A Price Worth Paying:

The Case for Controlling Marine Emissions in the Pearl River Delta

September 2012

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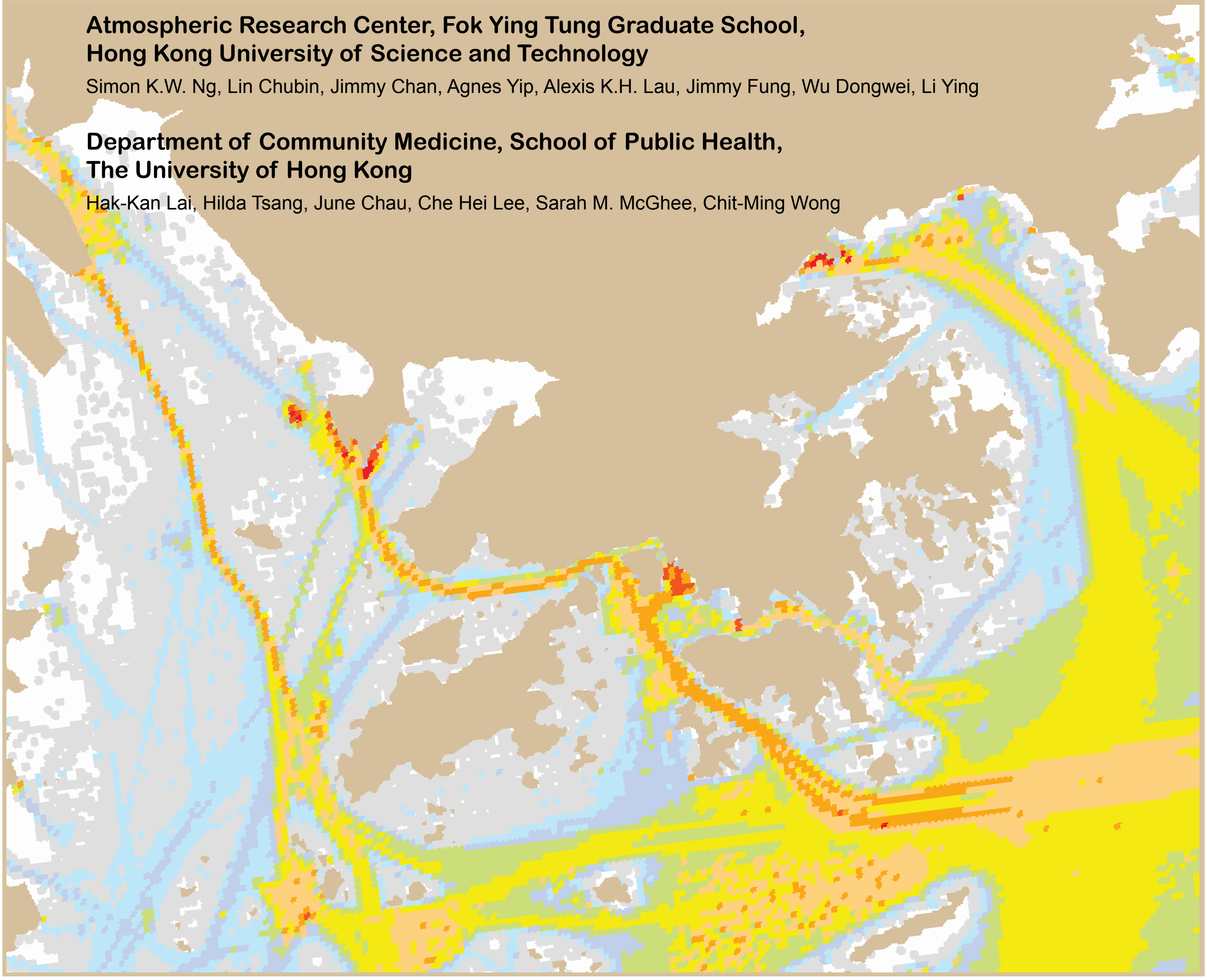

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About the Organisations

Civic Exchange, the Atmospheric Research Center of Fok Ying Tung Graduate School of the Hong Kong University of Science and Technology (HKUST) and the Department of Community Medicine, School of Public Health, Hong Kong University (HKU) collaborated to produce this report. The universities contributed the original research and scientific analysis, and Civic Exchange added the policy perspective.

Civic Exchange

Civic Exchange is a Hong Kong-based non-profit public policy think tank that was established in October 2000. It conducts research and stakeholder engagement to support evidence-based policy making in the public interest. Civic Exchange has solid experience in areas such as air quality, energy, urban planning, climate change, conservation, water, governance, political development, equal opportunities, poverty and gender.

Atmospheric Research Centre, Fok Ying Tung Graduate School
Hong Kong University of Science and Technology

The Atmospheric Research Centre (ARC) of HKUST Fok Ying Tung Graduate School aims to support and assist the development of effective regional air quality management strategies and control policy formulation for the entire region, through identifying basic problems and scientific issues related to air pollution in megacities around the Pearl River Delta (PRD). Six major research areas of ARC includes: (a) more coordinated species-wise observations and measurements in HK and the PRD; (b) better understanding of chemical and other dynamics contributing to the air pollution problem in the region; (c) a systematically derived and regularly updated emissions inventory for HK and the PRD; (d) an advanced air quality modeling system capable of predicting future pollutant responses under different control scenarios; (e) a comprehensive modeling system capable of estimating the corresponding health risk alleviation, visibility improvement, and economic cost-benefit under different control scenarios; and (f) more comprehensive education and outreach programs to instill better understanding amongst all stakeholders, including the public.

Department of Community Medicine, School of Public Health
The University of Hong Kong

The Department of Community Medicine (DCM) has contributed to the international literature and to the health of the local population in areas including tobacco control and advocacy, infectious disease, environmental air pollution, health services research and health economics, psycho-oncology and breast cancer research, and medical education. DCM has extensive experience conducting research on the health-related costs of air pollution, particularly in Hong Kong and the PRD.

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Mr. Chubin Lin obtained a Master of Science degree in environmental science programme from HKUST in 2005. He has been working as a research assistant in the Division of Environment of HKUST since graduation. His research interest includes utilization of cleaner and renewable energy, compilation of emission inventory, and environmental impact assessment. In the past few years, Mr. Lin devoted himself to a study on compilation of emission inventories of marine sources and to analyze potential control measures to reduce shipping emissions in both Hong Kong and Guangdong.

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Jimmy Fung, Professor, HKUST

Prof. Jimmy Fung is Professor in Division of Environment and Department of Mathematics at the Hong Kong University of Science and Technology. He specializes in air quality modeling. The current major focus of his research is in the understanding of the meteorology and air pollution problems in urban and coastal areas like Hong Kong and PRD. More recently, his research group has studied the impact of urbanization on air pollution in the PRD region. The evolution of local and regional sea-breeze circulation is believed to be responsible to form the necessary meteorological conditions for high air-pollution episodes in the PRD.

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Sarah M. McGhee, Professor, HKU

Prof. McGhee's principal research interests lie in applying epidemiological and economic techniques to questions related to health care. After moving to the Department of Community Medicine at HKU in 1994, she formed the Health Services Research Group (HSRG), which brought together the DCM's activities in health services research, economics and informatics.

Chit-Ming Wong, Associate Professor, HKU

Dr. Chit-Ming Wong is in charge of biostatistics teaching and consultation at the Department of Community Medicine. His research interests are in statistical modelling for population-based spatial and temporal data in environmental health studies. Dr. Wong is a coordinator and principal investigator for several regional collaborative research studies on the health impacts of air pollution and influenza.

Preface & acknowledgements

This report represents the culmination of nearly seven years of sustained work at Civic Exchange. We first took an interest in shipping and port-related emissions in 2005 when research in the US showed the substantial negative public health impact. In light of the higher population density in Hong Kong and other Asian port cities, we believed the issue needed to be urgently researched.

Initially, we invested our own resources in looking at how North American and European ports were starting to deal with shipping emissions. This led to Civic Exchange raising two rounds of funding from Millipede Foundation to support extensive engagement with shipping lines, ship owners, small craft operators and terminal managers that eventually led to the shipping industry's voluntary *Fair Winds Charter* in 2010. This came into effect in January 2011 for a period of two years.

We were also heartened that the Environmental Protection Department (EPD) commissioned the Hong Kong University of Science and Technology (HKUST) to compile a marine emissions inventory for Hong Kong. This showed that the HKSAR Government had acknowledged that the issue required attention. This gave Civic Exchange the opportunity to raise funding from the Rockefeller Brothers Fund (RBF) to assess shipping emissions in the Pearl River Delta. Thus, the EPD and RBF-funded reports provide a full picture for policymakers and the public to consider the way forward.

We are grateful to the encouragement of Edward Yau, the former Secretary for the Environment, to continue this work and for his support of the *Fair Winds Charter*, as well as the support from the dedicated officers at EPD working on marine emissions. We are also grateful to the officers of the Marine Department for their longstanding support. We are especially grateful to the shipping lines and ship owners for their continuing interest in promoting delta-wide regulation of shipping emissions. Thanks must also go to our research partners at HKUST and the University of Hong Kong. We have always admired their robust research. In collaboration, Civic Exchange is able to produce solid evidence-based policy analysis and recommendations.

We cannot sustain such long-term, heavy-duty work without our funders. For this particular report, we are most grateful to the RBF. Funding from Millipede Foundation and generous annual grants from ADM Capital Foundation for our work on air quality have enabled us to keep going for so many years on this area of study.

I am most grateful to green shipping and ports team at Civic Exchange – Mike Kilburn shepherded this report to its fruition, Simon Ng did groundbreaking research work at HKUST and is now back with us, and Veronica Booth for conducting many rounds of engagement work. Michelle Wong designed this report, and Cissy Lui translated it.

Christine Loh
Chief Executive Officer
August 2012

Table of Contents

Executive Summary **7**

1. Introduction 8
   - 1.1 Background
   - 1.2 Findings
   - 1.3 Collaborative Research

2. Assessing the Problem 12
   - 2.1 The 2008 ocean-going vessels emissions inventory
   - 2.2 Principal emitters
   - 2.3 Most harmful modes of operation
   - 2.4 Dispersion of pollutants
   - 2.5 Public health impacts of marine emissions

3. Control Measures 16
   - 3.1 Control measure 1: Switch to 0.5% sulphur fuel at berth in Hong Kong waters for ocean-going vessels
   - 3.2 Control measure 2: Switch to 0.1% sulphur fuel in Hong Kong waters for ocean-going vessels
   - 3.3 Control measure 3: Emissions Control Area: Switch to 0.1% sulphur fuel within 100 nm of Hong Kong (ocean-going vessels, river vessels and local crafts)
   - 3.4 Control measure 4: 12 knot vessel speed limit in Hong Kong waters for ocean-going vessels

4. Conclusion 22

Appendices
1. An Extract from the *Regional Coorperation Plan on Building a Quality Living Area* on recommendations related to marine pollution 23
2. Ocean-going vessel emissions inside and outside Hong Kong waters 24
3. Spatial distribution of cruise ship SO_2 emissions 26

Endnotes **27**

Executive Summary

Making the case for regulation of marine emissions in the Pearl River Delta

The Pearl River Delta (PRD) is a region with a single airshed, but different administrative and legal practices for controlling air quality. Under the *Regional Cooperation Plan on Building a Quality Living Area* (QLA Plan) released in June 2012 the Governments of Hong Kong, Guangdong and Macau have outlined a strategy to collaborate in reducing emissions from vessels throughout the PRD.

This report provides evidence designed to assist policymakers in the region with this objective. It focuses on regulating toxic exhaust emissions from ocean-going vessels (OGVs) – the most significant contributors of marine emissions. The findings show that marine sources of sulphur dioxide (SO_2) emissions currently account for 519 premature deaths per annum in the PRD. These deaths could be reduced by 91% should an Emission Control Area (ECA) mandating the use of fuels with lower sulphur content be introduced. The report also demonstrates that three less comprehensive control measures would also reduce OGV emissions and associated public health impacts by 41-62%. Policymakers are encouraged to introduce these measures as stepping-stones on the way to establishment of an ECA for the PRD.

1 Introduction

1.1 Background

PRD waters among the busiest in the world

The Pearl River Delta (PRD) is home to some 36 million people in Hong Kong[1], Macau and nine prefectures in Guangdong. It also plays host to three of the ten busiest container ports in the world, annually handling some 50 million TEU of containers[2], representing some ten percent of global container traffic, ranking the waters of the PRD among the busiest in the world.

No regulation of marine fuel in PRD

Emissions Control Areas (ECA) established in Europe and North America under Annex VI to the International Convention for the Prevention of Marine Pollution from Ships (MARPOL VI) impose strict standards on the quality of fuel ships may use within specified boundaries. There is no similar regulation in the PRD. Vessels in this region, including those using clean fuels elsewhere, typically burn more polluting bunker fuel in order to minimise costs, thereby generating substantially more harmful emissions.

Plans for regional collaboration

The PRD is a region with a single airshed, but different administrative and legal practices for controlling air quality. The Governments of Hong Kong, Guangdong and Macau have agreed to collaborate to reduce marine emissions under the June 2012 *Regional Cooperation Plan on Building a Quality Living Area* (see Appendix 1).[3] This plan calls for the development of an emissions inventory, an analysis of the costs and benefits of different control measures, plans for the introduction of tighter fuel standards and, tentatively, an ECA.

Private sector leadership through *Fair Winds Charter*

The private shipping lines have led the way in reducing emissions in the region. In November 2010, eighteen shipping lines worked with Civic Exchange to establish the *Fair Winds Charter* (FWC)[4], under which they agreed voluntarily to burn fuel with a sulphur content[5] of 0.5% or less for two years while at berth in Hong Kong. This is a significant improvement, as the bunker fuel used in modern ocean-going vessels (OGVs) typically has a sulphur content of between 2.8 and 3.5%. In December 2011, the Hong Kong SAR Government began the process of consulting Legislative Council members and the industry about a proposal to control emissions from ships.[6]

A ship emissions inventory for Hong Kong was completed for EPD

A key request of the FWC was for the region's governments to regulate fuel standards across the PRD. For regulation to be implemented policymakers must have an inventory of marine emissions on which to formulate and justify any new controls or incentives. This has been done for Hong Kong[7,8], but not previously for the entire PRD.

This report uses a new inventory for the PRD to support regulations

This report takes the significant next step of assessing these emissions from OGVs throughout the PRD. Its principal purpose is to provide data to support the development of regulations across all jurisdictions. Ultimately it aims to support the case for establishing an ECA covering the whole of the PRD region.

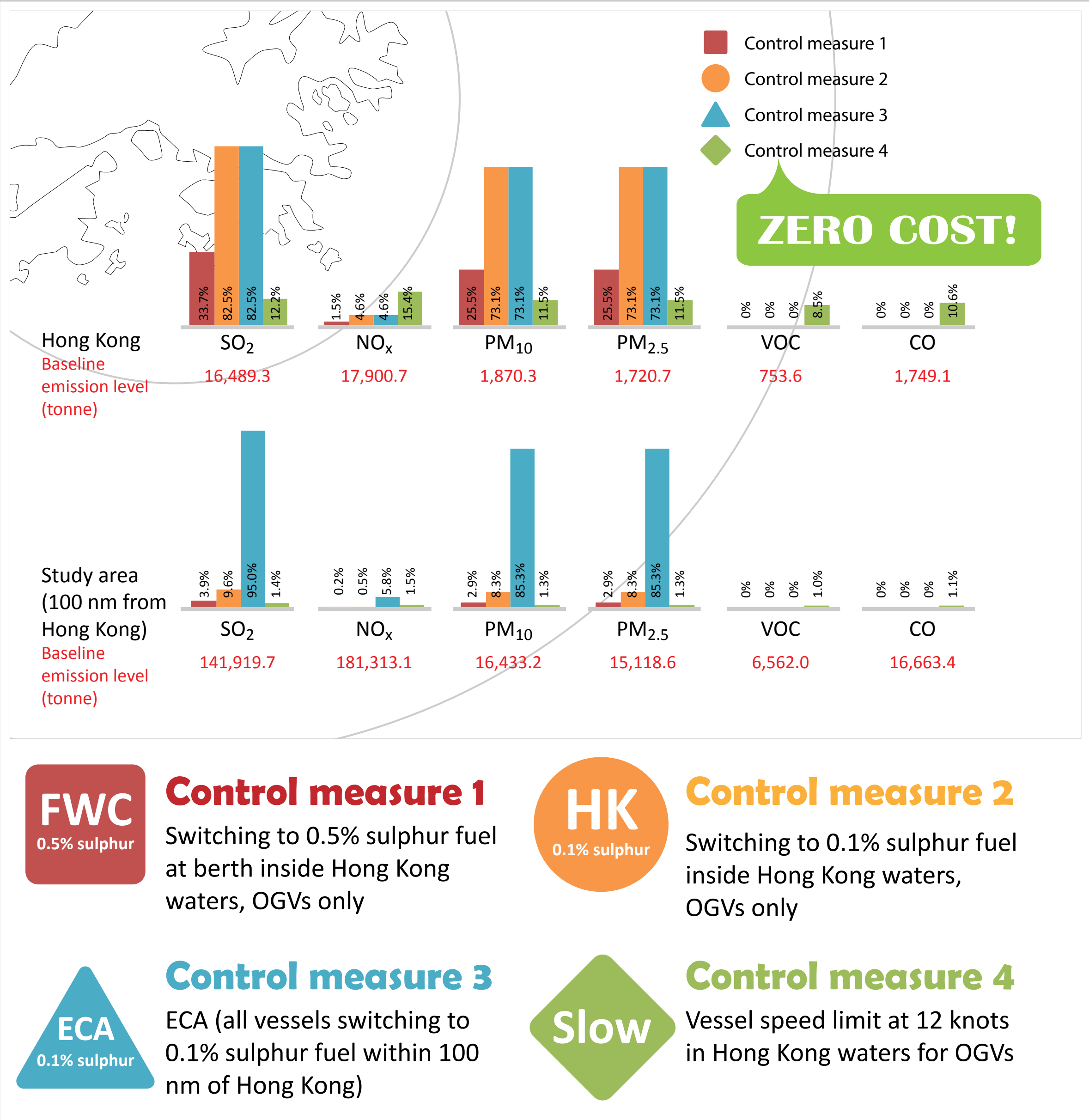
1.2 Findings

Four control strategies

The study provides guidance to policymakers by assessing the impacts of four different control strategies (Figure 1). These range from setting tighter standards for fuel used at berth (0.5% sulphur content), setting ECA level fuel standards (0.1% sulphur content) for vessels in Hong Kong waters and out to 100 nautical miles (nm), and imposing speed restrictions on vessels in Hong Kong waters. The latter measure will reduce all pollutants by 8.5-15% and will cost nothing – ships cruising more slowly simply burn less fuel.

This level of detail will enable both the shipping sector and the government to better understand the impacts of current OGV operations and to determine and justify the most appropriate courses of action for reducing emissions.

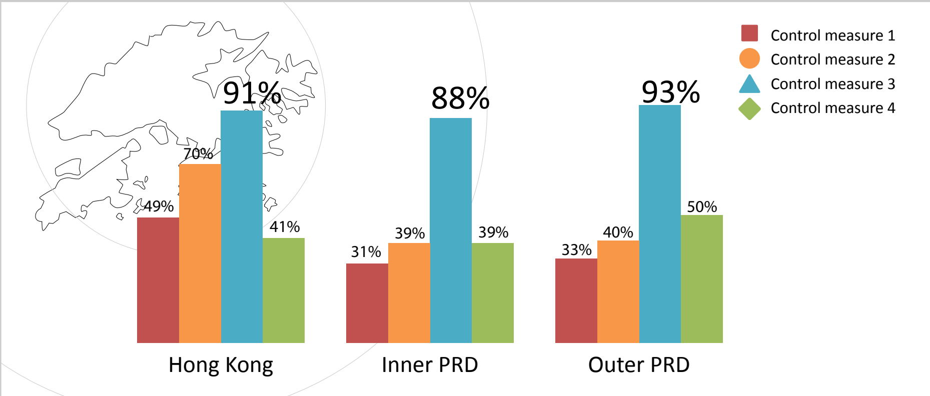
Figure 1. Percent reduction from ship emissions, 2008



ECA would cut deaths by 91%

Most significantly this report demonstrates to policymakers that sulphur dioxide (SO_2) emissions from OGVs and the associated public health impacts can be reduced by up to 91% if an ECA covering the waters of the PRD and out to 100 nm from Hong Kong were to be established. (Figure 2)

Figure 2. Percent reduction on excess deaths due to ship emissions



Hong Kong bears the brunt of impacts

It also demonstrates that Hong Kong citizens bear 74% of the impacts – and secure a corresponding proportion of the benefits of cleaning up – even though Hong Kong handled less than 50% of the PRD's container throughput. This is because the great majority of vessels calling at Shenzhen's twin ports of Shekou and Yantian also steam through Hong Kong waters, emitting significant tonnages of pollutants en route.

Proven low-cost solutions

This substantial reduction in health impacts does not require the development of new technologies or innovative control measures. It simply requires the existing fleet to burn cleaner fuel under widely proven operating conditions. This can be done relatively cheaply, and the costs can and should be shared by the shippers of cargo under the "polluter pays" principle.

Identifying key polluters and public health impacts

This report does more than showing the above. It provides an accurate picture of which classes of ships are the most polluting, where they generate their emissions and how these emissions are dispersed. For example, it highlights the specific emissions from cruise ships. It also provides the first insight into the health impacts of SO_2 emissions on people living in different prefectures and regions of the PRD and the relative significance of marine SO_2 emissions compared to other sources (see Section 2.4).

A roadmap towards an ECA for the PRD

Policymakers may consider specific issues, such as reducing the impacts from cruise ships, but it is hoped that they will use this data to support the establishment of a multi-stage path for progressive emissions reductions in all OGVs. This might begin with controlling emissions at berth over multiple jurisdictions, and be followed by the introduction of a low emissions zone covering only Chinese territorial waters. In the best case, this paper provides support for the "leapfrog" option of establishing an IMO-approved ECA for the PRD that would reduce OGV emissions and the associated public health impacts by an entire order of magnitude.

1.3 Collaborative Research

PRD cross-disciplinary collaboration

These findings are based on groundbreaking research involving Civic Exchange, HKUST's Atmospheric Research Center of the Fok Ying Tung Graduate School and HKU's School of Public Health.

HKUST – First activity-based inventory for PRD

HKUST laid the foundation by conducting the first ever activity-based inventory of OGV emissions across the whole PRD. This inventory takes into account many more variables and delivers significantly greater accuracy than traditional fuel-based inventories. HKUST also plotted the dispersion of pollutants by mapping concentrations of key pollutants from OGVs across each prefecture in the PRD.

HKU – First assessment of public health impacts

HKU took this information and, using regional health data, made the first ever assessment of the impacts of emissions from OGVs on the health of the population in each prefecture of the PRD, Hong Kong and Macau.

This report does not include the complex calculations and models that underpin these findings. HKUST and HKU have each produced a paper setting out the technical details, sources and assumptions on which this paper depends for the accuracy of its conclusions. Those seeking to delve deeper are accordingly directed to those papers as follows:

- Ng, S.K.W., Lin, C., Chan, J.W.M., Yip, A.C.K., Lau, A.K.H., Fung, J.C.H., Wu, D., Li, Y. (2012), *Marine Vessel Smoke Emissions in Hong Kong and the Pearl River Delta, Final Report*. Atmospheric Research Center, HKUST Fok Ying Tung Graduate School, Hong Kong University of Science and Technology.

- Lai, H.K., Tsang, H., Chau, J., Lee, C.H., McGhee, S.M., Wong, C.M. (2012), *Health Impact Assessment of Measures to Reduce Marine Shipping Emissions, Final Report.* Department of Community Medicine, School of Public Health, The University of Hong Kong.

2 Assessing the Problem

2.1 The 2008 ocean-going vessel emissions inventory

2008 OGV inventory for the PRD

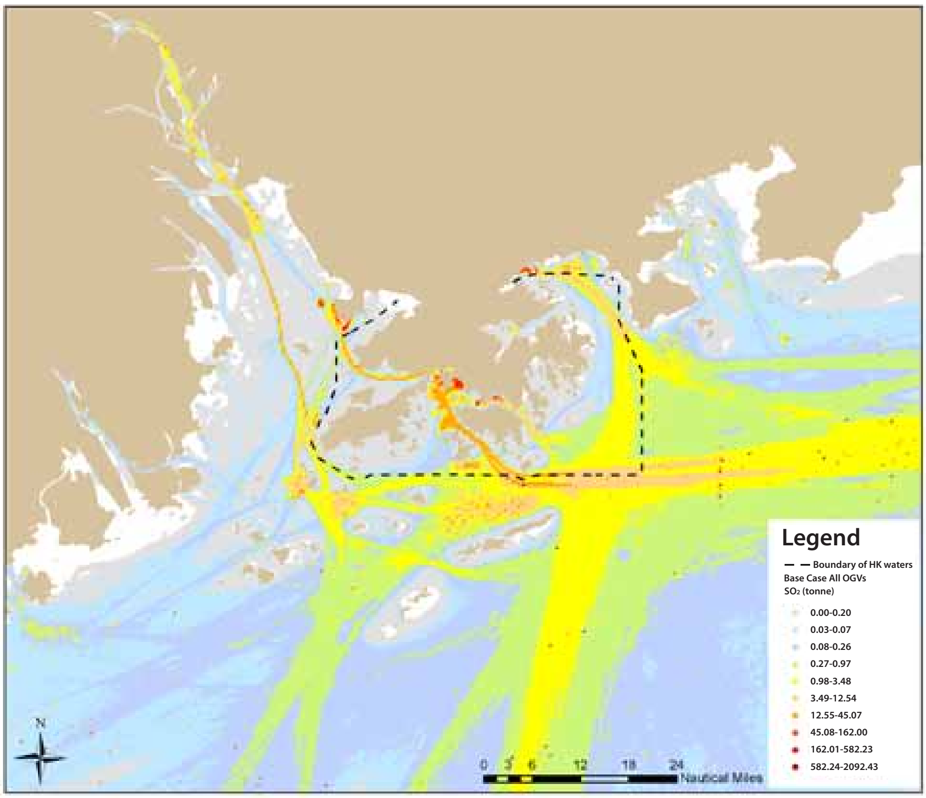
The scope of emissions from OGVs in the PRD region was assessed by monitoring the movements of some 50,000 vessels either calling at or passing through Hong Kong waters in 2008.[9] Six pollutants were assessed and classified according to vessel type and operational mode. Emissions from OGVs outside Hong Kong territorial waters but within 100 nm were also estimated (Appendix 2).

Baseline map

Figure 3, which shows the location of OGV-generated SO_2 emissions gives a broad indication of the ports and berthing locations (in red), the most widely-used fairways and the principal approaches used by ships entering and leaving the PRD. SO_2 is used as the indicator because SO_2 emissions from bunker-burning OGVs has a unique signature, making it readily identifiable. Other pollutants, once emitted, cannot be directly attributed to a specific source.

Breaking these emissions down by vessel class and operational mode allows policymakers to understand which vessels and operational modes are responsible for generating the most pollutants. It also allows them to determine the strategies to most effectively reduce these emissions.

Figure 3. Spatial distribution of OGV SO_2 emissions by 500 meter resolution, 2008[10]

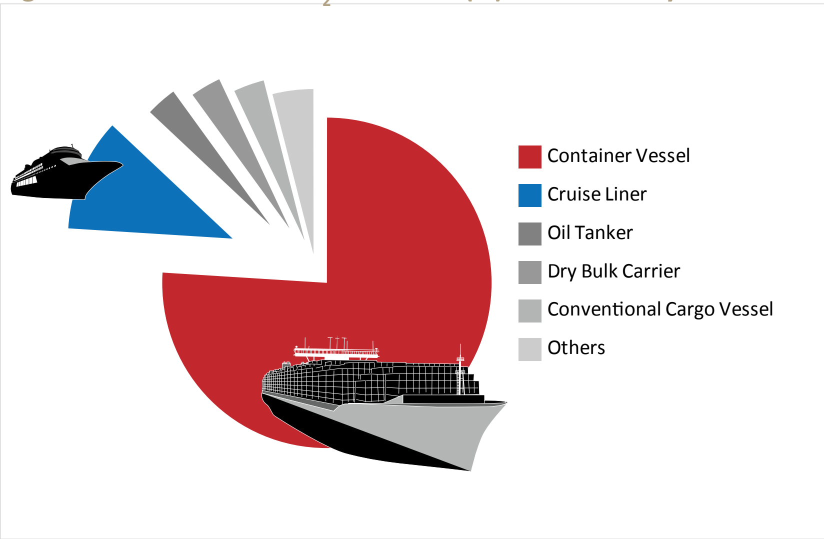


2.2 Principal emitters

Breakdown by vessel class

Some 75-80% of all emissions, both within and beyond Hong Kong waters come from container vessels (Figure 4). Other significant emitters include the cruise liners, which use clearly defined routes (Appendix 3) and therefore can be shown to have specific impacts on different locations within the PRD.

Figure 4. Breakdown of SO_2 emissions (%) from OGVs by vessel class

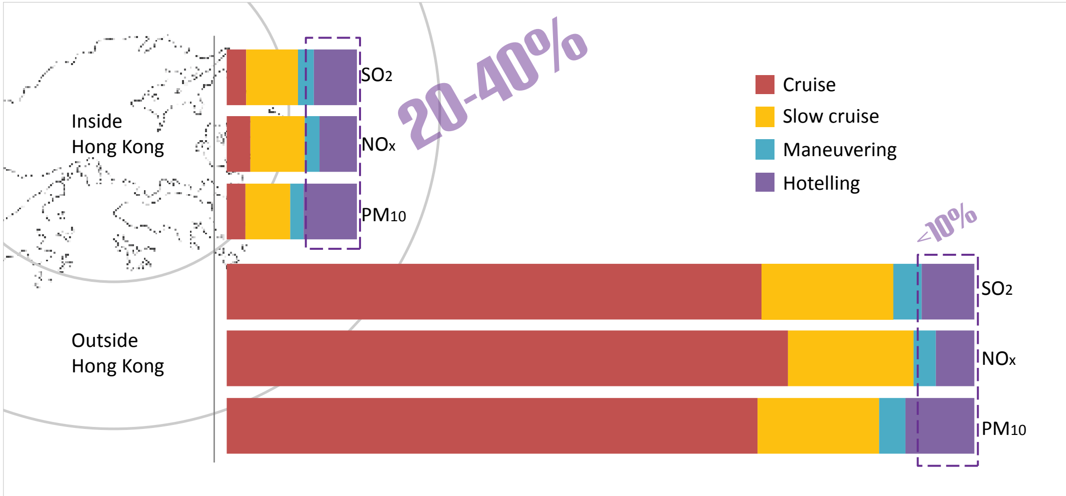


2.3 Most harmful modes of operation

Breakdown by operational mode

Figure 5 shows that different operating modes generate different proportions of the total emissions. Emissions outside Hong Kong waters are some six times greater than inside, but a key consideration is that emissions are most harmful when closest to the population that must breathe them. What this means in practice is that the relatively modest emissions from vessels at berth – 20-40% in Hong Kong and less than 10% in PRD – make a disproportionately high contribution to the negative health impacts of OGV emissions. Measures to control at-berth emissions will provide more substantial health benefits than these percentages first suggest.

Figure 5. OGV emissions (%) inside and outside Hong Kong waters by operation mode, 2008



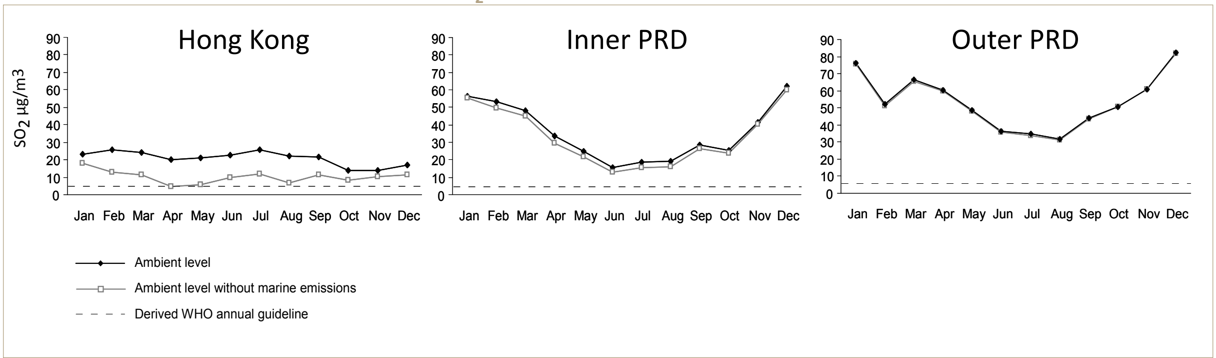
2.4 Dispersion of pollutants

Dispersion of pollutants

Pollutants are not necessarily breathed where they are emitted. A key consideration is that the closer to the source, the higher the concentration of the pollutant. Figure 6 is a map of PRD by prefecture. Simply stated, the closer a prefecture is to the concentration of terminals and approach routes of Hong Kong and Shenzhen the greater the influence of marine emissions on ambient SO_2 concentration. Conversely the more distant prefectures are much less affected (Figures 7 and 8).

Figure 6. Classification of reporting areas for health impacts

Figure 7. Monthly average ambient SO_2 with and without marine emissions, 2008[11]

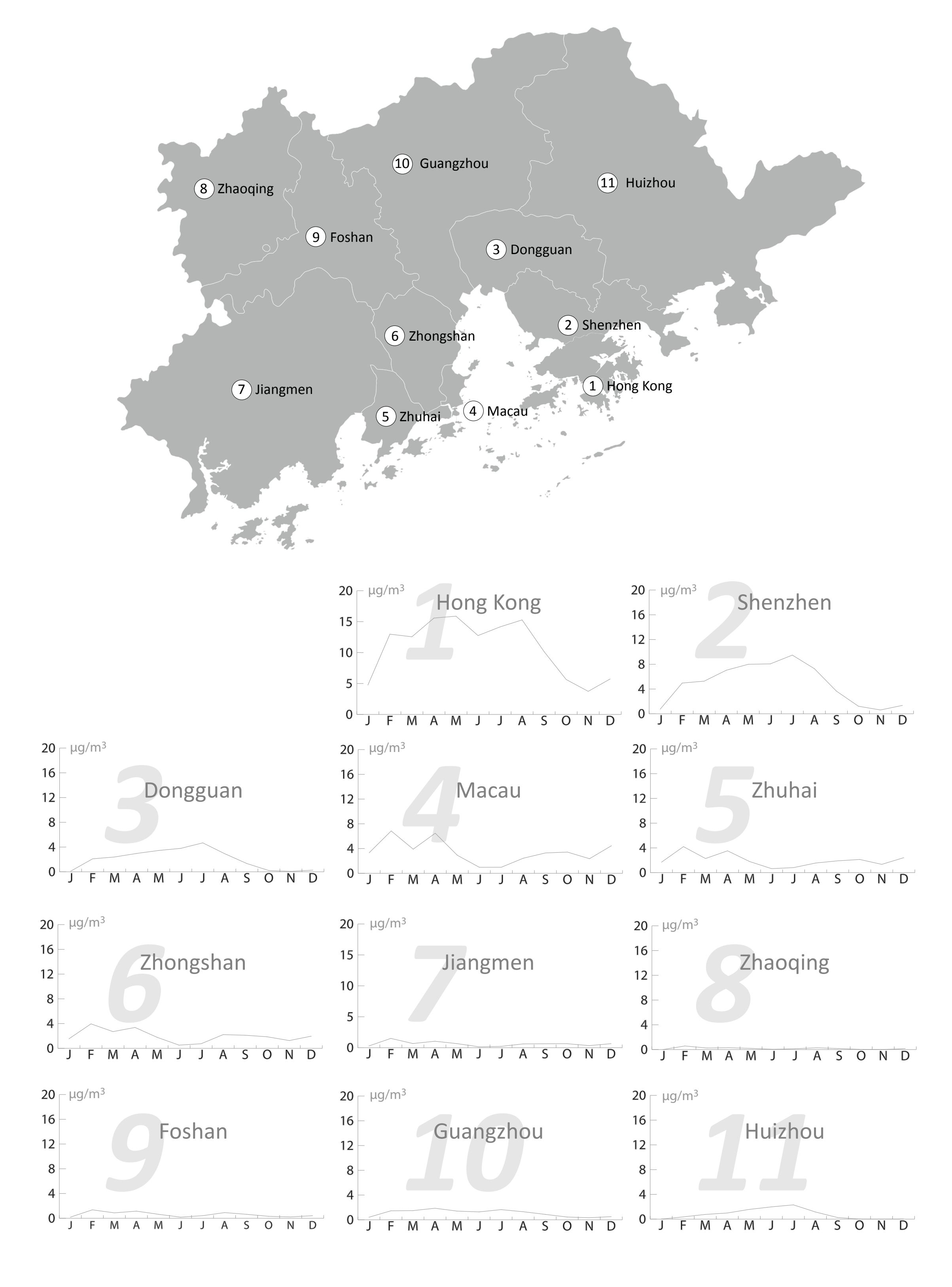


2.5 Public health impacts of marine emissions

519 avoidable deaths per annum

Some 519 premature deaths per annum are directly attributable to emissions from SO_2 emissions from OGVs in the PRD. The majority of these are suffered by the populations of Hong Kong (385 avoidable deaths) and the coastal prefectures (93 avoidable deaths). Impacts decline with distance from the major ports, and the prefectures further from the Pearl River Estuary (42 avoidable deaths) are barely impacted. Concentrations are averaged across the entire prefecture, but the brunt of impacts are suffered by those living closest to the terminals, anchorages and fairways where the concentrations are highest.

Figure 8. Monthly concentration of SO_2 (µg/m³) from marine emissions by prefecture, 2008



3 Control Measures

Controls for OGVs in the PRD

This section evaluates four measures for controlling emissions from OGVs in the PRD. Figure 8 in the previous section provides a vital link in the evidence chain, demonstrating how marine SO_2 concentrations are dispersed across the region. These concentrations provide the essential data for evaluating the public health impacts. Figure 8 also shows how pollutant concentrations change with the seasons, and how distance from the source reduces the influence of marine emissions – and the efficacy of control measures.

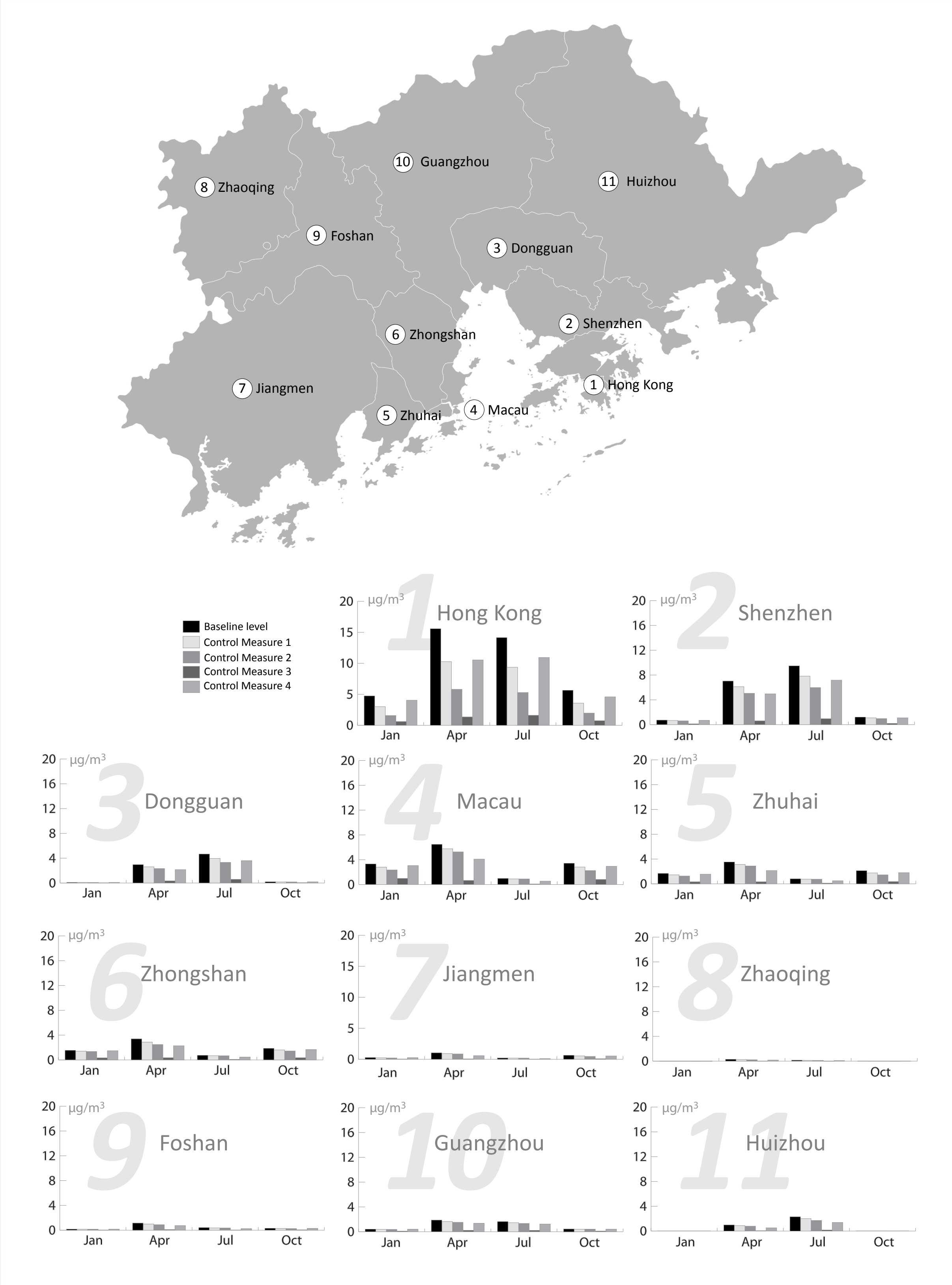
Summary of outcomes

For each control measure a map is included to show the change in location and intensity of emissions compared with the base case in Figure 3 on page 12. A short description explains the extent to which mortality associated with SO_2 emissions from OGVs can be reduced. The results of these control measures are summarised below so that the link between reductions of pollutants from marine sources and measurable improvements in public health outcomes can be clearly understood (Table 1 and Figure 9).

Table 1. Health impact reduction potential (avoidable deaths and percentage reduction) of four control measures for ships in Hong Kong waters and 100 nm from Hong Kong

		Hong Kong	Inner PRD	Outer PRD
Annual deaths (all causes, all ages)		39,799	67,070	86,041
Excess deaths due to SO_2 from ship emissions		385	93	42
Excess deaths under four ship emission control policies (% improvement)				
Control Measure 1	At berth fuel switch in Hong Kong waters (0.5% sulphur limit)	197 (49%)	64 (31%)	28 (33%)
Control Measure 2	0.1% sulphur limit with in Hong Kong waters	114 (70%)	57 (39%)	25 (40%)
Control Measure 3	ECA (0.1% sulphur limit) to 100 nm from Hong Kong	33 (91%)	11 (88%)	3 (93%)
Control Measure 4	Vessel speed reduction (12 knot) in Hong Kong waters	229 (41%)	57 (39%)	21 (50%)

Figure 9. Comparison of seasonal concentrations of SO_2 (µg/m³) in the PRD region under different control scenarios, 2008



3.1 Control measure 1:

Switch to 0.5% sulphur fuel at berth in Hong Kong waters for ocean-going vessels

This control measure follows the *Fair Winds Charter* (FWC), except that voluntary at-berth fuel switching is made mandatory. OGVs at berth must burn fuel with a sulphur content of no more than 0.5%[12] in their auxiliary engines and boilers. Emission reductions are mainly achieved at Kwai Chung Container Terminals, Ocean Terminal, and the following anchorages (Figure 10a):

1. Kowloon Bay (mostly used by cruise ships);
2. Fuel loading and unloading facilities south and west of Tsing Yi;
3. Western Harbour Anchorage;
4. North Lamma Anchorage; and
5. South Lamma Anchorage.

Figure 10a. OGV SO_2 emissions after switching to 0.5% sulphur fuel at berth in Hong Kong[13]

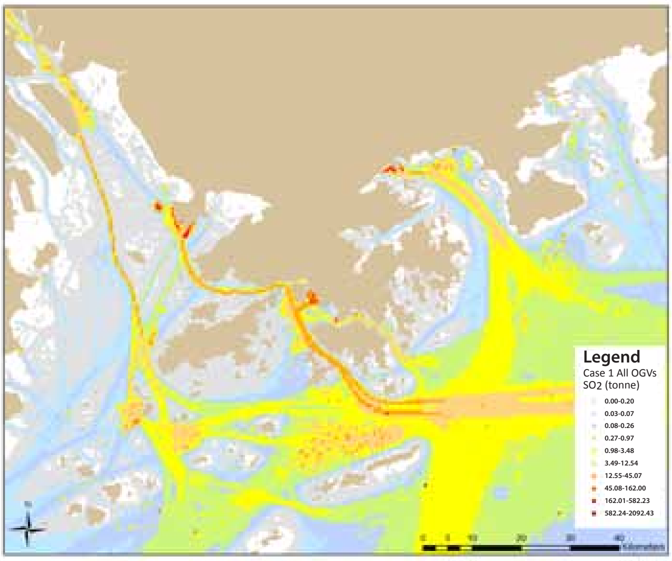
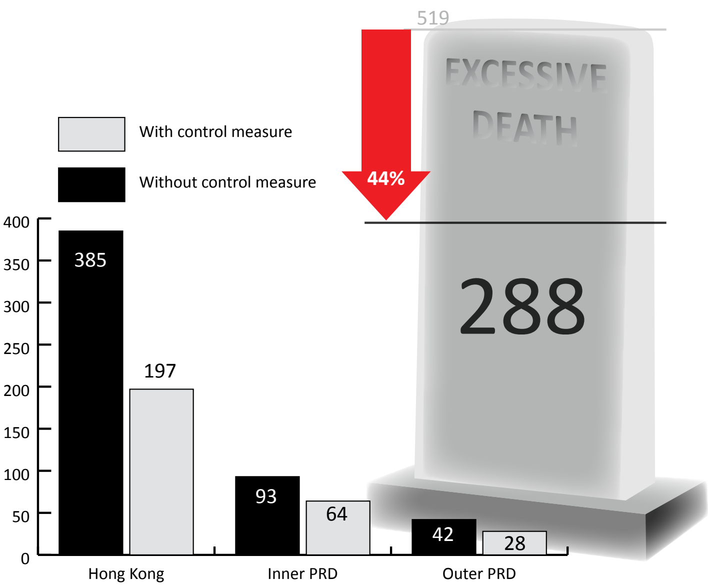


Figure 10b. Number of excessive death with or without switching to 0.5% sulphur fuel at berth in Hong Kong waters



Outcome:

Despite its limited scope this measure is expected to cut SO_2 emissions from OGVs by 33%, and particulates by around 25% in Hong Kong. This is expected to reduce avoidable deaths from OGV emissions in Hong Kong from 385 to 197, the Inner PRD from 93 to 64 and the Outer PRD from 42 to 28, for an overall reduction from 519 to 288 (Figure 10b). The main reason for the effectiveness of this measure is the reductions at the terminals and anchorages, which are to close centres of population, especially around Kwai Tsing district and Victoria Harbour.

3.2 Control measure 2:
Switch to 0.1% sulphur fuel in Hong Kong waters for ocean-going vessels

The second control measure requires all OGVs to switch to 0.1% low sulphur fuel inside Hong Kong waters. OGVs will have to start fuel changeover for all their equipment as they approach Hong Kong, and only switch back after leaving Hong Kong waters. The map shows that ship emissions from terminals, anchorages and shipping lanes (especially in eastern Hong Kong waters) will be significantly reduced (no more red or orange "hotspots"). (Figure 11a)

Figure 11a. OGV SO_2 emissions after switching to 0.1% sulphur fuel in Hong Kong waters[14]

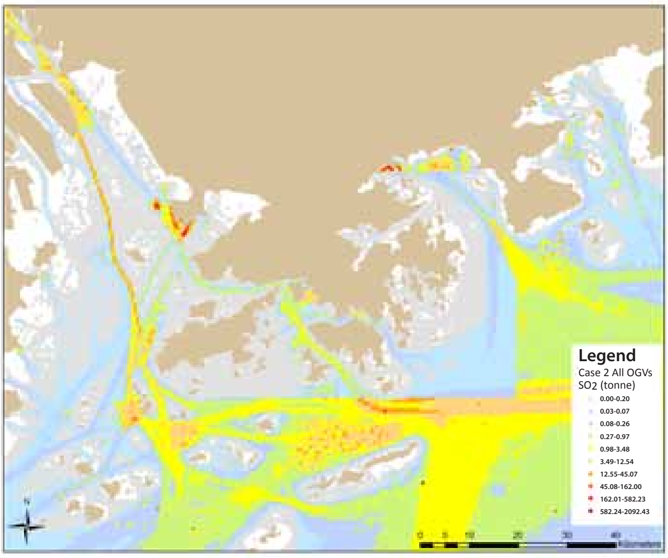
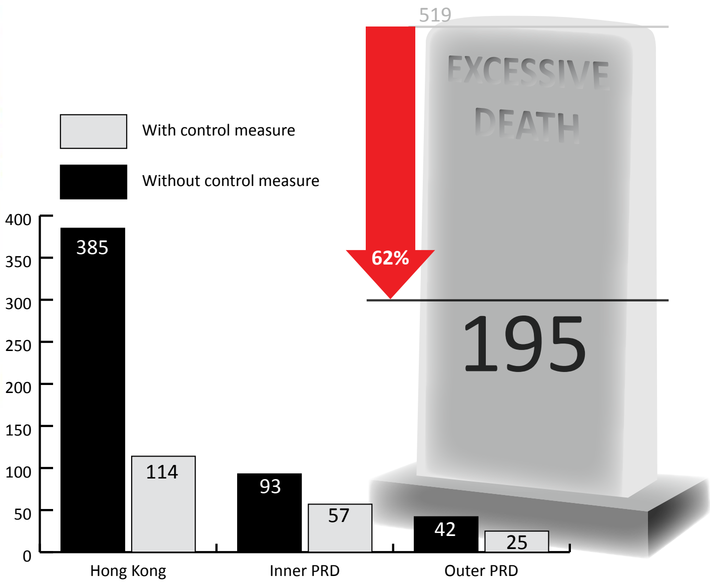


Figure 11b. Number of excessive death with or without switching to 0.1% sulphur fuel in Hong Kong waters



Outcome:

This more comprehensive measure will reduce SO_2 emissions from OGVs by 82.5% in Hong Kong waters and 9.6% across the entire PRD. Particulate emissions will drop by 73.1% in Hong Kong waters and 7.1% across the PRD. These reductions will lead to a drop from 385 to 114 avoidable deaths from marine emisisons in Hong Kong, from 93 to 57 in the Inner PRD and 42 to 25 in the Outer PRD (Figure 11b).

3.3 Control measure 3:

Emissions Control Area: Switch to 0.1% sulphur fuel within 100 nm of Hong Kong (ocean-going vessels, river vessels and local crafts)

All vessels, including OGVs, river vessels and local vessels, must switch to 0.1% low sulphur fuel inside an ECA covering the whole PRD out to 100 nm from Hong Kong[15]. Figure 12a clearly demonstrates that an order-of-magnitude reduction in ship emissions will be achieved under an ECA.

Figure 12a. SO_2 emissions under an ECA in the PRD within 100 nm of Hong Kong[16]

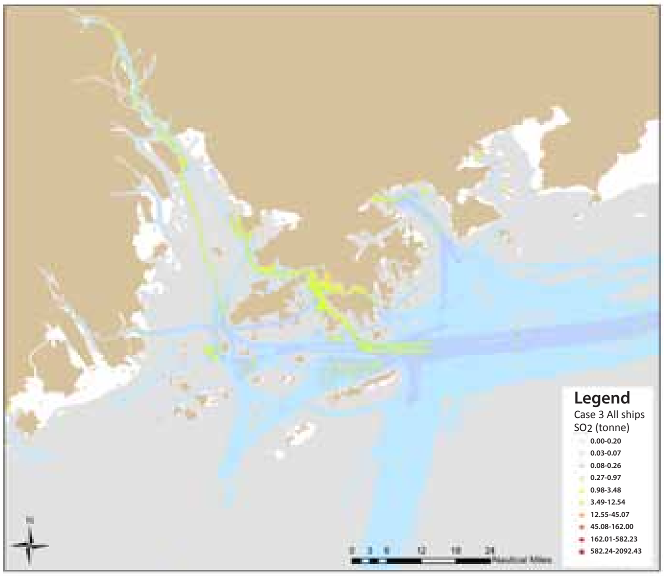
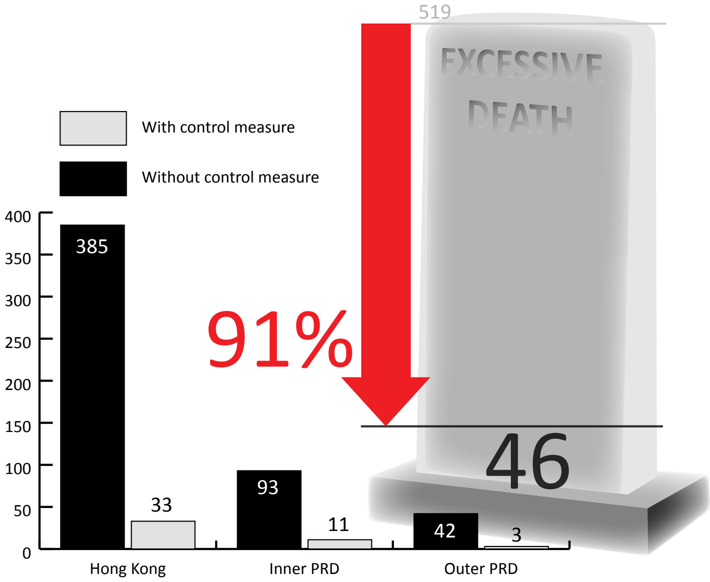


Figure 12b. Number of excessive death with or without an ECA in the PRD



Outcome:

The introduction of an ECA will reduce SO_2 emissions from OGVs by 82.5% in Hong Kong waters and 95% across the entire PRD. Particulate emissions will drop by 73.1% in Hong Kong waters and 85.3% across the PRD. These reductions will lead to a drop from 385 to 33 avoidable deaths from marine emissions in Hong Kong, from 93 to 11 in the Inner PRD and 42 to 3 in the Outer PRD (Figure 12b).

3.4. Control measure 4:
12 knot vessel speed limit in Hong Kong waters for ocean-going vessels

This measure addresses fuel efficiency rather than fuel quality. Under this scenario, all OGVs are required to limit their speed to 12 knots. Slower vessel speed reduces fuel consumption and emissions. Limits are already in force in Victoria Harbour and East Lamma Channel. There is no limit to the northeast towards Mirs Bay and Yantian, as well as between Ma Wan Fairway and Urmston Road. Figure 13a shows the potential impact of a vessel speed reduction scheme. Similarly, ship emissions south of Hong Kong near Po Toi Island and in southeastern waters have also be cut.

Figure 13a. OGV SO_2 emissions under 12-knot speed limit in Hong Kong waters[17]

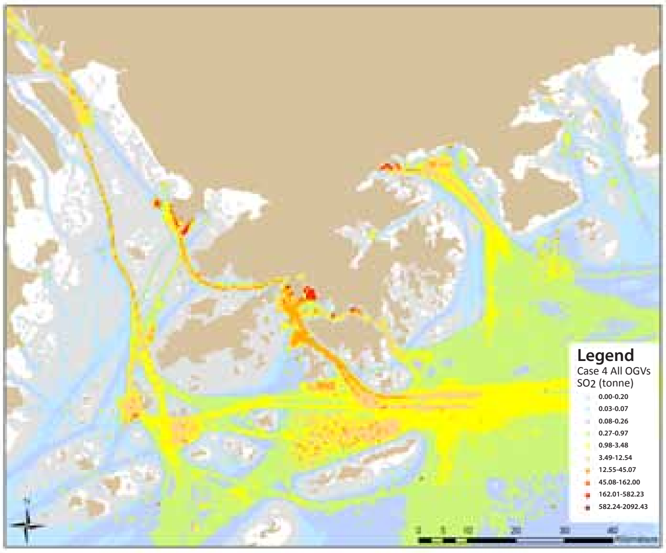
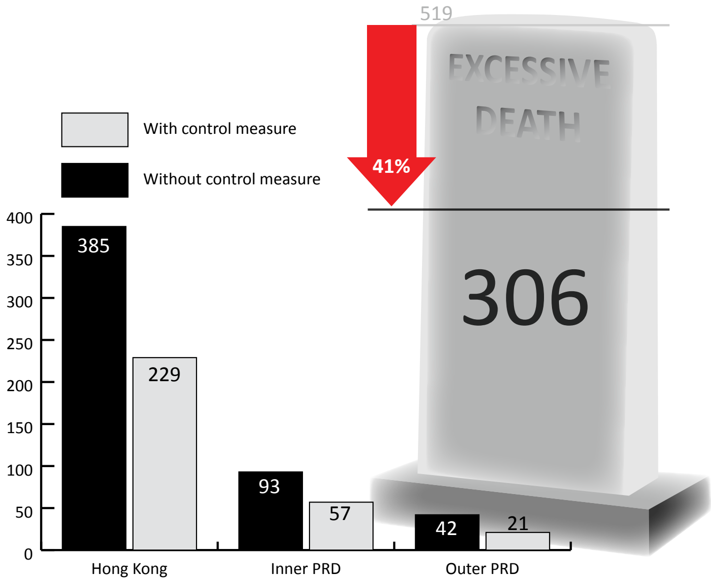


Figure 13b. Number of excessive death with or without vessel speed reduction in Hong Kong waters



Outcome:

The introduction of vessel speed reduction is unique in reducing all six classes of pollutants. Table 2 shows the percentage reduction in marine emissions. These reductions will lead to a drop from 385 to 229 avoidable deaths from marine emissions in Hong Kong, from 93 to 57 in the Inner PRD and 42 to 21 in the Outer PRD[18].

Table 2. Percentage reduction in marine emissions by implementing vessel speed reduction (12 knot) in Hong Kong waters and in study area, 2008

	SO_2	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO
Hong Kong waters	12.2%	15.4%	11.5%	11.5%	8.5%	10.6%
Study area (100 nm)	1.4%	1.5%	1.3%	1.3%	1.0%	1.1%

4 Conclusion

The opportunity

Officials tasked with addressing marine emissions in the PRD are in the enviable position of formulating controls that are actively being demanded by the shipping industry, the strategic directors of policy in Beijing, and the three governments of the PRD. However, there are currently no controls on marine fuel quality anywhere in the region.

The evidence

The findings in this paper provide a very clear indication that both fuel switching and vessel speed reduction can deliver measurable improvements in air quality and public health. Now that SO_2 emissions from the power sector have been controlled, marine emissions are the single largest source in Hong Kong, and are still rising.

Hong Kong must take the lead

Hong Kong bears the brunt of the public health impacts and will benefit most from the clean-up measures. It may also be able to use this new data to justify the introduction of a tighter air quality objective for SO_2. Hong Kong has a clear responsibility to continue to take the lead in rolling out a roadmap for controlling emissions across the PRD.

Legal mechanism for control

In Hong Kong responsibility for controlling fuel quality lies with the Secretary for the Environment under section 43 the Air Pollution Control Ordinance[19]:

> ***(1) For the purposes of this Ordinance, the Secretary may, after consultation with the Advisory Council on the Environment, by regulation provide for-***
>
> ***(p) the specification of the kinds of fuel, or any kind of other material that may evolve air pollutants (including fuel or other material used in the propulsion of any vessel ...), and the kinds of relevant plant (including any furnace or engine used in the propulsion of any vessel ...) to which the regulations are to apply;***

The National Development and Reform Commission has made clear that it is seeking innovative cross-border solutions to improve quality of life[20] under the QLA Plan. Taking the lead will send a strong message that Hong Kong still has much to offer the PRD as an innovator and leader in environmental management.

Pan-PRD decision-makers also have a role

Policymakers elsewhere in the PRD may also see benefits in supporting the development of China's first controls for marine emissions, especially as public expectations of environmental quality continue to rise, and polluters are increasingly being required to clean up if they want to expand, or even to stay in business.

The need for ongoing discussion

Even with these drivers in place the development of a framework for multi-jurisdictional regulation will remain complex. While stakeholders may agree in principle, the working out of practical detail that regulation inevitably requires is likely to need a carefully designed and managed engagement process. The sensitivities surrounding the "One Country Two Systems" principle will only make this more challenging. But developing a framework that may be used for resolving other cross-boundary environmental issues could have a value far beyond the reduction of marine emissions.

Appendix 1

An Extract from the *Regional Cooperation Plan on Building a Quality Living Area*[21] on recommendations related to marine pollution.

(4) Exploring opportunities in controlling air pollutant emissions from vessels in the Greater PRD waters

① proposing to conduct a joint basic study on controlling air pollution from vessels in the Greater PRD waters by the three sides, including compilation of an emissions inventory on vessels in the Greater PRD waters, for projecting the quantity of air pollution from vessels from 2012 to 2020; and

② formulating cooperation plans on controlling air pollutant emissions from vessels. Cooperation proposals include:

- **making reference to the regulations under Annex VI to the International Convention for the Prevention of Marine Pollution from Ships (MARPOL) to tackle vessel emissions, considering comprehensively the technical feasibility, emission reduction benefits and cost effectiveness of different measures, jointly formulating emissions reduction targets for vessels and their fuel standards, and actively encouraging other options that would bring similar emission reduction benefits, with a view to further strengthening control of vessel emissions;**
- **restricting emissions from vessels, including NOX emissions from new vessels which should be in line with the latest development of the engine manufacturing and ship building industries as well as the shipping sector;**
- **examining measures to encourage vehicles entering the port areas to use cleaner fuels, controlling emissions from non-road mobile machinery (NRMM), and enhancing modal coordination, with a view to reducing air pollutant emissions in their vicinity;**
- **exploring the possibility of using cleaner energy by providing onshore power supply to cruise vessels and ocean-going vessels berthing at the Greater PRD ports;**
- **considering requiring ocean-going vessels at berth and at anchorage at the Greater PRD ports to use low sulphur fuel or onshore power;**
- **providing incentives to encourage more ocean-going vessels to switching to cleaner fuel while at berth in Hong Kong waters; and**
- **studying and exploring the establishment of an "Emission Control Area" in Greater PRD waters.**

Appendix 2

Ocean-going vessel emissions inside and outside Hong Kong waters

Table A2-1. OGV emissions (tonne) inside Hong Kong waters by vessel type, 2008[22]

Vessel Type	SO_2	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO
Chemical Carrier/Tanker	71.5	69.2	7.7	7.1	2.7	6.1
Conventional Cargo Vessel	386.0	404.3	43.9	40.4	15.3	34.8
Cruise/Ferry	1,853.2	1,894.4	205.2	188.8	66.3	154.7
Dry Bulk Carrier	513.4	498.9	53.9	49.6	19.1	44.3
Fishing/Fish Processing Vessel	0.8	2.2	0.1	0.1	0.1	0.2
Fully Cellular Container Vessel	12,568.2	14,113.9	1,449.4	1,333.5	616.4	1,431.5
Gas Carrier/Tanker	64.8	58.2	6.9	6.4	2.1	4.7
Lighter/Barge/Cargo Junk	0.0	0.0	0.0	0.0	0.0	0.0
Oil Tanker	537.8	354.3	45.4	41.7	13.4	31.8
Pleasure Vessel	4.1	4.1	0.5	0.4	0.1	0.3
Roll On/Roll Off	112.2	128.0	13.1	12.1	4.7	10.9
Semi-container Vessel	8.6	8.3	1.0	0.9	0.4	0.8
Tug	144.3	146.2	17.3	15.9	5.4	11.8
Others	224.4	218.5	25.9	23.8	7.6	17.1
Total	16,489.3	17,900.7	1,870.3	1,720.7	753.6	1,749.1

Table A2-2. OGV emissions (tonne) outside Hong Kong waters but within the study area by vessel type, 2008[23]

Vessel Type	SO_2	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO
Chemical Carrier/Tanker	1,243.0	1,424.6	149.1	137.2	56.3	126.2
Conventional Cargo Vessel	3,679.7	4,481.4	453.0	416.8	170.9	384.9
Cruise/Ferry	1,832.1	1,959.7	218.3	200.8	75.6	166.0
Dry Bulk Carrier	7,140.2	9,170.4	871.7	802.0	344.7	786.8
Fishing/Fish Processing Vessel	7.7	22.2	1.0	0.9	0.9	1.9
Fully Cellular Container Vessel	100,910.8	134,527.5	11,688.4	10,753.4	4,729.4	12,410.8
Gas Carrier/Tanker	538.2	508.0	59.8	55.0	18.3	40.8
Lighter/Barge/Cargo Junk	0.0	0.0	0.0	0.0	0.0	0.0
Oil Tanker	6,252.7	6,611.3	653.9	601.5	242.2	599.5
Pleasure Vessel	0.3	0.1	0.0	0.0	0.0	0.0
Roll On/Roll Off	1,183.3	1,542.0	151.3	139.2	59.8	134.4
Semi-container Vessel	438.0	578.5	45.2	41.6	18.0	55.7
Tug	454.6	476.3	55.0	50.6	17.1	38.3
Others	1,749.7	2,110.3	216.2	198.9	75.4	169.2
Total	125,430.4	163,412.4	14,563.0	13,397.9	5,808.4	14,914.3

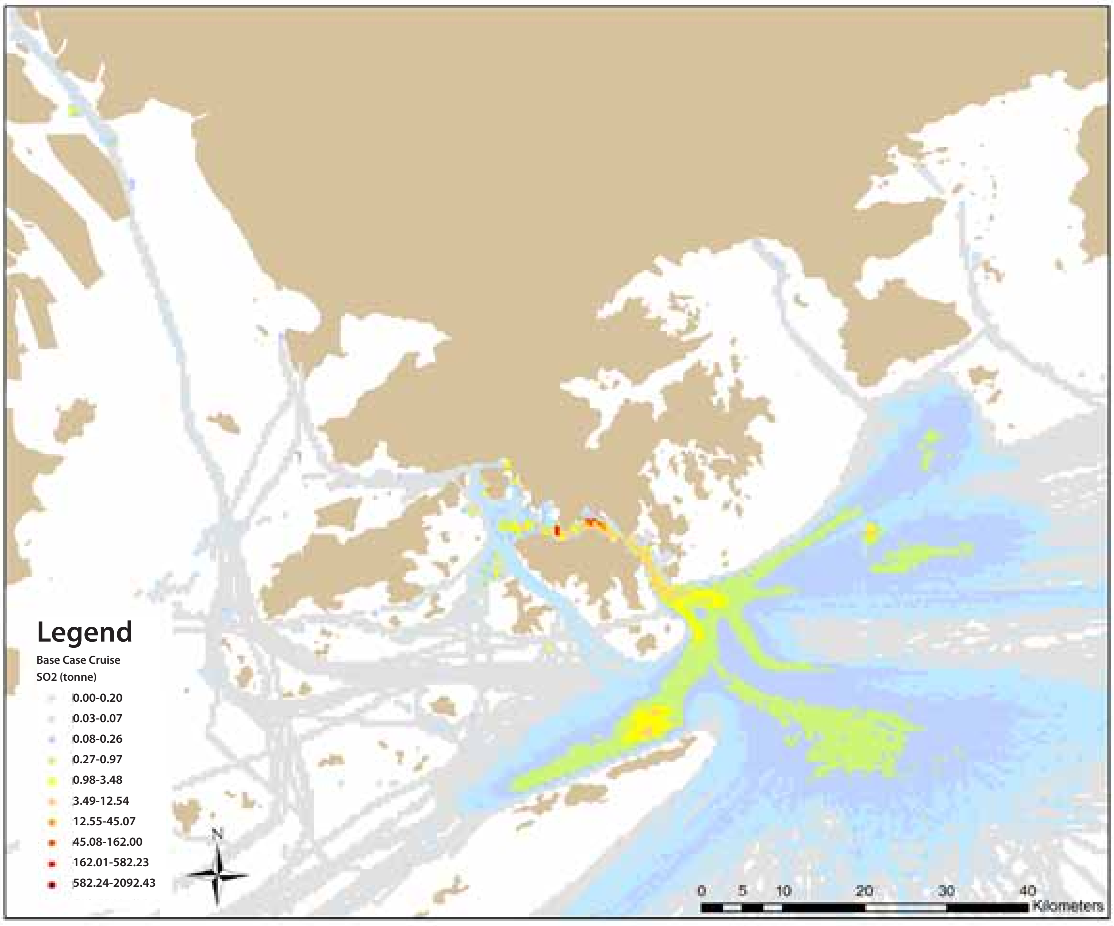
Table A2-3. Emissions reduction potential (tonne & percentage of baseline) of four control measures for ships in Hong Kong waters and 100 nm from Hong Kong[24]

	SO_2	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO
Hong Kong waters						
Baseline	16,489.3	17,900.7	1,870.3	1,720.7	753.6	1,749.1
Control measure 1	10,940.4 (33.7%)	17,623.8 (1.5%)	1,393.4 (25.5%)	1,281.9 (25.5%)	753.6 (0.0%)	1,749.1 (0.0%)
Control measure 2	2,880.0 (82.5%)	17,071.6 (4.6%)	502.8 (73.1%)	462.6 (73.1%)	753.6 (0.0%)	1,749.1 (0.0%)
Control measure 3	2,880.0 (82.5%)	17,071.6 (4.6%)	502.8 (73.1%)	462.6 (73.1%)	753.6 (0.0%)	1,749.1 (0.0%)
Control measure 4	14,484.4 (12.2%)	15,139.1 (15.4%)	1,655.8 (11.5%)	1,523.3 (11.5%)	689.8 (8.5%)	1,563.3 (10.6%)
Study area (100 nm)						
Baseline	141,919.7	181,313.1	16,433.2	15,118.6	6,562.0	16,663.4
Control measure 1	136,370.8 (3.9%)	181,036.2 (0.2%)	15,956.3 (2.9%)	14,679.8 (2.9%)	6,562.0 (0.0%)	16,663.4 (0.0%)
Control measure 2	128,310.4 (9.6%)	180,484.0 (0.5%)	15,065.8 (8.3%)	13,860.5 (8.3%)	6,562.0 (0.0%)	16,663.4 (0.0%)
Control measure 3	7,141.8 (95.0%)	170,712.3 (5.8%)	2,413.2 (85.3%)	2,220.2 (85.3%)	6,562.0 (0.0%)	16,663.4 (0.0%)
Control measure 4	139,914.8 (1.4%)	178,551.4 (1.5%)	16,218.7 (1.3%)	14,921.2 (1.3%)	6,498.2 (1.0%)	16,477.6 (1.1%)

Appendix 3

Spatial distribution of cruise ship SO_2 emissions

Figure A3-1. Spatial distribution of cruise ship SO_2 emissions by 500 meter resolution, 2008[25]



Endnotes

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5. The proportion of sulphur in fuel is directly correlated with emissions of SO_2 and fine particles, both of which have been identified by the World Health organization as harmful to public health.
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10. Note 8.
11. Note 1.
12. Under the *Fair Winds Charter* some vessels use fuel with sulphur content as low as 0.1%.
13. Note 8.
14. Ibid.
15. In order to demonstrate the full impact of an ECA, emissions from river vessels and local vessels that can be tracked by MD's radar system were included alongside OGV emissions. As smaller vessels without Automatic Identification System (AIS) systems cannot be tracked, emissions as shown on the map are under-estimated.
16. Note 8.
17. Ibid.
18. This is an underestimate as only the public health impact of SO_2 emissions have been calculated.
19. Air Pollution Control Ordinance, CAP 311, http://www.legislation.gov.hk/blis_pdf.nsf/6799165D2FEE3FA94825755E0033E532/86682A3515C78D29482575EE005BD610/$FILE/CAP_311_e_b5.pdf (accessed 6 September 2012).
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21. Note 3.
22. Note 8.
23. Ibid.
24. Ibid.
25. Ibid.

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