THE IMPACTS OF CLIMATE CHANGE ON HONG KONG AND THE PEARL RIVER DELTA

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Abstract

Climate change is expected to have a number of direct impacts on the Greater Pearl River Delta ("Greater PRD") area. Mean sea level is rising at around 1 cm per year. Temperatures are predicted to rise by 3.5 degrees on average by the end of the century. Rainfall is predicted to become more erratic, meaning that there will be more years of either heavy rainfall and flooding, or low rainfall and water shortages. Tropical storms may become more intense, although the scientific evidence for this is not conclusive.

The likely impacts of these climatic changes will be on the ecology, human health, transport infrastructure, coastal defences, supply of power and water, and drainage services of the Greater PRD. The real estate, supply chain, transportation/logistics and financial services sectors will all be affected by damage to this infrastructure and experience increases in operating costs. Climate change threatens the continued economic growth of the region, and by multiplier effects, the wider Chinese economy.

Even if a concerted world-wide commitment to reduction of greenhouse gas emissions were made, we are already committed to some level of climate change. These risks have been inadequately considered by governments and businesses in the Greater PRD, if at all. It is proposed that more region-specific research on climate change impacts be done, and that an adaptation strategy addressing key policy areas including urban planning, water resource management, flood management systems and coastal and river defence be developed and accurate monitoring networks be established to gather data on the pace and extent of climate change in the Greater PRD.

At the same time, policies focused on achieving rapid and widespread emission reductions in the Greater PRD must be developed. Energy efficiency improvement is one of the cheapest and quickest options for achieving this goal, and should be made a priority for businesses and governments in the region.

Keywords
Hong Kong, Pearl River Delta, Climate Change Impacts

1. Introduction

This paper provides a broad-brush view of how climate change is likely to affect the Greater Pearl River Delta ("Greater PRD") region (Hong Kong, Macao and the Pearl River Delta ("PRD")). It focuses on impacts on the physical infrastructure of the region, and the attendant economic impacts. The key recommendations are that more region-specific research be done so that appropriate adaptation measures can be planned and implemented; that an adaptation strategy be developed; and that energy efficiency measures be pursued aggressively throughout the region as the cheapest and most effective mitigation measure (although comprehensive mitigation will in fact require multiple actions).

2. Effects of climate change in the region

2.1 Changes in sea level, temperatures, and precipitation in the Greater PRD region

Current and predicted effects on the Greater PRD largely reflect global trends. The Hong Kong Observatory predicts that Hong Kong's annual mean temperature will rise by 3.5°C by the end of this century; and that although average annual rainfall will likely increase only slightly, year-to-year variability will increase, meaning more years with either heavier than usual or less than usual rainfall [LEUNG et al, 2006].

There is not enough evidence at present to say with certainty whether tropical storms and typhoons will increase in frequency as a result of global warming [CHAN 2006]. The first National Assessment Report on Climate Change in China, released in December 2006, forecasts that extreme weather events and natural disasters will occur more frequently; however, the Hong Kong Observatory has stated that there is not yet a definitive answer as to whether tropical cyclone activity has increased or will increase due to global warming. In fact, the annual number of tropical cyclones landing over the south China coast within 300 km of Hong Kong has been decreasing, from about 3 in the 1960s to 2.5 in the 1990s [LEUNG et al, 2006].

Rising sea levels are a matter of great concern particularly for the PRD, where both the physical geography (the Southern part of the delta lies between -0.3m to 0.4m relative to mean sea level) and the urban development of the region render it extremely vulnerable. The rate and amount of sea level rise is the subject of some dispute in the scientific literature.

Research has found that the sea level along the coast of Guangdong Province is rising by 1cm per year, and some scientists predict that it will rise 30 cm by 2030 [HUANG et al, 2004]. However, China's National Assessment Report predicts a much more conservative rise of 1 to 6 cm by 2030. NASA's Goddard Institute has warned that the Greenland and West Antarctic Ice Sheets are showing signs of thinning; and that a global temperature rise of 2-5°C might destabilize Greenland irreversibly and raise sea level by 5-7 m (though any significant meltdown would take many centuries) [GORNITZ 2007]. In either case, the risk of flooding will increase as sea level rise heightens the effect of storm surge (which occurs when high winds pushing on the ocean and low pressure at the centre of the storm cause water to pile up higher than the ordinary sea level). Existing coastal and river defences in the Greater PRD will be inadequate if storm surges increase in height and major flooding incidents occur more frequently.

2.2 Effects on ecology and human health

Rising temperatures are likely to have a negative impact on the health of people living in the region by increasing cardio-respiratory illness and mortality, heightening the risk of mosquito-borne diseases such as malaria and dengue fever, and compounding the already high levels of air pollution by accelerating photochemical reaction rates among chemical pollutants in the atmosphere [WATSON et al 2000].

The ecology of the region, already damaged by rapid industrialisation, will suffer further. Delicate wetland ecosystems such as the World Heritage-listed Mai Po marshes will be invaded by seawater, and if hemmed in by concrete their natural adaptive capacity will be eliminated.

2.3 Impacts on infrastructure

Extreme weather events can cause extensive damage to infrastructure and other productive capacity. Cities and infrastructure are built to accepted risk limits based on the expected return frequency of severe winds, heavy rainfall events, storm surges and so on. Above these thresholds, damage can accelerate in a non–linear way [ALLEN CONSULTING GROUP, 2005]. The Greater PRD is already a highly developed area, with high and increasing concentrations of assets and populations in hazard prone regions. There are substantial urban development projects under way in Guangzhou, Shenzhen, Dongguan and Foshan, among others, and Macao is seeing major investments in infrastructure and leisure facilities [ENRIGHT et al 2005]. The extent of potential damage to infrastructure and buildings in the Greater PRD due to climate-related events may therefore be significant and is likely to result in substantial financial losses. Key infrastructure at risk includes roads and railways, sea and river ports, airports, coastal defences, water supply and drainage systems, and power supply infrastructure.

Floods may damage building structures and cause soil erosion, which can lead to softening of building foundations. Resulting sedimentation can impact water management systems, damage buried pipes and semi-buried tanks and harm dam structures and pump equipment. Conversely, in dry periods, as soil moisture decreases, subsidence may affect underground pipes and cables. Windstorms bring additional loads to bear on buildings, affecting both structural and non-structural elements, but only minimally affecting foundations and underground elements [FREEMAN et al, 2001, ENTEK UK et al, 2002].

Enormous investment is planned to develop an extended network of highways throughout the Greater PRD, some of which will involve major bridge construction projects [ETWB 2006]. Any infrastructure of this type will be exposed to pressures brought about by climate change. A general increase in temperature could have negative effects on elements of transportation infrastructure, which would cause disruption and require increased spending on repair and maintenance. Studies in England have shown that roads could also be affected by higher temperatures in a number of ways, including rutting of the road surface, embankment subsidence, deterioration of concrete, problems with expansion joints, increase in dust levels and reduction in skid resistance [LONDON CLIMATE CHANGE PARTNERSHIP, 2005]. Very dry weather and higher temperatures can also damage highways and railways through foundation shrinkage, buckled rails and distortion of soldered rails [FREEMAN et al 2001]. Further research is needed to determine whether the increase in average temperatures projected for the Greater PRD will have similar effects on the soils and construction materials used here.

Storms and flooding can disrupt rail transport and temporarily close stations, as well as causing damage to infrastructure and to construction works on bridges and road developments. The underground train systems in Hong Kong, Guangzhou and Shenzhen, which are being rapidly built out at present, could be vulnerable to flooding, as well as to possible effects on tunnel structures caused by changes in groundwater such as greater hydraulic pressure on the tunnel walls [TITUS 2002]. Heavy rain can also cause electrical problems for rail systems: for example, in September 2006, rail services in Hong Kong were disrupted by wiring problems after heavy rain [PARWANI 2006].

In addition to damaging transportation infrastructure itself, severe weather events could also disrupt the distribution of transportation fuels, which might prevent some rail and road vehicles from operating.

The region's sea and river ports play a vital role in the region's economy. Several container ports have recently been developed in Shenzhen. Sea level rise and associated increase in storm surge would

increase the probability of inundation of wharfs and breakwaters, reducing the wharfs' working platforms. Heightened wave action would also accelerate the scouring effect of the tide on hydraulic equipment, which could shorten its service life [YANG et al 1996]. The upper delta and western delta areas have serious silting problems that limit the operations of their ports, and for many years Hong Kong possessed the only deep-water, modern container facilities in the region. Changes in sea level are likely to alter the balance of coast and beach erosion and sedimentation around harbours and their access channels [YANG et al 1996]. This could pose significant operating challenges for ports in the region and is likely to increase their operating costs for additional dredging. It is possible that other factors, such as higher water temperature and increased salinity, could also affect port infrastructure.

In the longer term, the most fundamental variable for port operators will be the defensive infrastructure strategy to be pursued in the Greater PRD. In a scenario where the government decides to build an extensive dyke system to protect the region, the question will be whether to follow the coast as it is today, or to follow the Dutch approach of shortening the coast (i.e. building a large dyke across the mouth of a bay or estuary). In the latter case, some of the existing ports could then be inside the dyke. Either ships would have to pass through locks or new deepwater ports would be built outside the dyke, which would take business away from the incumbents [TITUS 2002].

There are five airports in the Greater PRD, including Hong Kong and Macao. Although Chek Lap Kok airport is currently at 6m above sea level, the sea level rise predicted for the region and associated storm surge effects could increase its vulnerability. Storms and flooding could seriously disrupt air transport and cause airports in the region to be closed for longer periods than is the case today. Interruptions to passenger transport, in particular, put enormous strain on airport facilities and create significant management problems for airport operators, as large numbers of passengers are stranded at the airport.

Incremental damage could be caused if typhoons increase in intensity, including damage to parked aircraft, hangars or terminal buildings. As is the case for roads throughout the region, higher temperatures could also affect runways and airport roads, for example through deterioration of concrete, rutting or subsidence. Airports in the Greater PRD may also be affected by damage to other transportation networks that affects delivery of aeroplane fuel or cargos, thus slowing aeroplane turnaround time, or otherwise impacting the operations of the facility.

Flood control and management of large rivers, as well as construction and maintenance of coastal defences, are of vital importance to China's continuing economic development. Large-scale defensive structures, such as dykes and seawalls, as well as flood storage reservoirs and pumping stations in some urban areas, are in place throughout the Greater PRD in an effort to protect low-lying areas. Flood control on the Pearl River relies mainly on levees and reservoirs Levees along the main stream and the delta area are designed to withstand a ten- to twenty-year flood. Most infrastructure was originally planned in the 1950s, and was designed in accordance with the climate related estimates at that time. Only the most important dykes have been designed according to a fifty- to one hundred-year flood and tide standard [ZHANG et al 2001]. A 2003 study by the Guangdong Academy of Sciences warned that the present network of dykes and anti-flood measures may be inadequate to cope with rising mean sea level and associated higher storm surges In the opinion of Zhenguo Huang of the Academy, the enormous investment required for the construction of dykes and anti-flood works would be small in comparison with the huge losses caused by a disastrous flood [HUANG et al 2004]..

Water resources in the Greater PRD are already under pressure due to increases in demand caused by population growth and industrialisation. Development of water and sewerage systems is not always adequate to meet these demands in certain areas, while unregulated exploitation of groundwater exacerbates problems of water quality and land subsidence. Climate change is likely to increase the stress on rivers already under pressure from salinity, over-allocation and declining water quality. Reduced rainfall would mean that less water is available for human consumption. Reduced water supply can also affect water quality in rivers, while drought conditions can increase erosion, leading to higher sediment loads entering rivers following rainfall events [AUSTRALIAN GREENHOUSE OFFICE 2006]. It is likely that water treatment facilities throughout the Greater PRD would need extensive expansion and upgrading to cope with lower raw water quality. The China National Assessment Report predicted that a warmer climate will reduce the water flow in Southern rivers and increase the frequency of drought.

A rising sea will cause a large amount of tidal water to travel upstream in the delta. According to the China Climate Change Country Study's preliminary results in 1994 and investigations by the Chinese Academy of Sciences, the tidal boundary will move, bringing salt water further upstream: perhaps as far as 3 km further if there is a sea level rise of 40 cm to 60 cm in the Greater PRD region. Saltwater will intrude even to Guangzhou in a low-water period, affecting the residents' drinking water supply [YANG et al 1996].

Rising sea levels and heavy rains put pressure on drainage systems. When the sea level rises relative to ground level, stormwater drainage pipes fill with seawater. The seawater may flow back up the pipes; or simply make it harder for rainwater to be discharged to the sea, resulting in both cases in flooding [DSD 2006]. Existing drainage systems in many Greater PRD cities are inadequate. Guangzhou, for example, regularly experiences tidal flooding caused by water intruding up

through the drainage systems. This would clearly be worsened by sea level rise with resultant higher tides. In Hong Kong, the Drainage Services Department's view as of November 2005 was that a "wait-and-see approach … at least for the time being" was appropriate with regard to design for sea level rise [DSD 2005]. Given that some low-lying areas of Hong Kong are already subject to flooding due to seawater backflow when high tides combine with heavy rain - which would be considerably worsened by a rise in sea level - it may become necessary in the near future to develop a more proactive policy.

Sea level rise and tidal saltwater intrusion upstream will also cause the PRD's natural irrigation and drainage system to lose its effectiveness. It will become more difficult to drain wastewater from cities and towns, which will increase pollution of the river network and embankment area. The present twenty-year flood frequency could decrease to a frequency of approximately five years, increasing the cost of irrigation and drainage by 15-20% [YANG et al 1996].

Conversely, in the years with low rainfall, there may be less water available in the PRD river network to dilute sewage treatment work discharges. It is likely that improved treatment technology will be required to manage these physical challenges and to cope with the increased volume of sewage produced by growing cities in the PRD. If pressure on water resources from industry and the cities continues to grow, it may be necessary to develop water recycling systems to allow some wastewater to be re-used.

Climate change could have a significant impact on the infrastructure associated with fuel distribution and electricity transmission, both by increasing demand and disrupting supply. Demand for electric power in the Greater PRD has grown enormously in the last two decades. Demand for energy is temperature-sensitive – increasingly so as greater per capita incomes in the Greater PRD increase the use of domestic air-conditioning and as industry in the region adopts sophisticated manufacturing processes that require cooling and constant temperatures. Research carried out for Hong Kong's Environmental Protection Department in 2004 concluded that an increase in the ambient temperature of 1ºC would increase electricity consumption by 9.02%, 3.13% and 2.64% in Hong Kong's domestic, commercial and industrial sectors respectively [FUNG 2004]. As Hong Kong's industrial sector is extremely small, it can be estimated that this figure would be considerably higher elsewhere in the Greater PRD.

Electricity supply may be disrupted by damage to transmission and distribution infrastructure (power lines, pylons etc.), which can be damaged by storms or landslips following heavy rain. In addition, high temperatures degrade transmission capacity. [ALLEN CONSULTING GROUP 2005].

Most public power in the Greater PRD is supplied by coal-fired power plants, while generators are fuelled by diesel fuel and fuel oil. Production of energy depends on the consistent delivery of these fuels. China's coal and oil resources are mainly located in the interior and North of the country, and Guangdong's coal supplies are largely imported through its ports, so reliable transportation and storage infrastructure in the Greater PRD is vital to cater for the movement of these commodities [LOH 2006]. The reliability of the ports will become an increasingly important factor in the future as emissions regulations enforce the use of cleaner fuels, which are likely to be imported from outside China. In addition, any storm or flooding events that cause roads to be impassable or transportation to be delayed could cause disruption to fuel supply and thus to power supply.

While coal and diesel/fuel oil are used to generate the bulk of Guangdong's electricity supply, around 20% of supply is derived through hydro power. Hydro-electric dams are also considered to be vulnerable to climate change events. On the one hand, reduction of water flow in rivers during dry years could reduce the amount of power that can be generated. Conversely, dams could be susceptible to extreme rainfall events if these exceed historical design standards. A dam breakage or situation where water overtops the dam could have catastrophic flooding effects further downstream [ALLEN CONSULTING GROUP 2005].

The risks of climate change impacts to the region's physical infrastructure outlined above appear to have been inadequately considered by the authorities and investors, if at all.

2.4 Economic impact

The analysis of the costs and economic impact of projected climate change is at an early stage. As climate change study becomes more advanced, the science of environmental economics is attempting to address this issue. A number of frameworks for examining the impacts of climate change have been proposed and a great deal of work is under way to establish modelling techniques that can measure the impacts at different geographical levels and in economic, environmental and human terms. One of the greatest challenges involved in this analysis is to attempt to quantify the impacts of climate change on "non-economic" assets, such ecosystems or community well-being.

The Stern Review released in 2006 provides the best estimate to date of the economic costs of climate change worldwide, based on a wide range of evidence and using a number of techniques to assess costs and risks. The Review's sobering conclusion is that "if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever", and that "if a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more" [STERN 2006]. While it is impossible here to make detailed economic forecasts for the

Greater PRD, it is vital to heed the Stern Review's warning that "the benefits of strong, early action considerably outweigh the costs." This statement is particularly applicable to the Greater PRD, given the region's high vulnerability.

In economic terms, climate change acts as an external "shock" to the economic systems, which can be examined in terms of hypothetical costs if individuals, companies and governments take no action to avoid or reduce the costs associated with that shock; or costs in the more likely situation where action is taken to avoid at least some part of these costs by mitigating the size of the shock itself or by adapting to the shock as efficiently as possible [MARSDEN JACOB ASSOCIATES 2004].

The PRD Economic Zone ("PRDEZ"), which is formed by the cities of Guangzhou, Shenzhen, Foshan, Zhuhai, Jiangmen, Zhongshan, Dongguan, four districts and counties of Huizhou and four districts and counties of Zhaoqing, has been the most dynamic regional economy in China since the launch of China's reform programme in 1979. According to the World Bank, recent estimates indicate that sea level rise of 1-5 m would reduce China's GDP by 2.4-10.8% [BUYS et al 2006]. It is not clear what this would imply for the Greater PRD region, which is an enormous contributor to the country's GDP. Average growth in the PRDEZ over the last 25 years was over 16%, compared to a national figure of 9.5%, and GDP in the zone alone in 2004 was approximately 9.9% of China's total GDP [ENRIGHT et al 2005].

Several studies suggest that climate change could have a significantly harmful impact on the PRD economy. For example, one simulation announced by the China Meteorological Administration in 2002 suggested that a historical high tide, combined with sea level rise of 65 cm, would lead to flooding of about 3,400 km2, causing an economic loss of RMB180.8 billion (about US$21.9 billion) [PEOPLE'S DAILY 2002].

There is no consensus on projected figures in the published studies, and no generally accepted methodology for analysing conditions in the Greater PRD, but it is clear that climate change could threaten economic performance in the Greater PRD in many ways, some of which are outlined below.

Management of severe flooding events, caused by a combination of sea level rise and storm surge, and occurring more frequently in future decades, would require significant financial resources. It is likely that government will bear the greatest part of the responsibility for many aspects of preparation and response, such as monitoring and public warning systems. emergency response and evacuation of the public, cleaning-up operations, repair and replacement of public infrastructure, and economic assistance to communities and businesses.

While some funding for these activities may be drawn from the central government's budget, much of it is likely to come from local government funds. The necessary allocation to disaster management of capital that would otherwise have been invested in activities more directly related to economic activity, such as improved transportation infrastructure, technology or workforce training, may have an adverse effect on the level of economic growth in the region.

Greatly increased coastal and river defences will be required to protect the existing settlements of the Greater PRD from increased flooding due to sea level rise. One estimate suggested that engineering work needed to raise the design standard of 95 key defences in the delta to meet a 30 cm sea level rise would require 17.5 million m3 of soil and stone. Based on the price in 1998, the cost of this work – a fraction of the total infrastructure requirement - would be RMB 2,103 million (US$262.9 million) [HUANG et al 2004]. This defensive infrastructure may be funded from a variety of sources, but allocation of public funds to construction of sea-walls and dykes will reduce the capital available to invest more directly in the Greater PRD economy. Similarly, this construction may create a large number of jobs in the region in the short-term, but these jobs are likely to be low-skilled and to make a negligible contribution to economic growth. In the longer term, it is possible that the results of cost-benefit analyses of adaptation alternatives will show that increasing coastal defences is no longer a sustainable strategy and that it is necessary to withdraw from some areas and relocate assets or communities. Such an operation would incur considerable costs, including compensation for foregone assets. It would also entail significant non-economic, social costs.

It is likely that there will be heightened risk of frequent business interruption in the Greater PRD due to climate change. As described above, transportation infrastructure is vulnerable to storm and flooding events, which could lead to major delays and bottlenecks, disrupting delivery of raw materials, components or finished goods. Much of the industry in the PRD is supply chain driven and prompt delivery is vital to business competitiveness.

Electricity supply problems already hamper business operations in the PRD. For example, in the first quarter of 2005, Guangzhou reported acute power shortages when power had to be restricted in specific areas on 716 occasions. Those periods cost the city RMB10 billion (nearly US$1.3 billion) in industrial output [LOH 2006]. More frequent interruptions to power supply caused by damage to transmission lines or delays to fuel delivery could slow production and lower output even more seriously.

It is likely that the costs of doing business will rise as a result of climate change. For example, shipping and transportation costs may increase as disruption and delays force companies to make short-term or ad hoc arrangements. It may be necessary to add new storage facilities for inventory or fuel to prepare for possible disruptions. The cost of utilities may also increase, especially water, as market pricing is employed to control inefficient usage. In addition,

increased temperatures and heavy rainfall put greater strain on building materials and may cause increased building maintenance costs. It is also likely that the cost of insurance for certain physical assets in the Greater PRD will become a much greater burden, and, in some cases, may not be available at all. Business interruption insurance may also become extremely expensive or difficult to secure.

Greater pressures on the financial resources of the government at provincial or municipal level are likely to lead to increased taxation, even if central government is willing to assist financially. This burden is likely to be heaviest on businesses and could include direct levies for flood control projects, as contemplated in Article 51 of the national Law of Flood Control (1997). A higher tax burden on Greater PRD businesses will increase their overall operating costs, with consequent negative effects on profits and on the level of retained earnings available for reinvestment or expansion of the businesses. Paradoxically, this may mean that total tax revenues collected by governments fall, even as the tax burden on individual companies or employees increases.

Loss of supply chain orders, lower turnover and higher business costs would generate less attractive returns to shareholders, which may decrease investor appetite for the region. It is likely that a sizeable reduction in foreign direct investment ("FDI") would significantly inhibit the region's ability to maintain the pace of industrial development and consequent economic growth, as well as reducing technology transfer by foreign investors. The Greater PRD is also the source of investment for other regions in China, as well as providing employment for large numbers of workers who are able to send money to their families elsewhere in the country; an important market for capital goods and materials from other parts of China; and an important gateway to China. A serious economic slow-down in the Greater PRD would have far-reaching implications for the country as a whole.

The climate change effects described above will impact differently on particular industry sectors. The property, supply chain, transportation/logistics and financial services sectors are all likely to feel the impacts of disruptions caused by heat, flooding and storms. The unavoidable conclusion is that climate change is a business issue, and one that companies in the Greater PRD will have to address in the very near future if they are to avoid risking reduction in profits or even business failure. Managing climate change risk, and factoring climate change impacts into business plans and investment decisions, will become increasingly critical.

2.5 Adaptation and mitigation

A concerted and widespread effort to reduce greenhouse gas emissions provides the best hope for mitigating potentially disastrous effects. That said, the length of time that it takes for existing greenhouse gas concentrations to be reabsorbed by the Earth's natural systems means the world is already going to experience some level of change. Therefore, it is necessary to devise an adaptation strategy to increase the resilience of natural, human and economic systems to possible climate change effects and to reduce the level of damage that might otherwise occur. There is a need for such strategies to be developed to protect the economy and communities of the Greater PRD. Key policy areas include urban planning, water resource management, flood management systems, coastal and river defence, and long-term land use planning.

Strategies to reduce the region's rapidly growing energy use and greenhouse gas emissions must also be developed as a matter of priority. A comprehensive mitigation strategy will require action across all sectors; however energy efficiency measures should be pursued more aggressively as a matter of priority. Such measures offer an opportunity to meet growing demand for energy services while reducing CO_2 emissions, saving energy costs, and reducing local air pollution. Policies that should be pursued in this area include allowing utilities to profit from electricity saved as well as electricity generated (selling "negwatts") [LOVINS 2006]; encouraging upgrades to more energy-efficient technology in the industrial and transport sectors, and implementing demand-side management.

2.6 Conclusion and Initial Recommendations

This report identifies some of the ways in which climate change may affect the landscape and economy of the Greater PRD. We recommend that more detailed research and modelling be undertaken so that government authorities, business and civil society can better understand the impacts of climate change on the region, including ecological impacts. Economic valuation techniques must also be developed to allow more accurate assessment of the net costs of these impacts.

It is clear even from this initial assessment that these impacts are broad, and that the region's response must likewise be so. Policy makers need to consider both mitigation and adaptation measures. Risk assessment techniques and cost-benefit analysis can be used to compare mitigation and adaptation strategies, and further scenario and sensitivity analysis carried out to assess the possible outcomes.

As noted by the Stern Review, the costs of taking action now to reduce greenhouse gas emissions in order to avoid the worst effects of climate change will be far less than paying for the damage later. The latest warning from NASA's Goddard Institute – that the melting of the world's major ice caps could happen much more rapidly than previously thought – underscore the urgency of the problem. Policy makers, business leaders and individuals must take resolute action to reduce emissions within the next 10 years, if catastrophic changes to the planet are to be avoided.

More region-specific research must also be conducted on how best to achieve substantial emission reductions in the Pearl River Delta. For example, while it is apparent that one of the cheapest and quickest ways to reduce greenhouse and other polluting emissions is to improve energy efficiency, this does not seem to be appreciated by businesses or governments.

As pointed out by the Stern Review, "It is no longer possible to prevent the climate change that will take place over the next two to three decades, but it is still possible to protect our societies and economies from its impacts to some extent." As a first step towards an adaptation strategy, there is an urgent need for the authorities to review the many infrastructure plans in the Greater PRD (including land reclamation, construction of container terminals, bridges, roads, tunnels and transport-related projects) and the extent to which they may be impacted by climate change. To date, the discussion has centred on how to expedite plans and not how to review them in light of climate impacts. At the Hong Kong Chief Executive's Economic Summit on 10th September 2006, there was specific focus on port and transport infrastructure development, but climate impact was not mentioned in any of the discussion papers.

Finally, it is clear that policy makers and businesses in the Greater PRD must start to incorporate climate change risk into all long-term policies, infrastructure projects, business plans and strategic investments. Around the world, decision makers are beginning to realise that they must be proactive rather than reactive in order to meet the challenge of climate change. Planning today is the only way for local businesses and communities to be prepared for climate change and its potential risks.

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