lending



Source: HKMA

Operational losses associated with climate events

In the banks' physical risk assessment, business disruptions and damages to their own business premises are the major sources of operational losses. Most of the banks have made reference to data of historical climate events, with adjustments for the more intense climate hazards assumed under the scenario.

The banks project that the more intense climate hazards will cause them to suffer an annual operational loss of HK$2.2 billion, which is equivalent to 0.8% of their profit before tax in 2019. Out of this loss, HK$0.5 billion is estimated to come from business disruptions. While this amount appears insignificant as compared to other potential impacts of climate-related shocks, most of the banks explain that the adoption of technology solutions, flexible work arrangements and enhancements to business continuity plans in response to the COVID-19 pandemic have helped them reduce the potential operational losses associated with business disruptions.

2.1.4 Limitations of the physical risk assessment

Most of the participating banks consider it very challenging in performing the physical risk assessment because of insufficient data and the unclear linkage between climate change and economic performance, as discussed below.

- *Estimation of devaluation of properties:* Most of the banks only include physical damages to properties in estimating the devaluation of properties. Changes in market perception of property prices are less considered due to the difficulties in predicting market sentiment towards those affected properties under climate events. In addition, some of the approaches used for estimating the physical damages are based on data of historical climate events, which may not sufficiently capture the severity of damages caused by unprecedented climate events.

- *Economic impact of climate hazards:* Most of the banks do not incorporate the broader economic impact of the intensified climate hazards into their physical risk assessment. Such economic shocks can affect the general repayment ability of borrowers. In addition, some borrowers' repayment ability is more vulnerable to climate hazards, such as those in the agricultural industry and those with major production plants located in areas which are more vulnerable to climate events. However, the impact transmitted through this channel is not sufficiently captured in most of the participating banks' analyses.

2.2 Transition risk assessment

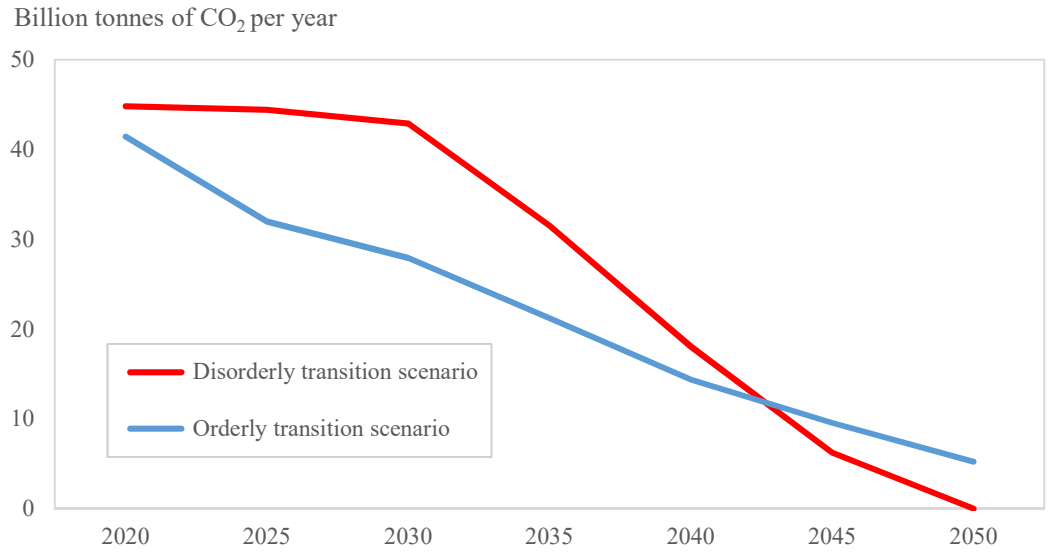
Transition risk emerges from the adjustment process towards a low-carbon economy driven mainly by changes in climate policies of authorities and technology advancements. The CRST assessment requires the participating banks to assess the 5-year impact under a disorderly transition scenario as well as the long-term impact up to 30 years under an orderly transition scenario.

2.2.1 Scenario assumptions

For the assessment of the transition risk, the HKMA has made reference to two representative scenarios developed by the Network of Central Banks and Supervisors

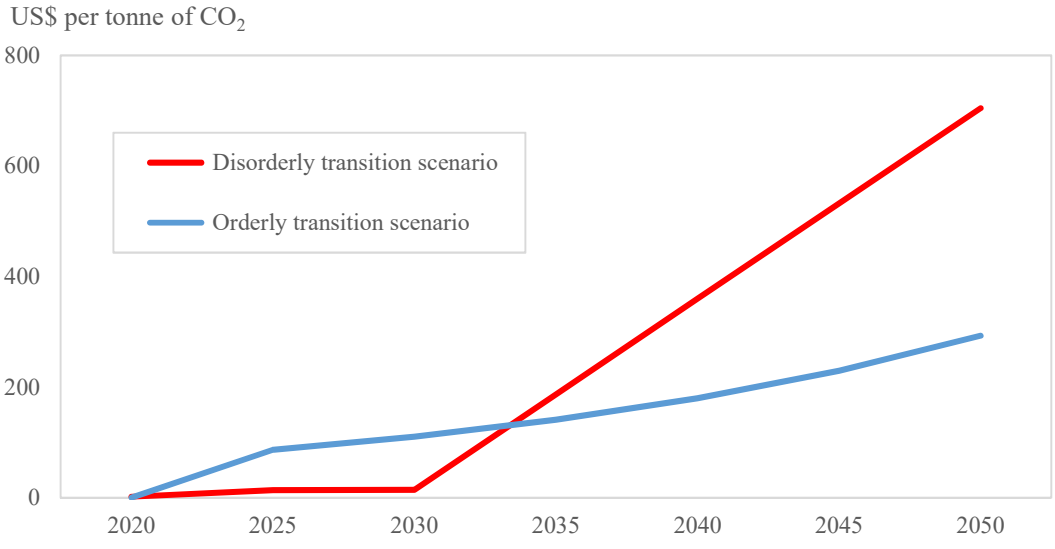
for Greening the Financial System (NGFS), namely the orderly and disorderly transition scenarios. The scenarios comprise a set of transition pathways towards a given climate outcome under different assumptions about policy actions and technology evolvements. They are characterised mainly by emission pathways of carbon dioxide (CO_2), changes in carbon price and energy mix (see Chart 5 to Chart 8 below).

Chart 5: CO_2 emission under different transition pathways



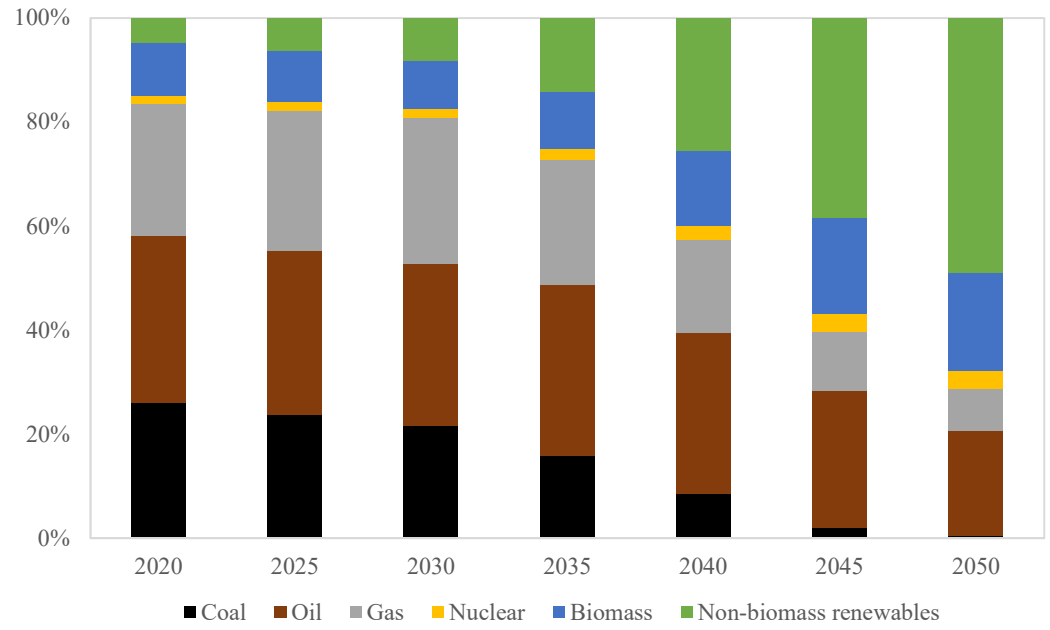
Source: NGFS

Chart 6: Carbon price under different transition pathways



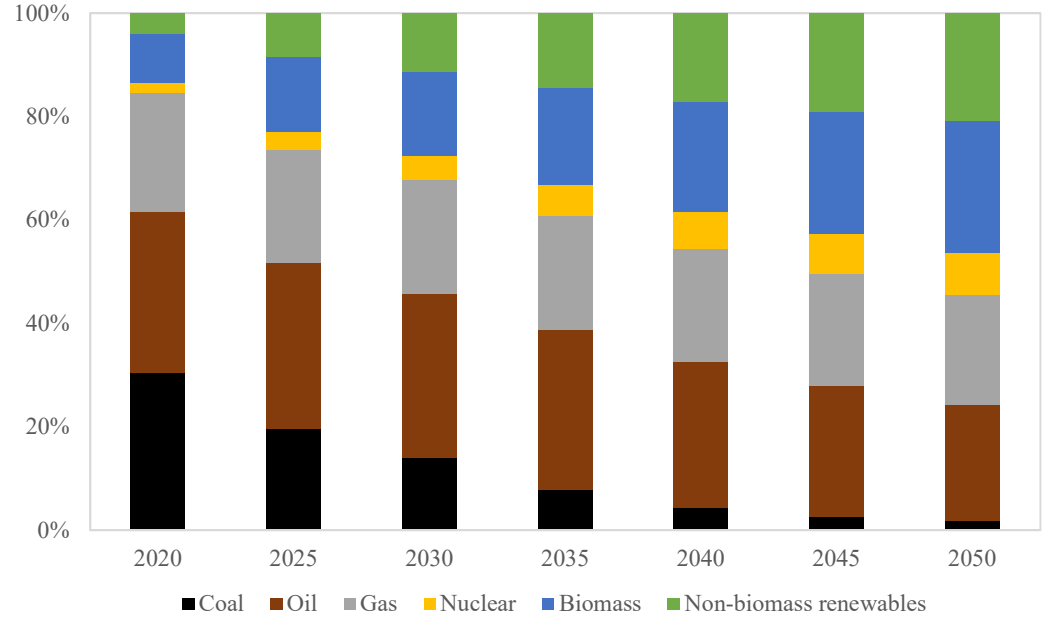
Source: NGFS

Chart 7: Changes in energy mix under the disorderly transition scenario



Source: NGFS

Chart 8: Changes in energy mix under the orderly transition scenario



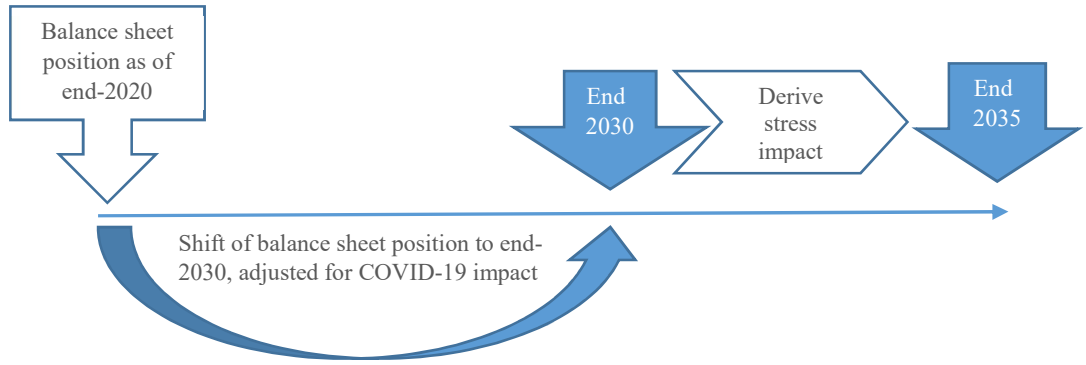
Source: NGFS

Disorderly transition scenario

The disorderly transition scenario adopted in the CRST assumes that the global economy will go through a challenging pathway in achieving the climate goals set out in the Paris Agreement, i.e. to limit global warming to well below 2°C, and preferably to 1.5°C, as compared to pre-industrial levels. Under this scenario, authorities will not introduce climate policies until 2030, leading to an abrupt reduction in GHG emission afterwards in order to achieve the Paris Agreement targets. This will give rise to conspicuous changes in energy consumption patterns and carbon price. As a result, the high-emitting industries will be significantly affected. The impact on the global economy will be noticeable as there will be substantial friction in the transition to low-emission energy sources and production processes.

The participating banks are required to evaluate the transition risk over a 5-year horizon from 2031 to 2035 under this scenario. Under the assumption of a static balance sheet, the banks use their balance sheet position at end-2020 as the initial position for the assessment (i.e. end-2030). They may remove the stress impact of COVID-19 by making suitable adjustments to their initial balance sheet position for the transition risk assessment. The estimated 5-year impact starting from 2031 can be viewed as the impact of an instantaneous shock to their initial balance sheet position.

Exhibit 1: Illustration of using the end-2020 balance sheet position as the initial position for assessing the transition risk under the disorderly transition scenario



Source: HKMA

Orderly transition scenario

The orderly transition pathway assumes that authorities will take early and progressive actions to reduce GHG emission with the availability of new technology. The resulting changes in energy consumption patterns and carbon price will be more gradual than those under the disorderly transition scenario. The Paris Agreement targets will be achieved in a more orderly manner and there will be fewer disruptions to the global economy throughout the process.

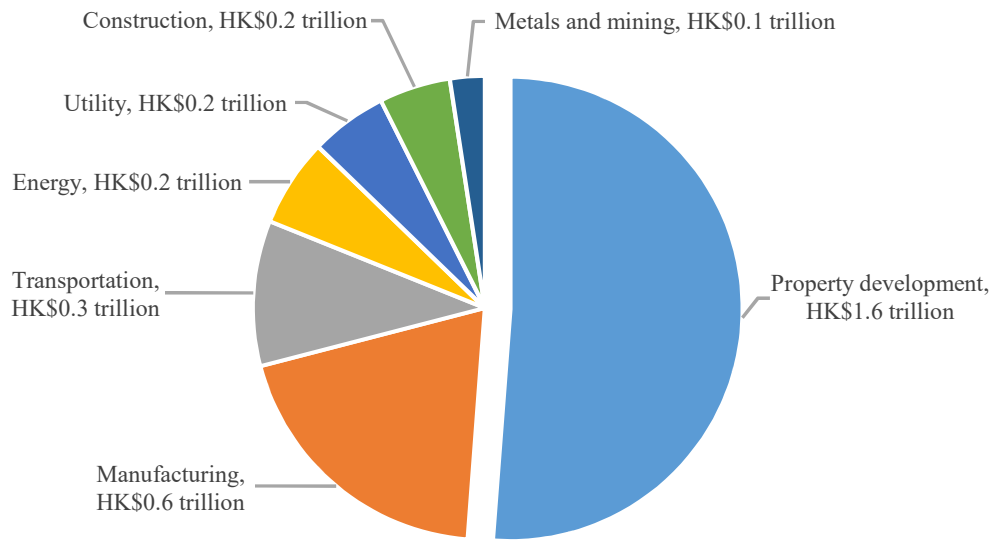
The domestic systemically important authorized institutions (D-SIBs) are asked to conduct a 30-year assessment between 2021 and 2050 under the orderly transition scenario. It is assumed that the banks will not change their business strategies over the horizon of assessment and will maintain a static balance sheet. On top of the HKMA's

requirements, some of the D-SIBs have performed additional analyses by incorporating the effect of actions to mitigate climate risks in their assessments.

2.2.2 Risk identification

The participating banks are asked to assess the transition risk for seven industries, including the property development sector and six high-emitting industries, namely energy, utility, metals and mining, manufacturing, transportation and construction. The banks identify their exposures to these industries according to their internal industry classification system. The identification process covers the banks' lending portfolios, and holdings in securities and other financial products. A major portion of the banks' exposures to these industries come from their lending portfolios, which in aggregate amount to HK$3.2 trillion or 31% of the participating banks' total lending (see Chart 9 below).

Chart 9: Composition of the participating banks' lending to the property development sector and the six high-emitting industries



Source: HKMA

Apart from conducting the transition risk assessment at the sector level, the participating banks are asked to conduct a more detailed counterparty-level assessment of those "high-emitting" corporates to which they have significant exposures. In general, the banks collect the following information to determine whether a particular corporate is "high emitting":

- carbon emission data;
- corporate awareness of climate-related issues which may call for a transition;
- transition plan to a low-emission business model;
- track records in implementing the transition plan; and
- Environmental, Social and Governance (ESG) score, if available.

2.2.3 Assessment results

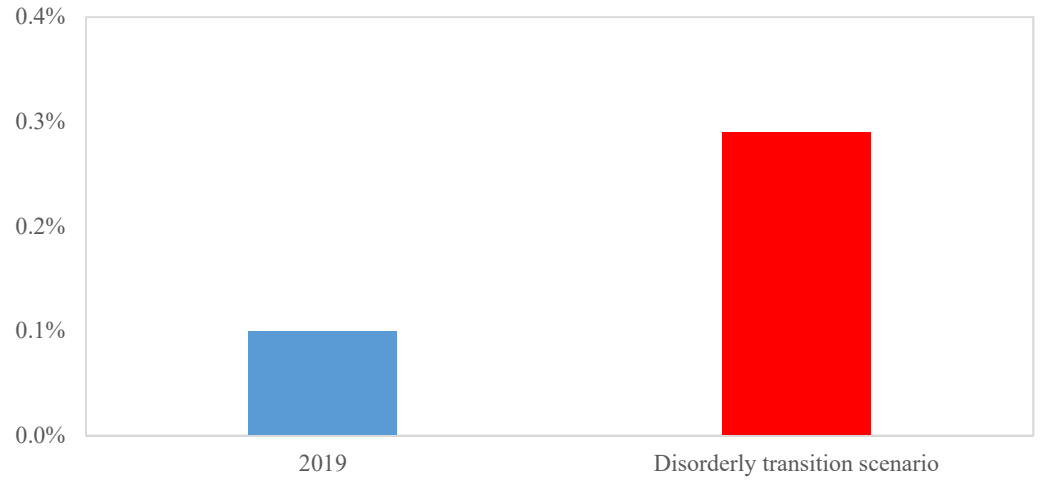
The participating banks assess that transition risk will manifest itself mainly in terms of increased credit exposures. To conduct the counterparty-level assessment, most of the banks have developed new models to project the impact of the prescribed transition pathways on the financials of a counterparty. The projected key financials, such as revenue and expenditure, are then used as inputs to the banks' credit risk models or evaluation frameworks for assessing the repayment ability of the counterparty. For the sector-level assessment, the banks either adopt the results from research papers studying the transition impact on different industries or extrapolate the results of the counterparty-level assessment to derive the impact on the whole sector.

The banks also assess traded risk under the transition risk scenarios and conclude that the impact is relatively small. It is observed that the approaches adopted by the banks to assess traded risk are different from those used to assess credit risk, reflecting the need to capture the distinct nature of trading instruments.

Results under the disorderly transition scenario

The impact on the banks' financial positions is found to be more pronounced under the disorderly transition scenario than that under the orderly transition scenario. The annualised credit cost [1] of the participating banks' lending to the high-emitting industries during the 5-year assessment horizon is estimated to rise by three times to reach 0.3% as compared to the level in 2019[2].

Chart 10: Annualised credit cost of lending to the high-emitting industries



Source: HKMA

[1] Annualised credit cost = Average annual change in ECLs / Average loan amount

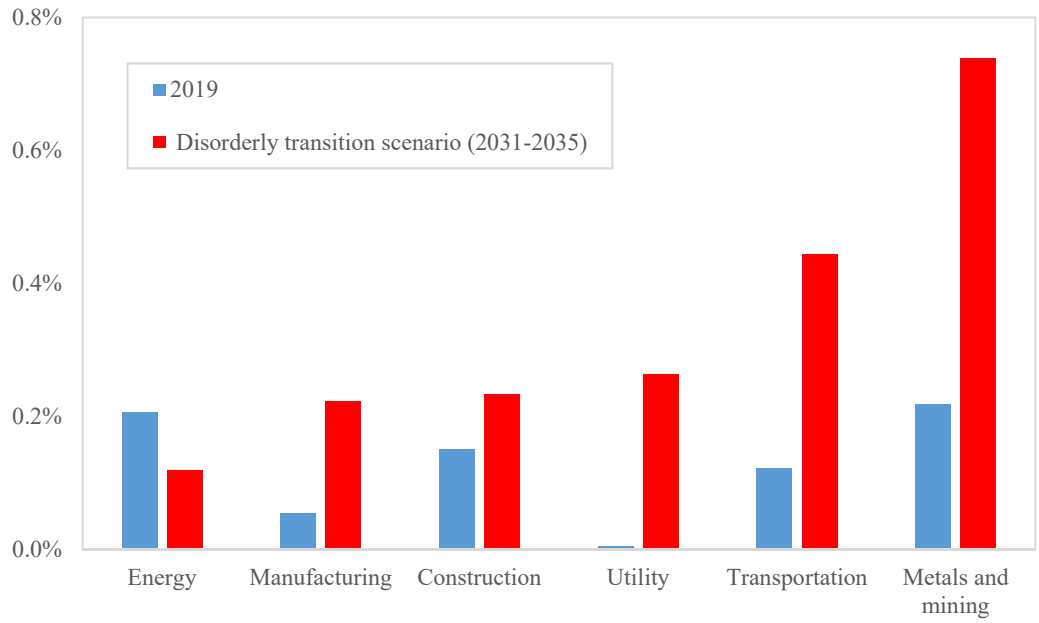
[2] Economic situation in 2020 was significantly affected by the COVID-19 pandemic. Therefore, statistics in 2019 are used as a benchmark for comparison.

The participating banks indicate that not many of the high-emitting corporates have established concrete transition plans. Taking a conservative approach, the banks assume that these corporates will not take any mitigating actions over the assessment horizon. As a result, an increase in carbon price will in general give rise to an increase in the credit cost of lending to these corporates.

The deterioration in corporates' financial conditions and hence creditworthiness under the transition risk scenarios will affect the banks' profitability, loan provisioning, credit risk-weighted assets (RWA) and consequently their capital positions. Specifically, the capital adequacy ratios (CARs) of the D-SIBs will on average drop by 3 percentage points over the 5-year assessment horizon under the disorderly transition scenario.

Chart 11 below compares the projected annualised credit cost of lending to each of the six high-emitting industries under the disorderly transition scenario with the actual credit costs in 2019. The credit cost of lending to the metals and mining and the transportation sectors is most severely affected.

Chart 11: Annualised credit cost of lending to the high-emitting industries in 2019 and 2031-2035 under the disorderly transition scenario



Source: HKMA

For the metals and mining sector, the banks assess that substantial investment will be needed for companies in the industry to adjust their energy mix and production technology, while the high production cost associated with the increases in carbon price may not be fully transferred to their customers. As a result, the profitability of these companies are projected to deteriorate, resulting in a more conspicuous increase in credit cost.

Similarly, the banks assess that it will not be easy for companies in the transportation industry to adjust their operating models and levels of energy consumption at the initial

stage of a disorderly transition. Thus, these companies will be particularly vulnerable when carbon price increases.

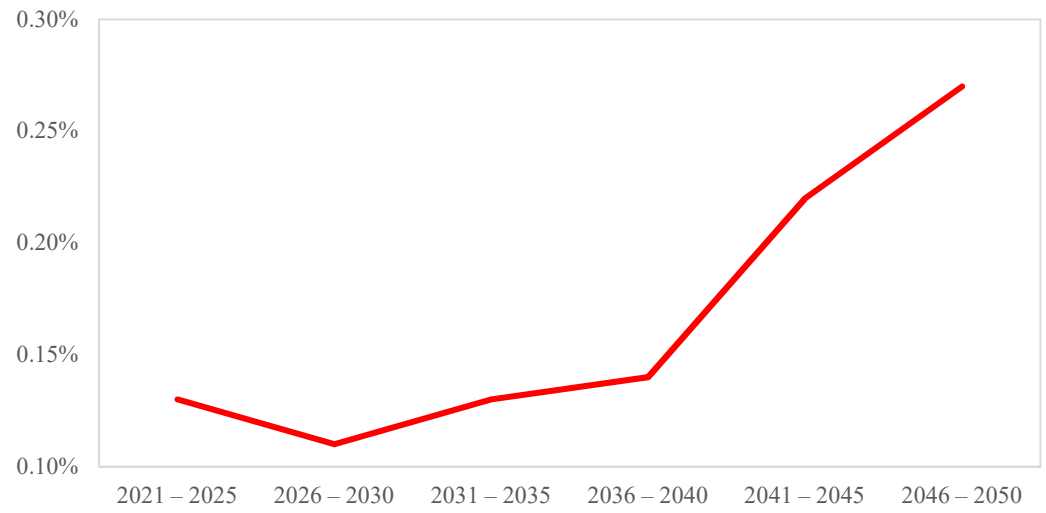
For the utility industry, the assessment results vary substantially across the participating banks, as the industry comprises different types of companies with distinct nature, such as water supply, waste and sewage treatment and electricity generation. These companies will be subject to different levels of shocks depending on the climate policies of the local authorities with respect to, for instance, the pricing of their services and types of energy used in their core business operations.

The transition risk impact on the energy industry under the disorderly transition scenario is projected to be milder as compared to that on other high-emitting industries. The banks assess that the demand for oil and gas, for instance, will not decrease substantially at the initial stage of the transition given the limited supply of the renewable energy and the inability of the downstream industries to change their business models in the short run. Thus, energy companies will be less affected at the beginning of the transition. Nevertheless, some of the banks assess that these companies will eventually suffer due to changes in global energy mix at the later stage of the transition.

Results under the orderly transition scenario and comparison with that under the disorderly transition scenario

Under the orderly transition scenario, the annualised credit cost of lending to the high-emitting industries will move higher steadily throughout the 30-year horizon, as shown in Chart 12. Specifically, the annualised credit cost is projected to increase from 0.1% at the beginning of the transition (2021 to 2025) to 0.3% at the end of the assessment horizon (2046 to 2050), which is comparable to the projected annualised credit cost under the disorderly scenario (0.3% during 2031 to 2035). This is because, similar to the assessment under the disorderly transition scenario, the banks assume that many high-emitting corporates will not take mitigating actions against transition risk over the 30-year assessment horizon. As a result, an increase in carbon price, together with changes in energy mix, will cause the credit cost of lending to the high-emitting industries to rise under the orderly transition scenario to a level similar to that under the disorderly transition scenario but at a steadier pace.

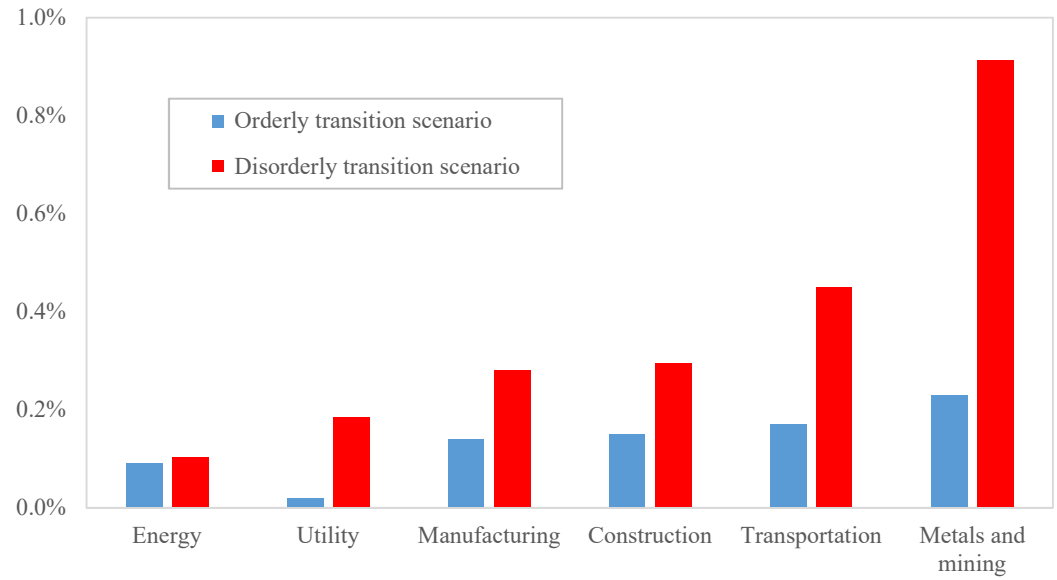
Chart 12: Annualised credit cost of lending to the high-emitting industries under the orderly transition scenario



Source: HKMA

Chart 13 compares the projected annualised credit costs of D-SIBs' lending to each of the high-emitting industries during the same period (2031 to 2035) under the two transition scenarios. It shows that the projected impact under the disorderly transition scenario will be much more significant than that under the orderly transition scenario, as the period concerned (i.e. 2031 to 2035) is still within the first half amid the 30-year assessment horizon and the transition risk impact will remain moderate at this stage.

Chart 13: Comparison of the projected annualised credit cost of lending to the high-emitting industries under the two transition scenarios during 2031 to 2035



Source: HKMA

2.2.4 Limitations of the transition risk assessment

Most of the participating banks' analyses have mainly focused on the direct impact of transition risk on their exposures to the seven prescribed industries. The second-order impact, such as the spill-over effect from the high-emitting industries to other sectors along the value chains, has not been fully evaluated in some of their analyses. This second-order impact can be material, as an increase in the production costs in the upstream industries can be partially, if not entirely, transferred to the downstream industries. There can also be feedback effect on the high-emitting industries, which again is not sufficiently captured in most of the banks' assessment.

In addition to the above sector-level second-order impact manifested through the inter-sectoral connections, the overall economic performance will also be affected during the transition. For example, deteriorated financials of companies affected by the transition may lead to retrenchment and hence a higher unemployment rate, affecting household income, private consumption and gross domestic product (GDP) growth. Although some high-level assumptions about the overall economic performance (e.g. GDP levels) have been provided under both the disorderly and orderly transition scenarios, some of the banks have not reflected these assumptions in their assessment adequately. The transition risk impact could have been more serious than that discussed above if these assumptions were fully taken into account in the banks' assessment.

As mentioned earlier, some of the banks have used the results of their counterparty-level assessment of the major high-emitting corporates to extrapolate the transition risk impact at the sector level. The projected transition risk impact on exposures which are not subject to the counterparty-level assessment, especially those to the small and medium-sized corporates, can be highly sensitive to the assumptions adopted for the extrapolation. The idiosyncratic nature of these exposures may have been missed under this approach, especially if the counterparty-level assessment only covers large corporates with strong financial positions.

2.3 Overall assessment

The assessment results indicate that, under the extreme scenarios assumed in the exercise, climate risks can potentially give rise to significant adverse impacts on the banks' profitability, capital positions and operations. ECLs of the banks' exposures directly affected by climate change, such as residential mortgages and lending to the high-emitting industries, are projected to increase sharply under the CRST scenarios, leading to a material reduction in the banks' profitability. The banks' capital positions will also deteriorate. The CARs of the D-SIBs, for instance, will on average drop by 3 percentage points over the 5-year horizon under the disorderly transition scenario. Some parts of the banks' operations will also be disrupted by the more intense climate hazards under the physical risk scenario. Notwithstanding the significant potential impacts of climate change, the Hong Kong banking sector should remain resilient to climate-related shocks given the strong capital buffers built up by the banks over the years.

3. Capability building of banks

All the participating banks have strengthened their capabilities for measuring and assessing climate risks through the efforts they spent on the exercise. Starting from data collection and risk identification, to risk assessment using newly developed methodologies and result reporting to senior management, the full cycle of the exercise has allowed the banks to raise the firm-wide awareness of climate risks and build up their capabilities for each of these steps. A discussion forum organised by the HKMA has also facilitated the banks' capability building by providing a knowledge-sharing platform for the banks to learn good practices from each other. However, some major gaps identified in the exercise, especially those concerning data availability and assessment methodologies, remain, owing to limitations such as the lack of widely accepted standards for risk identification and insufficient modelling expertise for this new subject.

3.1 Enhanced capabilities and risk awareness

The participating banks, particularly those at the early stage of establishing their climate risk management framework, have enhanced their awareness of climate risks and cultivated the knowledge in climate risk measurement through the risk identification and assessment processes.

Awareness of climate risks

Cross-functional collaboration within the participating banks and involvement of their senior management in the CRST are important to the successful completion of this pilot exercise. Business units reaching out to customers to understand their readiness for climate change, inter-functional discussions in the risk identification and model development processes, and industry specialists and modelling experts exchanging views on assessing the impact of climate risks have all been observed throughout the exercise. These joint efforts have contributed to the increased awareness among the relevant functions of the need to take climate risks into account when performing their roles. As required by the HKMA, the CRST results have been reported to the banks' senior management, thereby raising the institutions' firm-wide awareness of climate risks.

The HKMA has played a facilitating role during this process. The pilot CRST team within the HKMA has helped the banks better understand the supervisory expectations and reinforced the importance of managing climate risks through regular dialogues with the participating banks.

Capabilities in climate risk measurement

During the course of the CRST, the participating banks endeavoured to enhance their capabilities in measuring climate risks as they went through the risk identification and assessment processes. In particular, the exercise has prompted the participating banks to collect new data, understand the transmission channels of climate change and explore new analytic solutions and methodologies for assessing climate risks. In addition to internal development and research, many participating banks have acquired the relevant

skillsets and knowledge by engaging external consultants and data vendors with expertise in this subject.

Some of the participating banks benefit more by making extra efforts to conduct more granular and in-depth analyses beyond the HKMA's requirements. Examples include performing detailed counterparty-level assessment under the transition risk scenarios and analysing the impact of climate-related shocks over a horizon longer than required in order to obtain better insights into the trend and dynamics of the potential impact. Most of the participating banks have developed a dedicated framework for the CRST and established a specialised task force to coordinate work on the topic, with a view to making continuous improvements to the processes and capabilities.

3.2 Major challenges ahead

Although the participating banks have substantially strengthened their capabilities for measuring and assessing climate risks, major gaps, especially those concerning data availability and assessment methodologies, remain. The HKMA envisages that closing some of these gaps will require the concerted efforts of the industry.

The participating banks highlight that the inadequacy of granular and reliable data is the biggest challenge for modelling and assessing climate risks. For example, the banks' database may not keep the detailed information on the key attributes of property collateral for the physical risk assessment, such as the precise location of the properties and historical damage records. Similarly, customers' carbon footprints and transition plans may not be readily available for the transition risk assessment. The banks may need to put in considerable efforts to obtain such information from the public domain or directly from their customers. Many participating banks have turned to data vendors for solutions. However, the banks may not be able to understand how the vendors compile the data and ascertain the quality of the data acquired.

The data challenge is exacerbated by the lack of widely accepted standards for classifying and identifying climate risk exposures. Without these standards, the banks can only rely on internal classification system which may vary substantially across the industry and give rise to biases in the assessment. In many cases, judgemental assumptions have to be made in determining the vulnerable exposures. The aggregation and comparison of the assessment results across different institutions can, as a result, be problematic.

The uncertain timing of materialisation of climate risks and the lack of historical events have also made development and validation of models for assessing climate risks more challenging. As it is widely recognised that the impacts of climate risks manifest over a very long horizon, most of the banks' models developed for conventional stress testing are not fit for the CRST and they have to develop new models for the pilot exercise. Even for those banks which have in place models for long-term projections, most of these models are highly sensitive to the assumptions made, such as changes in climate patterns, policies of authorities, technology advancements and customers' business decisions. This can result in large variations in the model outputs and undermine the reliability of the banks' assessment. The lack of well-accepted, proven methodologies for capturing the unprecedented climate change scenarios poses key challenges in validating the model outputs as well. As explained in Annex B, the

participating banks have to attempt different approaches to testing their model outputs in order to assess model risks associated with the CRST results.

All the participating banks have devoted substantial resources to the pilot exercise. A major portion of these resources have been spent on overcoming the challenges regarding the data availability and modelling issues mentioned above. Notwithstanding this, the banks will need to step up their resources in order to strengthen their CRST capability further with a view to obtaining a more comprehensive and robust assessment result. The need for growing talents for climate risk assessment, and setting aside adequate resources for collecting and processing unstructured data relating to climate risks, such as customers' transition plans, is particularly pressing.

The unique characteristics of the Hong Kong banking sector, with a high concentration of global institutions, pose additional complexities to the banks in tackling these challenges. Given the variations in home-host regulatory requirements and CRST specifications, the multiple locations of the banks' operations and differences in the business models in these locations, the banks need to put in extra efforts to develop solutions and models in assessing climate risks. For instance, while the parent banks of some participating institutions have developed generic models for assessing climate risks at the group level, some of these institutions have to introduce tailor-made adaptations to these models for the pilot exercise in order to capture the unique features of their local portfolios having regard to the scenarios assumed in the CRST.

4. Actions to address climate risks

Although the resilience of the banking sector against climate-related shocks is well supported by the banks' strong capital buffers, the impacts brought about by climate change can be long-lasting and grow in severity over time due to irreversible changes in climate patterns. The more frequent and rapid shifts in climate policies in response to climate change can also pose additional transition risks to the banking sector. As required by the CRST, the participating banks have provided information on their plans to mitigate climate risks and address the vulnerabilities revealed by the exercise.

In relation to climate strategies, most of the participating banks have devised plans to allocate more resources to climate resilient activities, such as green financing and providing transition finance to support their customers' transition to low-emission business models. Leveraging the information they collected from their customers for the pilot exercise, some of the banks have already started to establish mechanisms for assessing the climate risk exposures of customers.

All the participating banks understand that climate considerations should be incorporated into their risk governance frameworks. In response to the vulnerabilities revealed by the exercise, some banks have incorporated a broader range of climate risk factors into their risk assessment frameworks. The scope of climate elements considered in their risk appetite has also been widened. Some banks have also developed plans to enhance their measurement metrics for managing climate risks based on the knowledge acquired from the CRST.

Noting that some of the major gaps revealed by the pilot exercise have not been closed, the participating banks have undertaken to keep abreast of market developments and put in continuous efforts to enhance their capabilities on climate risk management.

5. Way forward

In view of the potential challenges facing banks in closing the gaps identified in the pilot exercise, the HKMA will continue to engage the industry to support banks' capability building. It will also enhance the CRST framework with a view to obtaining a more comprehensive and robust assessment of the banking sector's climate resilience.

The HKMA will reach out to the industry to share the lessons learnt from the pilot CRST, and follow up with individual banks on their progress in closing the gaps identified in the exercise. Guidance will be provided to the banks to ensure that they are in the right direction of strengthening their capabilities in meeting the supervisory expectations on the CRST. In addition, the HKMA will explore possible solutions to tackle the challenges identified in the exercise, especially those requiring concerted efforts of banks and conducive to improving the climate resilience of the whole industry.

As discussed earlier in this report, the pilot exercise has some major limitations, such as variations in the approaches adopted by the participating banks, and exclusion of certain exposures or risk factors in their assessment as a result of the flexibility extended to the banks. The HKMA will enhance the CRST framework by refining the scenario specifications and reporting requirements, with a view to developing a more comprehensive framework for future exercises. For instance, the scenario specifications may need to be more granular in order to have a better comparison of the results across banks. The requirements on the assessment scope and methodologies, as well as the reporting framework for the stress test results may also need to be further standardised to streamline the analysis and reconciliation of individual submissions. The HKMA will collect the industry's feedback on the potential enhancements to the CRST framework. The current intention is to undertake another CRST in two years' time.

To avoid duplicated efforts in meeting different jurisdictional regulatory requirements on CRST, the HKMA will actively explore opportunities to collaborate with overseas authorities to promote greater consistency in CRST practices.

Annex A – Use of technology to identify exposure locations

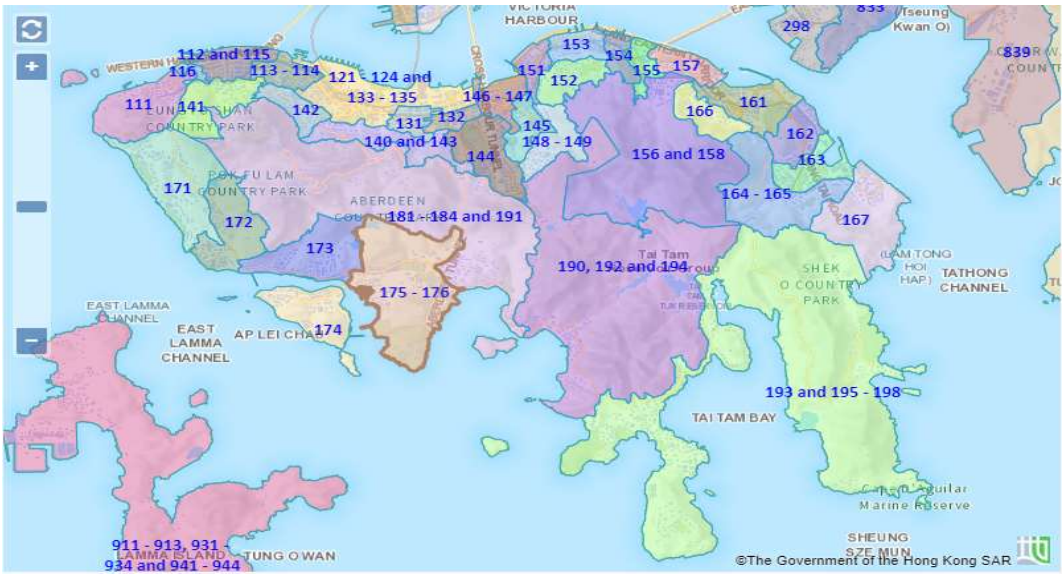
Physical risk assessment of property-related lending can be labour intensive given banks need to identify the locations of a large number of properties for the assessment. To overcome this challenge, some banks have applied technologies and utilised a database available in the public domain to automate the process of collecting the location information of properties. The automation has made the risk identification and assessment process more efficient without sacrificing much accuracy. The below description illustrates how these banks tackle the issue.

How to simplify the risk identification and assessment process?

To simplify the risk identification and assessment process for physical risk assessment, individual properties are grouped together based on their locations. In practice, the territory of Hong Kong is broken down into many small units, and properties within each of these units are assumed to be subject to a similar level of shocks of climate hazards. This assumption may not be perfect but it allows for a quicker derivation of the impact of climate hazards with reasonable accuracy. With this assumption, the remaining problem is how to map the property addresses to these units.

How to use technologies to automate the above process?

There are several approaches adopted by the banks in this respect. One way is to divide the territory of Hong Kong into small squares based on latitude and longitude coordinates (geolocation). Another way is to directly adopt the Tertiary Planning Units (TPUs) used by the Planning Department for town-planning purposes. The diagram below shows the TPU boundaries of Hong Kong Island.



Source: https://www.bycensus2016.gov.hk/en/bc-dp-tpu.html

Having chosen the division approach, the banks will map the property addresses to their corresponding geolocations so that the properties can be grouped into the relevant units. Among various data sources of property geolocations, DATA.GOV.HK is the public platform containing the geospatial data with open Application Programming Interface

(API), which enables the banks to use computer programmes to extract the geolocation data based on property addresses. If a bank adopts the TPU as the division approach, it can obtain both the TPU information and the geolocations of property addresses from DATA.GOV.HK, and use computer programmes to map property addresses to the TPU automatically based on the geolocation data.

Annex B – Practices for assessing model risk

As the use of statistical models for climate risk assessment is still nascent and bounded by various limitations, the participating banks' assessment results can be subject to material model risks. In light of this, some of the participating banks have adopted the following approaches to validating their model outputs in the absence of suitable benchmark models.

Result cross-checking

As historical data are limited, many banks have tried to validate their model outputs with external information or literature results. For example, in validating the property damage ratio in physical risk assessment, some banks have compared the ratio estimated by themselves with those published by credible organisations. These banks may further investigate the differences if there is significant deviation, and apply judgemental overlays to the ratio to be used in the physical risk assessment.

Internal model review

Some advanced banks have engaged their internal model review teams to oversee the model development process and assess the model risks. As many models used for climate risk assessments are novel without sufficient evidence to validate their robustness, the model review cannot be conducted as comprehensive as it should be under the process adopted in the banks' existing model validation framework. The review focus is normally placed on the fundamental setup and conceptual soundness of the models.

Model governance framework for vendor models

Some banks' model review teams have pointed out the potential risk of using third-party models or data as they do not know whether (and how) the data or model have been validated. In view of this, these banks have started to perform reviews on whether the validation frameworks adopted by the external vendors can meet their internal standards.

Sensitivity analysis

Sensitivity analysis is commonly used by some banks as part of their model validation process. In conducting the analysis, the banks will check the correlation between the risk drivers and model outputs to understand whether the model concerned exhibits any abnormal behaviour. For example, some banks have studied the relationship between the intensity of climate hazards and the devaluation of property collateral in physical risk assessment. A range of results are then generated to evaluate whether the sensitivity of the model is reasonable.

Annex C – List of participating banks

Bank of China (Hong Kong) Limited
Bank of Communications (Hong Kong) Limited
Bank of Communications Co., Ltd.
Bank of East Asia, Limited (The)
China CITIC Bank International Limited
China Construction Bank (Asia) Corporation Limited
China Construction Bank Corporation
Chiyu Banking Corporation Limited
Chong Hing Bank Limited
Citibank (Hong Kong) Limited
Citibank, N.A.
CMB Wing Lung Bank Limited
Credit Suisse AG
Dah Sing Bank, Limited
DBS Bank (Hong Kong) Limited
DBS Bank Ltd.
First Abu Dhabi Bank PJSC
Fubon Bank (Hong Kong) Limited
Hang Seng Bank, Limited
Hongkong and Shanghai Banking Corporation Limited (The)
Industrial and Commercial Bank of China (Asia) Limited
Industrial and Commercial Bank of China Limited
Nanyang Commercial Bank, Limited
OCBC Wing Hang Bank Limited
Public Bank (Hong Kong) Limited
Shanghai Commercial Bank Limited
Standard Chartered Bank (Hong Kong) Limited