Executive Summary

This consultancy project is composed of three main parts:
(1) Urban Heat Island in the Hong Kong Special Administrative Region,
(2) Hong Kong's global warming indicators
(3) Impacts of Global warming in Hong Kong - estimation and adaptation.

Urban Heat Island

The urban heat island effect in Hong Kong was successfully measured using land based mobile experiment. Four temperature sensors, two global position system receivers (GPS) and two motor vehicles were deployed. One thermocouple, one thermister and one GPS were mounted on the roof of each vehicle. Temperature sensors were housed inside a white box similar to the Stevenson screen to reduce wind chill and solar radiation effects. Temperature measurements was accurate to 0.1 ^{o}C whereas latitude and longitude were accurate up to 10 m. One vehicle scanned the northern part of Hong Kong Island and the other vehicle scanned the Kowloon Peninsular. Altogether six field trips were carried out, two trips in summer, two trips in fall and two trips in winter. Three trips were carried out in weekdays and three trips were carried out in weekends.

The UHI values were defined by the difference between the air temperature measured and the air temperature at the Cheung Chau Station. The UHI value was about 2.17^{o}C in Hong Kong. The largest UHI occurred in the mixed commercial urban areas of Causeway Bay, Yau Ma Tei and Mongkok. The average UHI values were 2.12^{o}C in summer, 3.04^{o}C in autumn and 1.35^{o}C in winter.

In summer, the average UHI values were between 1.01^{o}C and 4.12^{o}C in weekdays and between 0.89^{o}C and 4.15^{o}C in weekends. In autumn, the average UHI values were between 3.05^{o}C and 3.28^{o}C in weekdays and between 2.30^{o}C and 3.49^{o}C in weekends. In winter, the average UHI values were between 0.26^{o}C and 2.75^{o}C in weekdays and between 0.82^{o}C and 1.94^{o}C in weekends. The values of UHI in summer and fall were higher than those in winter. The maximum UHI values in summer occurred in the morning while those in winter occurred at night. From the perspective of UHI, there was no difference among the commercial, residential and industrial districts.

Hong Kong Global Warming Indicators

An analysis of the long term climate data was carried out by the Hong Kong Observatory (HKO). According to the long term observation of the HKO, a secular temperature rise was observed in both the rural and urban areas of Hong Kong. The sea level measured in the North Point and Quarry Bay indicated there was a rise in sea level in the Victoria Harbour. It appeared that long term weather records in Hong Kong supported the existence of global warming. The visibility had decreased and there were less evaporation but more clouds. As a result, the mean global solar radiation decreased. There were more heavy rain episodes and more thunderstorms but the frequency of tropical cyclone decreased. The long term trends are summarized in Table 1.

Meteorological Characters	Change due to climate (in the past)
Rural Temperature	Increased 0.2^{o}C/decade
Urban Temperature	Increased 0.6^{o}C/decade
Daily Diurnal Range	Decreased 0.28^{o}C/decade
Percentage of Time of Reduced Visibility	Increased 1.9%/decade
Cloud Amount	Increased 1.8%/decade
Global Solar Radiation	Decreased 1 MJ/m^2 per decade
Evaporation	Decreased 184 mm/decade
Frequency of Heavy Rain	Increased 0.4 days/decade
Frequency of Thunderstorms	Increased 1.7 days/decade
Number of Tropical Cyclones	Decreased 0.17/decade
Sea Level Rise	Increased 2.3mm/year

Table 1 Summary of Climate Change in the HKSAR

Characterization of the Impact of Global Warming

Energy Industries

The consultants believe that the major impact of global warming in Hong Kong is on the energy sector. An original methodology was devised by the consultants to estimate the impact of global warming on energy usage in Hong Kong. It is a bottom up method. It is based on the present data and is not a prediction. It does not account for population rise, future change in hardware (e.g new refrigeration principle, introduction of renewable energy), habit or culture. The methodology looks for dependence between energy consumption E and the ambient temperature T. If the two variables are correlated, the energy consumption can be expressed as a function of temperature E(T). The yearly average or the aggregated data cannot yield the empirical relationship. The monthly or daily data have to be available. When the ambient temperature T of a certain month is known, E(T) is also known. E(T+1) can be computed using the empirical function. Then $\Delta E = E(T+1) - E(T)$. By summing up ΔE for all twelve months in a year, the impact on energy usage for an increase in the ambient temperature by 1^{o}C is obtained.

The analysis concluded that raising the ambient temperature by 1^{o}C would increase the electricity consumption by 9.02%, 3.13%, and 2.64% in the domestic, commercial and industrial sectors respectively. However, the gas consumption would decrease when the ambient temperature increased. For 1^{o}C temperature rise, the gas demand would be reduced by 2.39% in the domestic sector. The gas consumption rates in the commercial and industrial sectors and the consumption of oil products did not depend on the ambient temperature. Therefore they were not directly affected by climate change.

For 1^{o}C temperature rise, the economic impact on the total electricity consumption was HK$1.72 billion (using year 2002 as reference). For 2ºC rise, the estimated impact was HK$3.26 billion. For 3ºC rise, the estimated impact was HK$5.50 billion. At the same time, for 1^{o}C temperature rise, the impact on gas consumption in the domestic sector was -HK$0.074 billion. For 2ºC rise, the estimated impact was -HK$0.149 billion. For 3ºC rise, the estimated impact was -HK$0.222 billion. The consumption of oil products was

not affected by climate change. Summing up, for 1°C temperature rise, the total energy costs of Hong Kong would increase by HK$1.65 billion.

To improve the credibility of the work above, the analysis was repeated using air cooled and water cooled air conditioning units. Electric bills were collected from six government buildings. Three buildings used air cooled a/c units and three used water cooled ones. For 1°C temperature rise, the electricity consumption in government buildings with air cooled and water cooled a/c units would increase by 2.86% and 4.61% respectively. These figures were very close to the 3.13% increase computed from the commercial electricity consumption. The results showed that the electricity consumption per kW cooling capacity of the water cooled a/c systems in buildings was 50% less than that of air cooled systems. (Remark: the energy consumption of water cooled system was 50% less than that of air cooled system. The water cooled system was 50% more energy efficient than the air cooled system. Please see which way you would like to put in the above sentence.)

Dengue Fever and Malaria

The impact of global warming on dengue fever and malaria are characterized by the epidemic potential EP of these diseases. EP is used as a comparative index in estimating the effect on the risk of vector diseases. EP is a function of *a*, *p* and *n* where *a* is the biting frequency of taking meals on human blood, *p* denotes the survival probability of the mosquito and *n* represents the incubation period of the parasite in the vector. Since all three parameters are temperature dependant, the consultants applied the same methodology devised and used in the energy section. The impact of temperature rise on the transmission of dengue fever and malaria was successfully quantified in Hong Kong. Once again, population growth, human intervention, and other non-climate dependent parameters were ignored.

The ΔEP of dengue fever was estimated to be 1.24%, 2.62% and 4.12% for 1°C, 2°C and 3°C temperature rise respectively in Hong Kong. The results showed that the risk of dengue would increase due to global temperature rise but the impact was not significant. The increase was only in a few percentages. The ΔEP of malaria was estimated to be 6.7%, 13.0% and 18.7% for 1°C, 2°C and 3°C temperature rise respectively in Hong Kong. The risk of malaria would also increase with temperature. The impact on malaria was more significant than that on dengue fever. The maximum impact on dengue fever was in summer months while that on malaria was in spring and fall.

Mortality Rate

The mortality rate in Hong Kong had a correlation with the ambient temperature. There was a strong seasonal pattern in the mortality series with more deaths occurring in the winter months each year. Regression analysis is carried out. The correlation between relative humidity and mortality rate was not significant, whereas the correlation between temperature and mortality rate was significant. It appeared that the mortality rate would increase in both extremely cold and extremely hot days. Increase in 1°C in hot days was associated with 6.82 increase in deaths (95% CI -0.38 to 14.02) while increase in 1°C in cold days was associated with 0.61 decrease in deaths (95% CI -0.2 to 0.82).

Heat Stroke

The number of reported heat stroke in Hong Kong is too small and there is no clinical detail. It is impossible to carry out further analysis.

Air Pollution

The impact of global warming on the air quality in Hong Kong is still largely unknown. In the United States, there are publications reporting an increase in surface ozone due to temperature rise. The ozone exceedance in the air monitoring stations in Hong Kong was studied. The percentage of ozone exceedance in Tung Chung was four times of that in Tap Mum and more than ten times of that in the other stations. It was discovered that the ozone concentration in Tung Chung had correlations with temperature, wind speed and solar radiation. When the ambient temperature increased by $1^{o}C$, the ozone concentration increased by about $4.6\mu g/m^{3,}$ which was just 2% of the ozone standard of $240\mu g/m^{3}$. Thus the amount of ozone augmented during the episode days due to climate change was insignificant. The more important point is whether the frequency of episode days will increase due to climate change. Since temperature is correlated with ozone concentration in photochemical smog, it is likely that photochemical smog will occur more frequently in the future when temperature rises.

Others

Other topics that have been explored include agriculture, water resources, flooding, migratory birds, hill fire, coral reef, mangrove, dolphins, eco-tourisms and sea-level rise. This project is only able to give an account of the existing adaptation measures and report the potential ones. Exploratory works were limited to elementary statistics compilation and regression analysis.

Agriculture has been phasing out in Hong Kong. In 2003, the gross value of agricultural production was HK$1,052 million (< 0.1% of GDP). Local production accounted for 5 percent of fresh vegetables, 23 percent of live poultry and 32 percent of live pigs for local consumption. The impact of global warming on local agriculture was considered insignificant.

The water supply in Hong Kong should not experience any direct impact of global warming. In Hong Kong, the average annual rainfall is about 2,214 millimeters. This amount is insufficient to meet the annual water demand, which was 946 million cubic metres (mcm) in 2002. 80% of the water supply of Hong Kong comes from Guangdong and the rest is supplied by local reservoirs. There are 17 local reservoirs with a total storage capacity of 586 million cubic meters. They are mainly used for backup, conservation and recreational purposes.

Flooding is a concern in Hong Kong. During rainstorms, the rural low-lying areas, the natural flood-plains in the northern part of the territory and some locations in the older urban areas suffer serious flooding. Not much impact study can be carried out because Hong Kong does not have a good flooding database. The present analysis by the consultants are based upon some surrogates. They include the number of rainstorm

warnings, the number of flooding announcements and the number of flooding complaints. The HKSAR has already introduced mitigation measures to alleviate flooding problems in the future. It is anticipated that Hong Kong will be able to adapt to climate changes that increase the risk of flooding.

Migratory birds are likely to be affected by global warming. Hong Kong is an urbanized city. Highways and concrete roads prohibit the retreat of mangroves inland. Mangroves may be able to adapt or they will shrink in population due to sea level rise. The impact of global climate change on Hong Kong's migratory birds is still uncertain. Owing to the urbanization of Shenzhen and the Pearl River Delta, more and more migratory birds stop at Mai Po. Both the food supply and the living space are under stress due to such an increase in immigration.

Hill fire is quite a common phenomenon in Hong Kong. Regression analysis was carried out to study the correlation between temperature, relative humidity and the number of hill fires. No significant correlation was identified. The consultants tried to quantify the economic lost of hill fire but were unsuccessful. A direct way to estimate the economic loss due to hill fire is to multiply the total number of trees burnt by the replanting cost of each tree, but no data is available on the burnt area of each fire. A trial was undertaken to estimate the economic loss by an indirect approach. We multiplied the number of trees planted each year with the replanting cost of trees in restoration programs and treated it as the loss due to hill fires. We found out that the planting cost of trees has been coming down in recent years and the number of trees planted has been increasing since 1997, whereas the number of hill fires did not have such a trend. It is obvious that the increasing number of trees planted per year is due to human intervention and is market driven. The number of tree planted in one year does not represent the number of trees burnt in that year or the year before. This method can only be applied to estimate the cost of hill fires for a much longer period such as one decade.

Hong Kong has corals. There are 2 km^2 of reef areas and there is no true reef structure in the Hong Kong waters. About 84 species of reef-building corals have been identified as coming from 28 genera of 12 families, with about 10 species of non-reef-building corals coming from 4 genera. The impact of global warming on corals is still largely unknown. It is difficult to find publications discussing the impact of global climate change on corals. We only know that corals are vulnerable to extreme conditions. In Hong Kong, the maximum monthly temperature of sea water recorded at Waglan Island was 27.7^oC in summer and 14^oC in winter. Judging from the large difference in sea water temperature between summer and winter in Hong Kong, it is believed that coral species are capable of tolerating different sea water temperature as long as the temperature change is gradual. The key parameter that governs the health of corals should be the fluctuation of the sea water temperature. The lethal temperature limit is about 2^oC higher than the mean sea surface temperature. A sudden change of temperature, such as an elevation of temperature to 3 to 4^oC above the normal summer ambient maxima in only a few days or an elevation of temperature to only 1 to 2^oC above the summer ambient temperature in several weeks, can cause coral bleach.

The most important and the largest coastal wetland in Hong Kong is the Mai Po RAMSAR Site. It has an area of 15 km^2. It is the sixth largest coastal wetland in China. In Hong Kong, there are 8 true mangroves species in 44 clusters covering an area of about 2.9 km^2. Concerning the impact of global climate change, the main threat to the Mai Po comes from sea level rise. Hong Kong is an urbanized area. Artificial barriers such as concrete roads and anti-wave structures restrict the migration of mangroves. Bulkheads, dikes, and other structures keep new wetlands from forming inland. Even in case of no restriction, both the irregular coastline and the topography of Hong Kong tend to compress mangrove stand. If adaptation measures are not taken, there is a possibility that mangroves in Hong Kong may be inundated by sea water in the future and may suffer a reduction in the number of species owing to sea level rise.

There are Chinese white dolphins (also known as Indo-pacific humpback dolphin) and finless porpoises in the Hong Kong waters. The population of Chinese white dolphins in the Pearl River estuary is estimated to be over 1000 individuals. Population of finless porpoises is estimated to be 217 in the Hong Kong waters. Climate change may alter the sighting seasons for dolphins and their regional abundance, but it may not pose a direct threat to their lives. This is because they may migrate to other water areas when the water temperature changes.

Tourism is one of the major economic sectors in Hong Kong. The consultants were unable to estimate the impact of global warming on tourism. Focus was put on the more directly related eco-tourism. The eco-tourism values of migratory bird watching, dolphin watching, and hiking were estimated to be HK$72 to 720 million, HK$1 million, and HK$118 to 1180 million respectively in 2002. The impacts of global warming on them are considered minor. Wetland, mangrove, corals are anticipated to experience negative impacts due to global warming.