CONSULTING SERVICES BY ENVIRONMENTAL RESOURCES MANAGEMENT

FINAL REPORT

The Hongkong Electric Company, Limited

Stage 1 EIA for a New Power Station :
Stage 1 EIA Report Volume II

November 1997

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Reference C1432

For and on behalf of ERM-Hong Kong, Ltd

Approved by: S.M. LAISTER

Signed: S M Laister

Position: Deputy Managing Director

Date: 14th November 1997

Compendium of Technical Papers

This document presents the Technical Papers prepared by ERM-Hong Kong during the Stage 1 EIA of Hongkong Electric Company's proposed new power station. The Compendium comprises the following Technical Papers:

- *Power Generation Technology Review*: The identification of the most environmentally friendly power generation technology for the two fuel options, coal and pipeline gas;

- *Pearl River Delta Air Quality Assessment:* An evaluation of the regional air quality implications of the development of the new power station for the Pearl River Delta;

- *Greenhouse Gas Study:* An assessment of the implications of the contributory emissions from the proposed new power station for Hong Kong and regional greenhouse gas emission targets;

- *Waste-to Energy Incinerator Study*: An examination of the feasibility of co-siting a waste-to-energy incineration facility as part of the development of the site identified for the new power station; and

- *Environmental Comparative Fuel Study*: An assessment of the environmental implications of coal versus pipeline natural gas.

TECHNICAL PAPER

The Hongkong Electric Company, Limited

Stage 1 EIA for a New Power Station : *Power Generation Technology Review*

November 1997
DMS#77909

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CONTENTS:

1 INTRODUCTION

1.1 BACKGROUND

This Technical Paper presents the findings of the Power Generation Technology Review undertaken by Hongkong Electric Company, Limited (HEC) and has been prepared for submittal as part of the Stage 1 EIA to address the requirements set out in the Hong Kong Government's *Study Brief for the Stage 1 EIA (or EIA of Alternative Sites and Fuels) for a New Power Station Proposed by HEC.*

The Stage 1 EIA is to be overseen by the Hong Kong Government's Environmental Protection Department (EPD) and will be undertaken as an integral part of the proposed Site Search Study that is to be conducted under a separate Study Brief. The Site Search Study will be overseen by the Planning Environment and Lands Branch (PELB) of the Hong Kong Government and will incorporate the findings and recommendations of the Stage 1 EIA as well as discussions of wider implications for non-environmental issues.

As part of the Stage 1 EIA study, the Power Generation Technology Review serves to provide an environmental comparison on the impacts arising from different power generation technologies and identify the most environmental friendly technology and design for each of the two fuel options: coal and pipeline natural gas.

The findings of the Review will be fed into the Site Search Study and will be reported as part of Technical Report No. 1 (TR No.1) on Fuel, Power Generation Technology and Design, which will recommend the preferred technology and design for each fuel option. As the most environmental friendly power generation technology may not be the same as the preferred technology recommended in TR No. 1, this Technical Paper will also comment upon the maturity of the power generation technologies so as to arrive at a proposed power generation technology and design to form the basis for subsequent Stage 1 EIA Study. Justification of the proposed technology and design will be detailed in TR No.1.

This Technical Paper outlines generic gas emissions, water quality impact and solid waste by-product arising from the new power station based on different power generation technologies. The generic measures required to mitigate these environmental impacts are identified.

During Phase III of the Stage 1 EIA, a more detailed environmental evaluation of the shortlisted sites for the proposed/preferred technology and design for each fuel option will be conducted and mitigation measures will be proposed.

1.2 STRUCTURE OF THE REPORT

The remainder of this Technical Paper is structured as follows:

- *Section 2* provides the findings of the review of generation technology options for a coal fired power station;
- *Section 3* provides the findings of the review of generation technology

options for a pipeline gas fired power station;

- *Section 4* presents the conclusions of the review and identifies the selected generation technology for each of the fuel options.

2 COAL FUEL OPTION

2.1 INTRODUCTION

2.1.1 *Overview*

As the most abundant and economical fuel in the world, coal is currently the most widely used fossil fuel for power generation. Traditionally, coal is pulverised and introduced into a furnace where direct combustion converts water to steam which in turn drives a steam turbine generator to produce electricity. Such conventional pulverised coal-firing has been demonstrated to be a proven and reliable technology for power generation.

In line with the worldwide recognition of the need to minimise the environmental pollution implications of coal combustion, advanced environmental control measures have been developed to improve the environmental acceptability of coal-fired power stations. In parallel, the past two decades have seen the expenditure of considerable effort by the power sector and related industries to develop clean and efficient coal burning technologies. So-called *Clean Coal Technologies* have received widespread interest and a number of solutions with different degrees of success have emerged; some of these solutions have entered commercial operation in the past decade.

2.1.2 *Power Generating Technologies*

New coal-based technologies include fuel cells, magnetohydrodynamics, ultra clean coal, underground coal gasification, coal diesel and external coal fired combined cycle. However, these technologies are still in a very early stage of development with small units of capacity ranging from several hundred kW to a few MW sizes under testing and research, and hence are not worth to be considered in this Study. The power generation technologies with coal as the primary fuel that are commercially or would be commercially proven can be broadly classified as:

- Pulverised Coal-firing (PC)
- Fluidised Bed Combustion which comprises two variants:
    - Circulating Fluidised Bed Combustion (CFBC) and
    - Pressurised Fluidised Bed Combustion (PFBC)
- Integrated Gasification Combined Cycle (IGCC)

The first two technologies, PC and the Fluidised Bed systems, involve the direct combustion of coal to produce energy for the generation of steam to produce electricity. The third option, IGCC, involves the conversion of coal to a gaseous fuel through a pre-combustion gasification process, followed by the combustion of the synthesis gas, or *syngas*, in a gas turbine to produce electricity. The waste heat in the gas turbine exhaust gas is also recovered to generate steam for secondary production of electricity, hence the term combined cycle (gas and steam cycles combined). The fluidised bed combustion and integrated gasification combined cycle technologies are often classified as *Clean Coal Technologies* as the pollutants inherent in the combustion of coal are avoided.

Each of these three alternative coal-fired power generating technologies is examined separately and then compared in the sub-sections that follow.

2.2 MODERN PULVERISED COAL FIRING PLANT

2.2.1 General

In a conventional pulverized coal-firing (PC) plant, coal is ground (*pulverized*) into fine particles in a coal pulveriser and is then fed to a boiler furnace where it is burnt with an excess supply of air to ensure complete combustion. The heat produced from the combustion process is utilised to convert water to steam. The steam is generated under high pressure and temperature in the boiler and is fed to drive a steam turbine which in turn drives a generator to produce electricity. Flue gas from the furnace is passed through 'scrubbing' equipment to remove certain dirty gaseous by-products before discharge via a tall chimney to the atmosphere. A schematic representation of a modern pulverised coal-firing plant is shown in *Figure 2.2a.*

Although coal itself is the cheapest of all fossil fuels, conventional PC power plants require the installation of costly environmental control facilities in order to mitigate environmental impacts and to meet modern stringent control standards; these additional costs have rendered conventional PC less competitive and has resulted in other forms of coal firing receiving more recent attention in many parts of the world. However, the current review has indicated that developments in the pulverized coal-firing technology and associated environmental mitigation measures in the past two decades have ensured that conventional PC remains one of the most reliable, cost-effective and environmentally acceptable solutions for large capacity power generation.

The primary objective of recent developments in PC technology has been an improvement in the overall economics of the technology. This has resulted in two specific outcomes:

- In order to reduce the specific construction and operation costs per unit energy produced, there has been an increase in the size of power station machines; and
- An increased emphasis on the maintenance of generating output whilst reducing the amount of fuel being consumed through efficiency improvements.

This latter emphasis has led to substantial improvements in the cycle efficiency of the steam power plant by increasing the steam conditions to the highest tolerable by the plant equipment without exceeding the metallurgical limits. Steam conditions are increased to *supercritical* pressure at very high steam temperatures, under which there is physically no difference between the liquid and gas phases. This has been realised through advances in the material technology applied to the production of plant components allowing them to operate under severe steam conditions while maintaining the same reliability as the conventional *subcritical* steam power plants.

Large supercritical PC units of capacities ranging from 500MW to 1,000MW with supercritical steam pressure at 246 bar and main/reheat steam temperatures of 566°C or over, are recognised as one of the most efficient and cost-effective

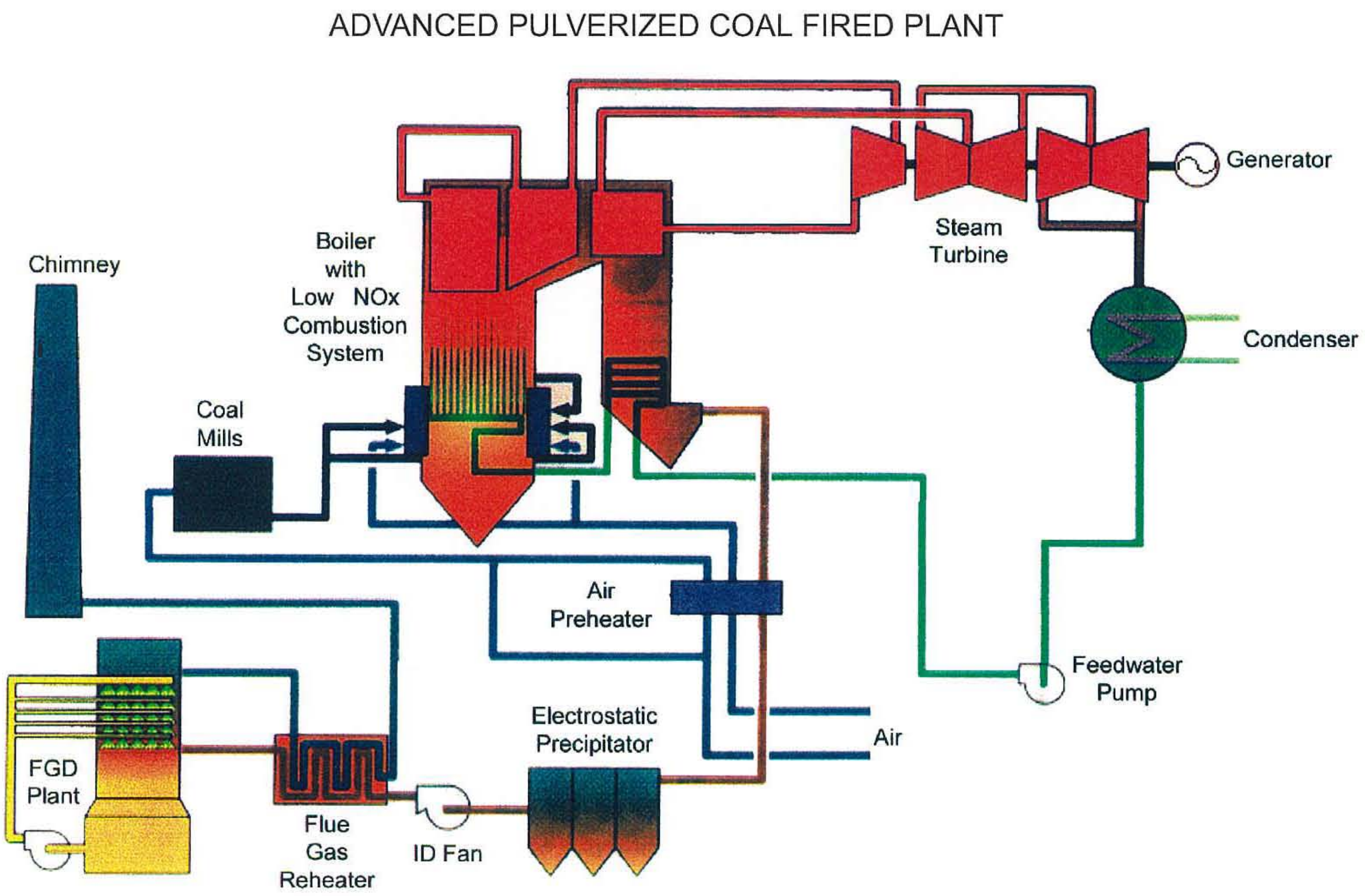

FIGURE 2.2a - A SCHEMATIC REPRESENTATION OF A MODERN PULVERISED COAL-FIRING PLANT

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design options and have been adopted in many of the large capacity power plants recently built in Japan. The adoption of this technology is in line with the Japanese Government's policy to advocate high efficiency power generation as Japan is a country with nearly 100% reliance upon imported fuel. The capital investment for a typical 600MW class generating unit operating under supercritical steam conditions is only about 5% higher than a subcritical unit of similar capacity, but the cycle efficiency is 3% (absolute) higher resulting in fuel savings over the life of the plant, which outweigh the additional capital investment, whilst reducing the emission of pollutants. With the development of high strength steel materials, the cycle efficiency can be further improved by adopting even higher steam temperatures of about 600°C.

In the sections that follow the major equipment required for a 1,800MW supercritical pulverized coal-firing power plant are described.

2.2.2 *Generating Unit*

Boiler Plant

The main function of the boiler is to utilise the heat produced in the combustion of coal to convert water into steam. It consists of a large furnace made up of a large number of membrane wall tubes where combustion of coal takes place. Water passing through the membrane wall tubes is heated to steam which then passes through superheaters to become superheated steam before going to the steam turbine. Steam condition of 24.6 MPa and superheated steam temperatures of 566°C is commonly adopted.

Since the combustion of coal in the boiler furnace is at very high temperatures of over 1,000°C, oxides of nitrogen (NO_x) which is one of the main acid rain contributors will inevitably be formed. In addition, the nitrogen compounds in the coal itself will further increase the NO_x production to a level which may be of environmental concern. However, a modern boiler will normally be fitted with state-of-the-art low-NO_x combustion features including advanced low-NO_x burners and an over-fired air system to minimize NO_x formation during combustion in the furnace. Since the amount of excess air is critical for NO_x production, the coal pulverisers are designed to achieve high coal fineness thereby reducing the amount of excess air required in the furnace for complete combustion and producing less NO_x. These features can help reduce NO_x production by more than 60%. An NO_x emission level of 150 - 180 vppm (based on 6% O_2) of flue gas at the boiler outlet can now be achieved.

Figure 2.2b illustrates a typical arrangement for a supercritical boiler plant.

Turbine Plant

The steam turbine is a rotating machine comprising a series of turbine blades. Steam generated from the boiler passes through the blades and drives the turbine which is in turn connected to an electricity generator. To improve the aerodynamic efficiency of the turbine, advanced blade design such as full three-dimensional blade profiles and long last stage blades are adopted.

After driving the turbine, the exhaust steam enters a large heat exchange condenser to convert back to condensate water for pumping back to the boiler to complete the thermal cycle. Sea water will be used for the cooling process and discharged back to the sea through an open cycle cooling water system.

Adopting supercritical steam conditions, the turbine heat rate can be improved substantially and a gross unit efficiency of 43% or above, based on higher heat value (HHV) of coal, is commonly achievable.

2.2.3 *Ancillary Plant*

Coal Handling Plant

For coastal power stations, coal is delivered by ocean-going vessels which will berth along a fuel jetty designed to accommodate large capacity colliers. For faster and more efficient coal unloading, continuous ship unloaders may be installed to unload the coal which is then transferred by belt conveyors to a coal storage yard.

For the maintenance of Hongkong Electric's system generation reliability, a strategic storage capacity of six weeks coal consumption (at peak demand) is desirable. On the basis of the coal stock at the existing Lamma Power Station and the fact that the new power units will be on base load, a coal stock level of about 500,000 tonnes for the new power station may be required.

Coal storage yards have been widely adopted for coal-fired power stations due to ease of construction, ready maintenance and low capital cost. Stacker/ reclaimers will be installed to reclaim the coal from the coal yard. The coal will then be transferred to each unit through pipe conveyors or similar enclosed belt conveyors thereby minimizing the generation of fugitive dust during the operation of the coal handling system. Fugitive dust is further suppressed with a system of water spraying guns installed around the perimeter of the coal yard. The coal yard run-off will be collected and recycled for coal yard water spraying.

As an alternative, coal silos of significant higher capital cost may be installed where space constraints exist such as for an extension of the in-service power station. Area required for coal silos will be less than half of that for coal storage yard of similar storage capacity. The initial concept would be to build a number of silos of unit capacity 60,000 tonnes each probably in two stages to match the installation programme of the generating units. Due to operating in a closed environment, coal silos are in general considered more environmentally friendly.

Cooling Water System

A once-through cooling water system will be adopted. Sea water will be extracted from one side of the site and discharged to the other side after passing through the condensers. The intake and discharge points will be well separated to avoid recirculation of the cooling water. The cooling water flow required for 1,800MW plant will be around $66m^3$/sec (see *Annex B* for calculation of cooling water requirement).

Fuel Oil System

Light gas oil with sulphur content less than 0.5% will be used for boiler start up and flame stabilization. A fuel oil system consisting of a berth, oil tanks, fuel oil pumps and piping system would be installed for the unloading, storage and transferring of the light gas oil.

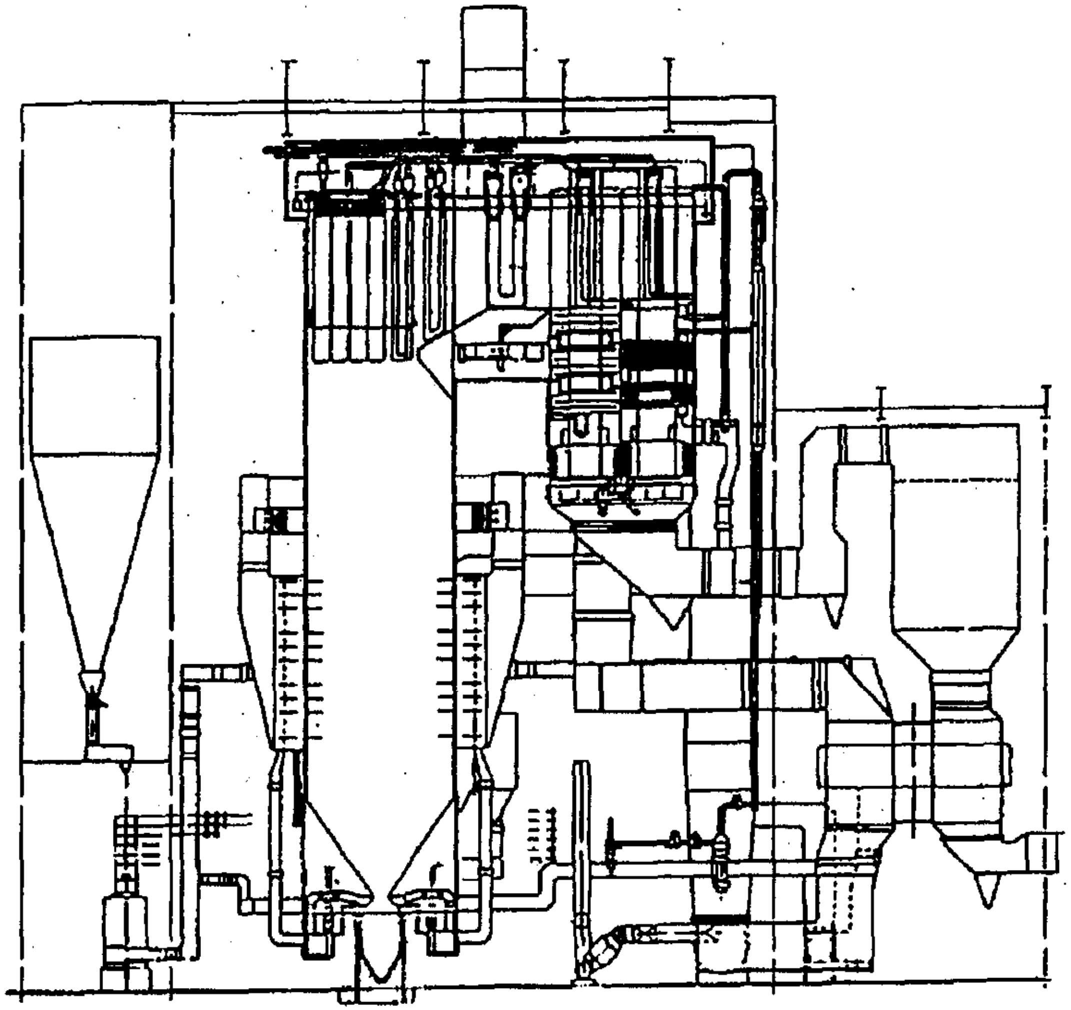

FIGURE 2.2b - A TYPICAL ARRANGEMENT OF A SUPERCRITICAL BOILER PLANT

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Raw Water Supply System

Major water consumption in a coal-fired plant includes demineralised water supply for the steam cycle and make-up, maintenance use, plant washing, fire services system, air-conditioning system and potable water system. Depending on the site location, submarine water pipelines may have to be installed to supply water to the power station site.

2.2.4 *Environmental Control Facilities*

Electrostatic Precipitator

Over 80% of the ash from the combustion of coal is entrained in the flue gas. The flue gas leaving the boiler will pass through electrostatic precipitators of over 99% removal efficiency to control particulate emissions. Inside the electrostatic precipitators there are a large number of electrodes. The entrained particulate in the flue gas will be attracted by the electric field and eventually collected in the hopper at the bottom of the electrostatic precipitators. Further reduction of the particulates in the flue gas will be achieved through the use of an FGD plant (see below). The combination of these measures will achieve very low dust emission levels in the range of 20 to 30 mg/Nm^3. Despite the introduction of fabric filtration as an alternative flue gas cleaning technology, electrostatic precipitation is still widely accepted as the most popular and reliable flue gas cleaning technology.

Baghouses

As an alternative to electrostatic precipitation, fly ash from the flue gas can be removed by means of fabric filtration using baghouses. The baghouses are designed in such a way that when flue gas enters the baghouse, it will follow a specific flow path and pass through a number of filter bags inside the baghouses. The filter bags are made of surface filters which can effectively collect the entrained ash in the flue gas onto its surface. The ash will eventually be collected in the hopper at the bottom of the baghouses. Baghouses can achieve a particulate emission level of 20 to 50 mg/Nm^3. It has a lower capital cost than electrostatic precipitator but the filter bags require regular replacements. Baghouse will therefore have a higher operating and maintenance costs comparing with electrostatic precipitator.

Flue Gas Desulphurisation Plant

The presence of sulphur in coal leads to the formation of sulphur dioxide during the combustion process. Removal of sulphur dioxide from the flue gas downstream of the backend of the boiler is commonly adopted using flue gas desulphurisation plant (FGD). FGD plant of the wet limestone-gypsum type, capable of removing up to 95% of the SO_2 generated from the combustion process, is commonly adopted in many other installations in the world. This type of FGD was also installed in the recent units in Lamma Power Station and its reliability and high SO_2 removal efficiency have been demonstrated. Furthermore, a complete package design could be pursued whereby the backend environmental control facilities including electrostatic precipitators, FGD absorption tower and gas heaters will be arranged in one compact package to reduce land requirements and to enhance FGD efficiency. The combustion gases from the boiler pass through the electrostatic precipitator and then come into contact with limestone slurry in the FGD absorption tower. The limestone reacts with the sulphur dioxide in the flue gas to form gypsum as a usable byproduct, while the 'scrubbed' gas is discharged to the atmosphere through a chimney of sufficient height to ensure adequate dispersion.

Limestone powder for the FGD process is stored in silos. Gypsum produced by the process will be stored in the gypsum silos prior to disposal for commercial use such as cement making and also as a raw material in the manufacture of wall- and plaster-board.

NO_x Control

Low-NO_x Combustion System

The latest low-NO_x combustion technology, consisting of advanced low-NO_x burners and staged combustion in the furance, together with improved coal pulverisers and strict control of air supply, can achieve a reduction in NO_x levels of around 60%. The merit of this method is that it is a simple and direct reduction in the combustion process and does not require any chemical or catalyst for chemical conversion of NO_x.

De-NO_x Plant

In addition to low-NO_x combustion system, further reduction of NO_x from the flue gas is possible by installing a De-NO_x plant at the backend of the boiler. The most cost effective process is the Selective Catalytic Reduction (SCR) process. In the SCR De-NO_x reactor, ammonia is injected to the flue gas causing the NO_x to be converted at the catalyst surface into nitrogen and water. Depending on the degree of NO_x reduction achieved in the boiler combustion system, design of the SCR process can be optimised. A NO_x removal efficiency of 65% is often adopted in similar installations in industrialised countries. An outlet NO_x level as low as 60 vppm can be achieved. For a 1,800MW plant with a 65% removal efficiency De-NO_x facility, about 13 tonnes of ammonia will be consumed per day. The ammonia gas has to be imported from other countries and stored in the power station. Moreover, about 80% of the catalyst has to be replaced for every 10 years operation. In addition to the initial capital investment of a De-NO_x facility, the operating cost associated with the large consumption of ammonia and periodic catalyst replacement is high, it would therefore be prudent to also look into the economical impact in addition to environmental consideration to justify the necessity of a De-NO_x plant.

Waste Water Treatment Plant

An effluent management scheme can be formulated to minimise the generation of effluent through proper design and to maximise reuse of effluent that would inevitably be generated.

Surplus effluent will be treated in an advanced treatment process for precipitation of heavy metals, removal of total nitrogen, removal of suspended solid and neutralization to ensure compliance with established TM limits before discharging to the sea.

Ash Handling/Disposal Plant

When coal is burned, ash is produced in quantities which vary with the quality of the coal. For typical bituminous coal, the ash content ranges between 8 to 15%. About 90% of the total ash produced will be of fine dust size and precipitated out from the flue gas through the electrostatic precipitators. This is commonly termed *pulverized fly ash* (PFA). The other 10% of the ash is of relatively larger size that cannot be carried away in the flue gas but falls to the bottom of the furnace where it sinters to form a coarser material known as furnace bottom ash (FBA).

Both the PFA and the FBA can be beneficially used for manufacturing of cement, production of concrete or as a filling material. However, it would be expedient and prudent at the planning stage to cater for contingency storage of ash. An ash lagoon is commonly constructed for this purpose. The ash lagoon can be of impermeable or semi-permeable design to minimize migration of leachate to the sea.

The expected production of ash from a 1,800MW coal-fired plant is around 570,000m^3 per year (see *Annex B* for calculation of ash production). On the basis of desirable economies of scale that minimize investment costs per tonne of ash to be handled, it is desirable that the ash lagoon's design capacity should be sufficient to accommodate several years of ash production; in circumstances where there are space constraints, shorter ash production periods may need to be accepted. To further prolong the operating life of the lagoon, facilities will be provided for harvesting of the ash for use as general fill for other infrastructure projects in the territory.

The transfer of both PFA and FBA to the lagoon can either be in conditioned dry form or wet slurry form depending on the detailed design of the disposal system. After discharging into the lagoon the ash settles and consolidates under its own weight.

2.2.5 *Plant Efficiency*

A gross unit efficiency of 43% or above can commonly be achieved for a 600MW class pulverised coal-firing unit operating at supercritical steam conditions of 24.6MPa and superheat/reheat steam temperatures of 566°C as demonstrated in existing commercial installations. Assuming an in-house power consumption of 8% for the common auxiliaries including the coal handling plant, cooling water system, ash handling and disposal plant, as well as the FGD plant, the net plant efficiency will be around 40%.

2.3 *INTEGRATED GASIFICATION COMBINED CYCLE (IGCC)*

2.3.1 *General*

IGCC is a gas turbine combined cycle power plant coupled with a coal gasifier. Coal is converted to synthesis gas (*syngas*) through a special process in the gasifier where the carbonaceous substances in the coal are partially oxidized under high pressure and temperature to form CO and H_2. This syngas is then combusted in a gas turbine to produce electricity. The resulting exhaust gas is passed to a heat-recovery steam generator to produce steam, which in turn drives a steam turbine for secondary electricity production. During the coal gasification process, before the syngas enters the gas turbine, most of the residual substances, such as sulphur and ash, are removed. Modern gas turbine design can also control combustion to achieve very low NO_x levels in the exhaust gas. There are currently four medium capacity IGCC plants in operation in the USA and Europe. The largest plant has a capacity of just over 250MW. All these projects are developed under demonstration programmes funded by grants from government/international agency. It is claimed by some suppliers that a net plant efficiency of up to 43% can be attained. *Figure 2.3a* shows a typical IGCC process.

2.3.2 *Generating Unit*

Coal Gasifier

The gasification of coal is a lean combustion process since the fuel is present in excess relative to the amount of oxidizing air or oxygen. The syngas produced in the gasification process contains mainly CO and H_2. To generate the gas, coal is fed either in dry form as coal powder or wet slurry form to the gasifier and heated to between 800°C and 1600°C under high pressure. Oxygen and steam are injected to the gasifier to make the conversion.

Three basic types of gasifiers (fixed bed, fluidized bed and entrained flow) are available to be integrated into a combined cycle power plant. Among the three types of gasifiers, entrained flow gasification process is able to provide the highest overall IGCC plant net efficiency and hence is commonly adopted for power generation. The other two types of gasifiers have not been further developed for power generation purpose due to their low coal gasification efficiency compared with entrained flow gasifiers.

Entrained flow gasifiers use very fine-grained coal of less than 0.1mm for feeding to the gasifier either in the form of dust or slurry. This type of gasifier operates at high temperatures which enable the non-convertibles, or the ash, to flow out of the gasifier in the form of slag.

Combined Cycle Plant

The syngas will first be cleaned to remove all harmful and non-combustible substances (see *Section* 2.3.4 below) before feeding to the gas turbine. The cleaned syngas will be mixed with compressed air and burned in the combustion chamber of the gas turbine. Nitrogen (from an air separation plant), and sometimes steam, is injected to control the formation of NO_x to very low levels. The hot gas from combustion then drives a gas turbine and generator whereby the heat energy is converted into mechanical and electrical energy. The exhaust gas from the gas turbine which is still at a high temperature (between 500 to 600°C) is passed to a Heat Recovery Steam Generator (HRSG) to recover exhaust heat which can be sensibly utilised. Steam from the HRSG is used to drive a steam turbine and generator. Except for the gasifier portion, operation of the power block itself is similar to a conventional gas-fired combined cycle power plant.

2.3.3 *Ancillary Plant*

Air Separation Unit (ASU)

The air for the ASU, which operates at high pressure, is extracted from the gas turbine compressor. The ASU cryogenically separates air into oxygen and nitrogen. Oxygen is supplied to the gasifier for coal gasification to produce syngas with a reasonable calorific value (ie small gas volume with high energy content) for further combustion in the gas turbine combustion chamber. Nitrogen, as a by-product of the gas gasification process, is also fed to the gas

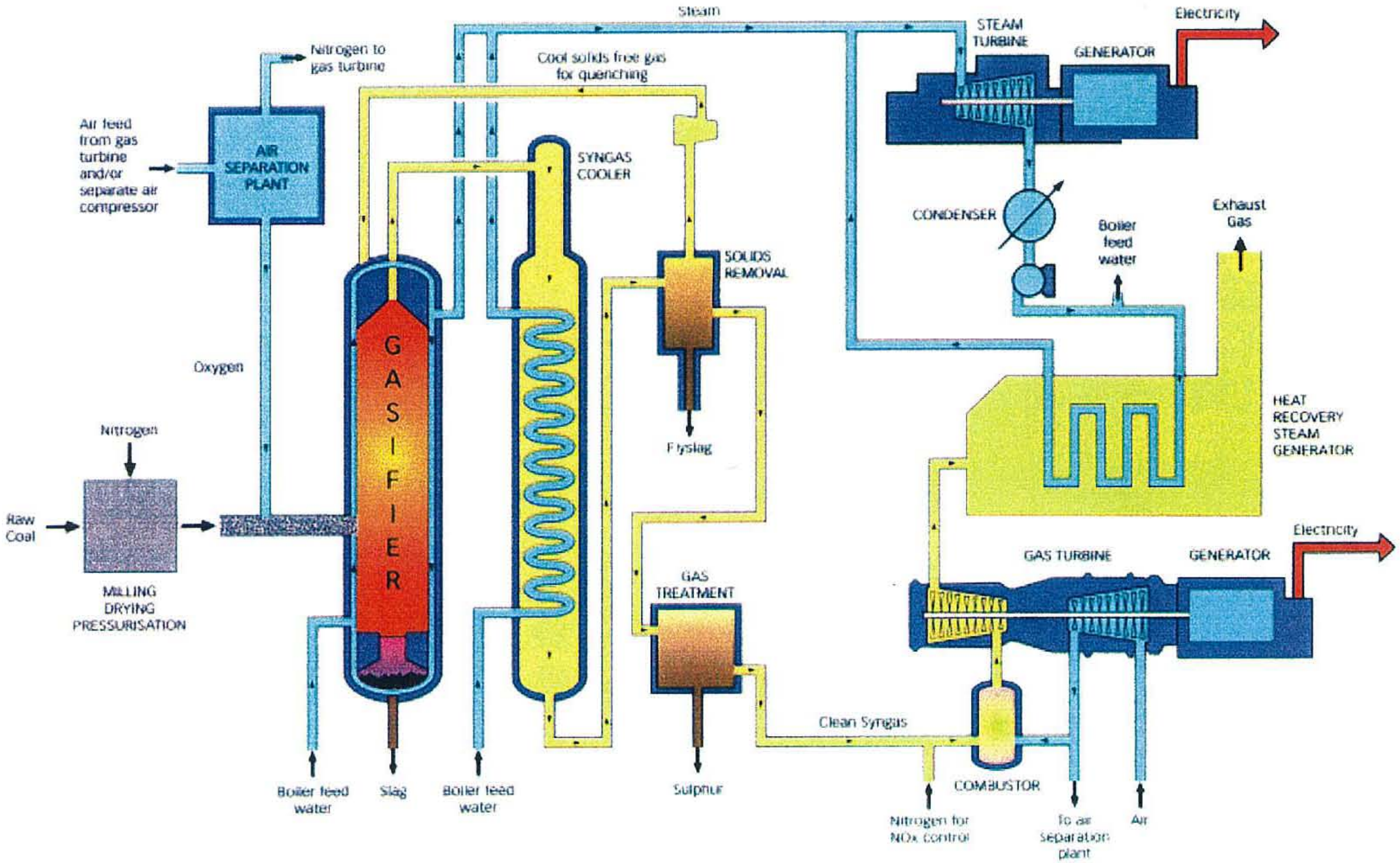

FIGURE 2.3a - A TYPICAL IGCC PROCESS

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turbine combustion chamber to lower the firing temperature of syngas in order to suppress the formation of NO_x and increase the mass flow of hot gas through the gas turbine for more power output. It is claimed that NO_x emission level of about 75 vppm (based on 6% O_2) can be achieved.

Other Ancillary Plants

The following ancillary plants will be required for a 1,800MW IGCC plant:

- ***Coal handling plant:*** Similar design and capacity as that described above for the pulverised coal-firing plant; coal consumption for the two plant types is broadly the same.

- ***Cooling water system:*** Cooling water flow required will be approximately half that required by the pulverised coal-firing plant as only 45% of the power is generated from condensing steam turbine. Hence, a smaller capacity cooling water system will be required.

- ***Fuel oil system:*** Similar to pulverised coal-firing plant; the fuel oil system is required for start up purposes as the gasifier needs to be heated before the gasification process can begin.

- ***Raw water system:*** Raw water consumption will be less than that of pulverised coal-firing plant due to smaller steam cycle plant.

2.3.4 *Environmental Control Facilities*

Gas Clean-up System

For IGCC plants, gas cleaning is carried out before combustion and not after. Since the syngas volume is only about 2% of the combusted gas volume, a much smaller gas cleaning plant is required compared to the flue gas scrubbers required for pulverised coal-firing plants. The reducing atmosphere of the gasifier leads to the formation of hydrogen sulphide (H_2S) and carbonyl sulphide (COS) as by-products instead of SO_2. A cold gas cleanup system is normally adopted in which the raw syngas is cooled to about 40°C. After the removal of fly ash by filtering or cycloning, the cooled gas goes to a gas treatment plant for the removal of sulphur through a series of chemical process. The sulphur removal efficiency is normally over 90% and higher efficiencies of up to 99% are claimed to be achievable for coal of high sulphur content (3 to 4%). The end by-product is elemental sulphur. In countries where IGCC are in operation, this sulphur by-product is being used for making sulphuric acid (H_2SO_4); however, as there is no ready chemical industry market in Hong Kong, the sulphur may need to be disposed of as a chemical waste or exported overseas for industrial utilisation.

Waste Water Treatment Plant

Waste water that is produced mainly from the gas cleanup system will be treated (precipitation of heavy metals, removal of total nitrogen and suspended solids, and pH adjustment) in an advanced treatment system to ensure that the effluent discharged will meet regulatory requirements.

Ash Handling/Disposal Plant

Most of the non-convertible ash will be removed from the coal gasifier in the form of molten slag. For a 1,800MW power plant, the quantity of slag formed will be about 400,000 tonnes per year. For some overseas plants the slag is being used off-site as a filling material or for concrete production. Similar use of the slag could be explored in Hong Kong, but an ash lagoon will be constructed as a fall back disposal arrangement.

2.3.5 *Plant Efficiency*

Based on the information obtained from existing installations, IGCC plants require large auxiliary power consumption due to the need for a large capacity air separation plant and the net plant efficiency achievable is only about 41%. A summary of the plant efficiencies for some existing installations is given in *Table 2.3a*.

It should be noted that the state-of-the-art Puertollano IGCC Plant is scheduled for commissioning at the end of 1997 and therefore it has yet to be demonstrated that the design net plant efficiency of 43% is achievable. In fact, whether or not the IGCC plant efficiency can be boosted up to over 43% in future as claimed by some of the manufacturers would depend on a number of factors such as the application of hot gas cleaning, air blown coal gasification technology and further increase in efficiency of the gas turbine combined cycle plant.

Table 2.3a *Summary of plant efficiencies for IGCC plants*

	Wabash River USA	Pinon Pine USA	Tampa Electric USA	Buggenum Netherlands	Puertollano Spain
Gross Plant Output/MW	297	107	313	285	335
Auxiliary Power, MW	35	7 (no ASU)	63	32	35
Net Plant Output, MW	262	100	250	253	300
Net Plant Efficiency (HHV)%	38	40.7	40	41	43

2.4 FLUIDIZED BED COMBUSTION

2.4.1 *General*

Fluidized Bed Combustion (FBC) is a technology initially developed for combustion of a wide variety of fuels and wastes. The fluidised bed is essentially a holding vessel containing a mixture of predominantly inert material. The majority of the bed materials (over 90%) are non-combustible materials, mainly ash and limestone, while the coal feedstock constitutes about 10%. The mixing bed is supported by a uniformly perforated base plate through which air is supplied. This fluidizing air provides the oxygen, time and turbulence required for efficient combustion. As the air velocity increases, the bed material is forced upward and becomes suspended; rapid mixing of particles occurs, and the bed surface is no longer well-defined.

Gas or oil preheat burners warm the bed to between 540°C to 700°C, depending on the design and the type of fuel fired. The temperature ultimately rises to between 700°C to 850°C at which combustion of the coal takes place and the chemical reaction becomes self-sustainable.

Removal of sulphur originating in the fuel which would otherwise be oxidised to sulphur dioxide, is achieved by the addition of limestone to the bed. As the bed operates at temperatures in the region of 700-850°C, the limestone can achieve optimum binding of the sulphur present. It is claimed that up to 95% of sulphur can be removed in this way. The low combustion temperature of less than 850°C in the bed also helps in reducing the amount of NO_x formation to low levels of about 100-150 vppm.

There are basically two types of FBC systems appropriate to coal fired power production: *Circulating FBC (CFBC)* and *Pressurised FBC (PFBC)*.

2.4.2 *Circulating Fluidised Bed Combustion*

In the CFBC process, fuel and limestone are fed into the lower part of the combustion chamber in the presence of fluidizing air flows, which causes the fuel and limestone bed material to rise, circulate and enter the hot cyclone separator. Bed materials including any unburned fuel, are separated from the flue gas in the cyclone and reinjected into the combustion chamber. Continuous circulation of solids through the system provides long fuel residence time, resulting in very efficient combustion. Similar to the conventional coal-fired boiler, the CFBC boiler consists of a large furnace made up of membrane wall tubes and a large number of tube panels. The heat of combustion in the fluidised bed furnace is utilised to convert water to steam which is used to drive a steam turbine connected to a generator for power generation. *Figure 2.4a* illustrates a typical schematic diagram of CFBC.

The main advantages of CFBC plants are that very low grade coals can be burned and it is not necessary to install an FGD plant. It is therefore a more economical alternative to conventional pulverized coal-firing which requires FGD plant for SO_2 scrubbing. However, it has the inherent disadvantage of a high auxiliary power requirement for the recirculation of the bed material, making the plant efficiency less attractive when compared to advanced PC plants. Moreover, the flue gas moves at a speed of 5 to 8 m/sec carrying with it a large amount of fluidised bed materials consisting of limestone, ash and unburned coal. The materials carried along with the flue gas stream are separated in a hot cyclone and returned to the combustion chamber. Due to high flue gas velocity and temperature and the erosive nature of the bed materials, erosion of boiler tubes in the flue gas path is inevitable and is considered a general problem for CFBC plants. Hence, this type of FBC is mainly installed in places where there is indigenous low grade coal source nearby or where combustion of low grade fuels (such as waste derived fuel, wood, etc.) is required. The largest CFBC in operation is about 250MW.

2.4.3 *Pressurised Fluidised Bed Combustion*

PFBC consists of three basic components: a fluidized bed boiler; a gas turbine; and a conventional steam turbine. Coal is burned in the combustion chamber which is essentially a pressure vessel with an operating pressure between 1 to 3MPa, in the presence of a limestone sorbent for removal of sulphur compounds. Similar to the CFBC, the heat of combustion in the fluidised bed is utilised to convert water to steam which is used to drive a steam turbine connected to a generator. The combustion gases reach temperatures of around 850°C at high pressure and are cleaned as they leave the fluidised bed to remove entrained particulate in a series of cyclones followed by a hot gas filter. The cleaned gas then expands through a gas turbine which in turn drives a generator for production of electricity. About 80% of the plant output is generated from the steam turbine and the remaining 20% from the gas turbine. The largest PFBC unit currently in operation is less than 100MW. Due to the high pressure of the air and gas system, PFBC is more compact than other types of FBCs. *Figure 2.4b* illustrates a typical schematic diagram of PFBC.

2.4.4 *Ancillary Plant*

The following ancillary plants will be required for a 1,800MW CFBC/PFBC plant:

- ***Coal Handling Plant:*** Similar design and capacity as that described above for the pulverised coal-firing plant; coal consumptions are broadly the same.

- ***Cooling Water System:*** Cooling water flow required for CFBC plant will be broadly similar to the pulverised coal-firing plant while for PFBC, the cooling water required is reduced by 20% as 80% of the power is generated from the condensing steam turbine.

- ***Fuel Oil System:*** Similar requirements as those defined for the pulverised coal-firing plant; the fuel oil system is utilised for start up purpose.

- ***Raw Water System:*** Raw water consumption will be less than that of the pulverised coal-firing plant as FGD plant is not required.

2.4.5 *Environmental Control Facilities*

De-NO_x Plant

Low combustion temperatures of less than 850°C in the fluidised bed aids in reducing the levels of NO_x formation. Where more stringent emission levels are required, a De-NO_x plant may be installed to further reduce NO_x emissions. A typical design is to have a De-NO_x reactor installed along the gas path downstream of the gas turbine exhaust.

Waste Water Treatment Plant

A waste water treatment plant can be provided to treat the plant effluent to meet regulatory requirements prior to discharge. Since no FGD plant needs to be installed, the amount of plant effluent for FBCs is much less than conventional PC plants with FGD installed.

Ash Handling/Disposal Plant

Fly ash collected in the cyclones and ceramic hot gas filters (for PFBC) is continuously removed by a pneumatic transport system. The ash is cooled and a portion of the heat is recovered in the combustion air. The fly ash is fed to an enclosed conveyor system and transported to storage silos. Granular bed ash is

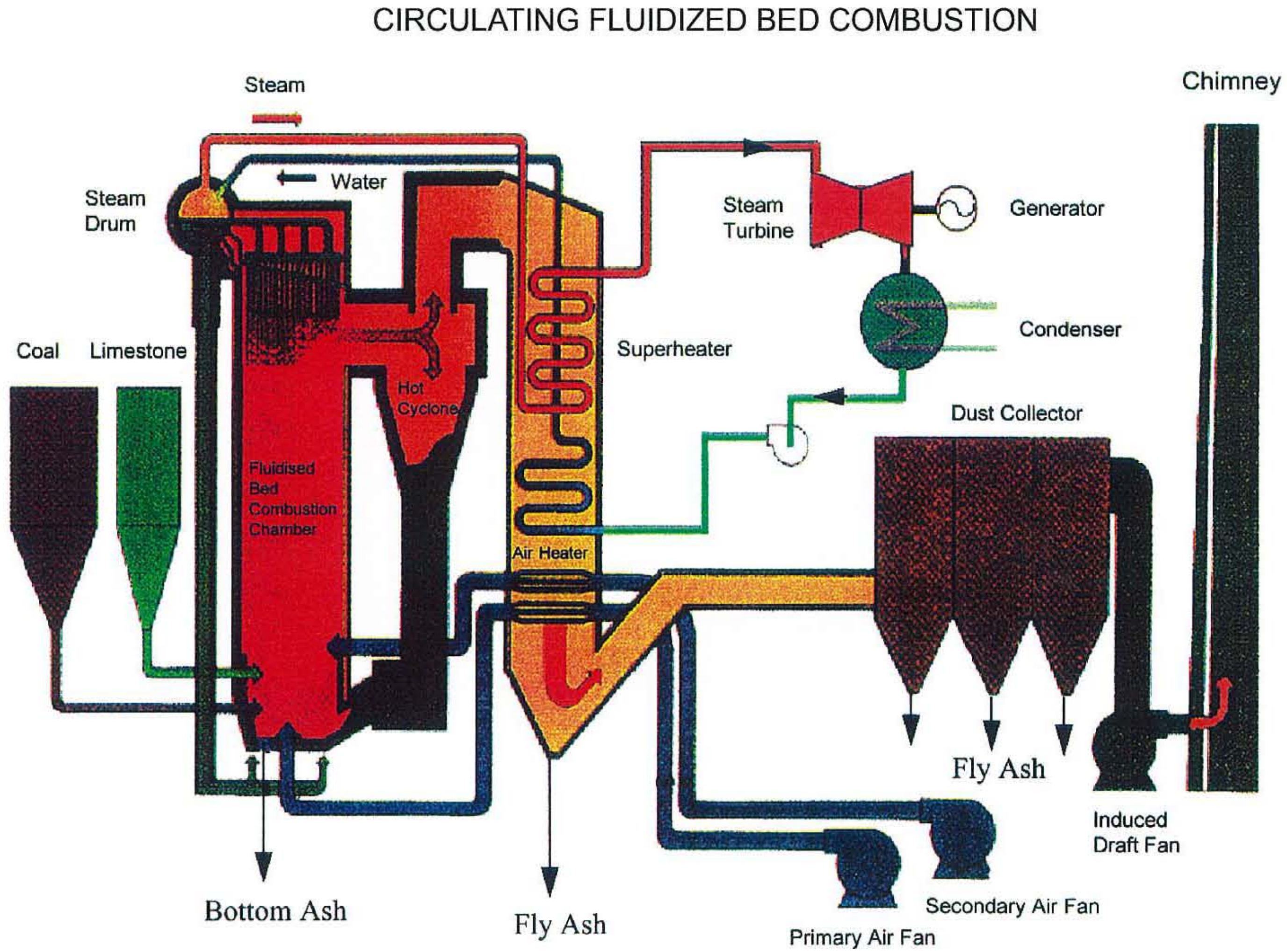

FIGURE 2.4a - A TYPICAL SCHEMATIC DIAGRAM OF CFBC

ERM-Hong Kong, Ltd
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong
ERM

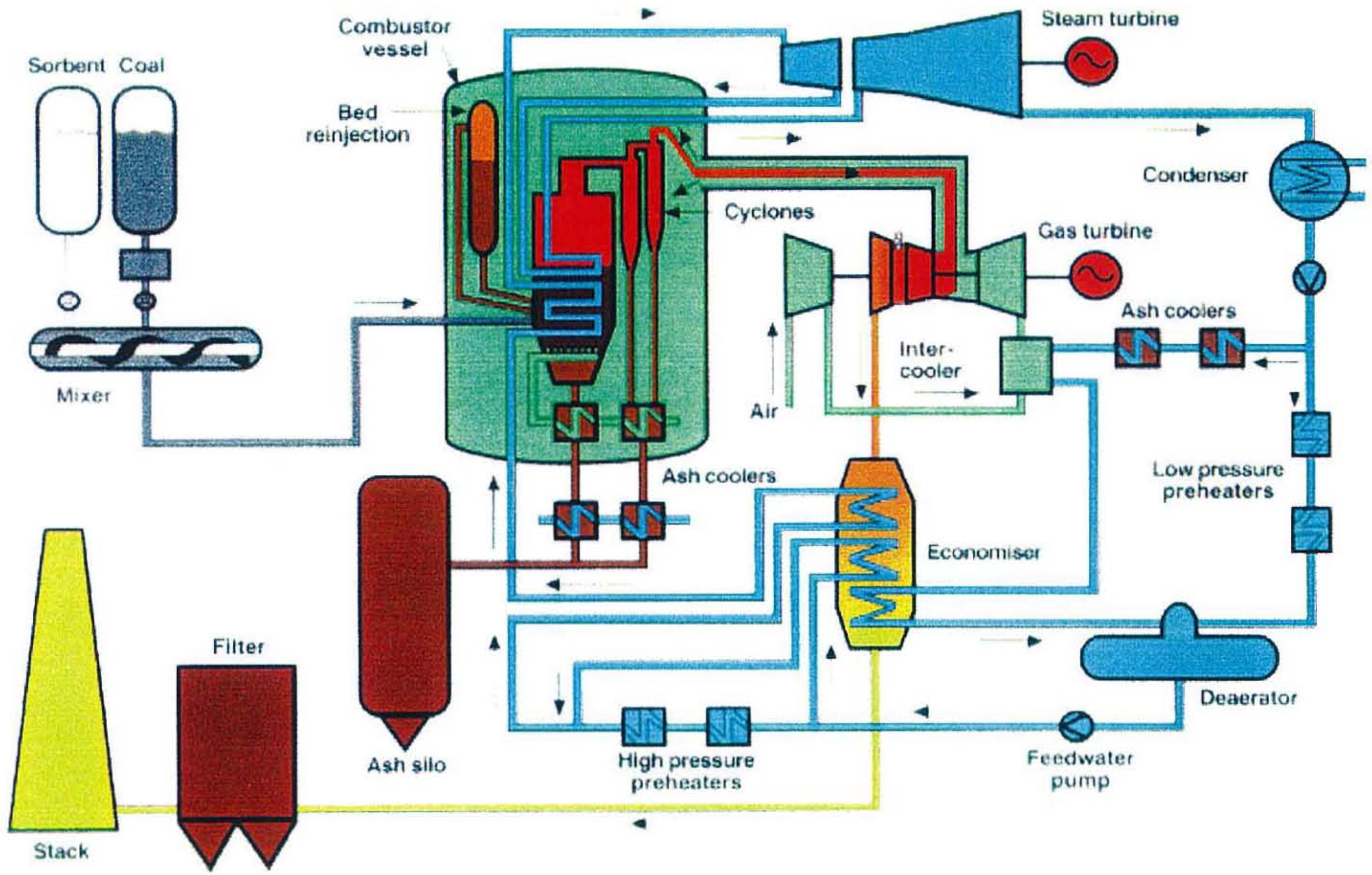

FIGURE 2.4b - A TYPICAL SCHEMATIC DIAGRAM OF PFBC

ERM-Hong Kong, Ltd

6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

continuously removed by gravity from the boiler bottom hoppers in order to maintain the desired fluidized-bed level. The ash is cooled by water and transported to storage basins for disposal.

As the ash is mixed with other bed materials, such as sand, limestone and calcium sulphate, the suitability of the ash for industrial usages or as land fill material has yet to be assessed. An ash lagoon may therefore be required for the contingency of long-term disposal of the ash.

2.4.6 *Plant Efficiency*

CFBC

Plant efficiency of CFBC is relatively low due to the high auxiliary power requirement for the recirculation of the bed materials; the net plant efficiency of CFBC plants is about 33 - 36%.

PFBC

Net plant efficiency of the first generation of PFBC plants currently in operation of capacity 70 - 80MW is about 35 - 38% as shown in *Table 2.4a*. The first 350MW PFBC plant is the Karita Plant which is under construction for Kyushu Electric Power Company in Japan. The plant is scheduled for commissioning in 1999 and is claimed to have a net efficiency of 41.6%. Future developments to further improve the overall efficiency will include additional fuel firing before expansion in the gas turbine to increase the gas inlet temperature, and the adoption of supercritical steam conditions in the steam cycle.

Table 2.4a ***Summary of Plant Efficiencies for existing PFBC Plants***

	Vartan Sweden	Escatron Spain	Tidd USA	Wakamatsu Japan	Tomato Azuma Japan
Commissioning Year	1991	1992	1992	1993	1996
Net Power Output, MW	(2 units) 135*	79.5	70	71	85
Net Plant Efficiency (HHV), %	85%*	36.4	35	37.5	38

Note * This is a co-generation plant with 135MWe and 224MWth output and an overall thermal efficiency of about 85%.

2.5 ENVIRONMENTAL ASSESSMENT

With coal as the primary fuel, the environmental impacts of a particular power generation technology depend mainly on the plant efficiency, the adopted environmental mitigation measures and their efficiency. The environmental assessment of the four power generation technologies is based on typical designs currently adopted; the typical specification for each of the coal-firing technologies is provided below.

Advanced PC: Net plant efficiency of 40% (HHV)95% removal efficiency FGD

	plant *Without De-NO_x* - Advanced low NO_x burners (LNB) to reduce NO_x emission to 370mg/Nm^3 (based on 6% O_2) *With De-NO_x* - Advanced LNB and 65% De-NO_x to reduce NO_x emission to 130 mg/Nm^3 (based on 6% O_2) EP & FGD to reduce particulate emission to 30mg/Nm^3
IGCC:	Net plant efficiency of 43% (HHV) 95% removal efficiency desulphurisation plant Low NO_x combustion gas turbine to reduce NO_x emission to 150mg/Nm^3 (based on 6% O_2) Cyclone & ceramic filter to reduce particulate emission to 20mg/Nm^3
PFBC:	Net plant efficiency of 42% (HHV) 95% in-furnace sulphur removal efficiency Low temperature combustion to reduce NO_x emission to 250mg/Nm^3 (based on 6% O_2) Cyclone & ceramic filters to reduce particulate emission to 20mg/Nm^3
CFBC:	Net plant efficiency of 36% (HHV) 95% in-furnace sulphur removal efficiency Low temperature combustion to reduce NO_x emission to 250mg/Nm^3 (based on 6% O_2) Cyclone & EP to reduce particulate emission to 50mg/Nm^3
Load factor:	0.8

Sulphur content in coal: 1% by weight.

2.5.1 *Air Quality*

The combustion of coal for electricity generation results in the production of a number of gaseous and particulate pollutants. The main pollutants are:

- Sulphur dioxide (SO_2)
- Oxides of nitrogen (NO_x)
- Dust Particulates
- Carbon Dioxide (CO_2)

The quantities of air pollutants generated from different power generation technologies are compared whilst their effects on ground level pollutant concentrations (for the preferred technology) will be assessed during Phase III of the Stage 1 EIA when the shortlisted sites are identified.

Sulphur Dioxide Emission:

Based on the worst scenario of burning coal with maximum allowable sulphur content of 1% by weight (as required by the EPD), the unmitigated SO_2 emission level will be around 2,000mg/Nm^3.

Advanced PC: With the adoption of FGD plant with 95% removal efficiency, the SO_2 emission can be reduced to 100mg/Nm^3. The adoption of supercritical steam conditions to enhance the plant efficiency can further lower the SO_2 emission by reducing the amount of coal consumption. For a modern 1,800MW coal-fired supercritical plant equipped with 95% removal efficiency FGD plant, the annual SO_2 emission is estimated to be 4,300 tonnes.

IGCC: The sulphur in coal is converted to hydrogen sulphide (H_2S) and carbonyl sulphide (COS) in the coal gasifier instead of SO_2 as coal is present in excess to the amount of oxygen. With the provision of gas cleaning facilities capable of removing 95% of the sulphur in the syngas, the SO_2 emission from combustion of the syngas in the gas turbine is reduced to 100mg/Nm^3. Due to high efficiency of IGCC, the annual SO_2 emission is around 4,000 tonnes for a 1,800MW plant.

PFBC: Limestone ($CaCO_3$) is directly injected to the fluidised bed where the chemical reaction to convert SO_2 to $CaSO_4$ takes place. The bed temperature of about 850°C in PFBC is in the temperature range for optimum Ca utilization and hence a high sulphur removal efficiency of 95% can be attained. This is equivalent to an emission level of 100mg/Nm^3. For a 1,800MW PFBC plant, the annual emission is estimated to be 4,100 tonnes.

CFBC: Continuous circulation of the bed materials results in efficient reaction between the limestone and SO_2 and a sulphur removal efficiency of 95% can be attained, equivalent to an emission level of 100mg/Nm^3. For a 1,800MW CFBC plant, the annual SO_2 emission is about 4,800 tonnes.

Comparison: All four power generation technologies can achieve an emission level of 100mg/Nm^3 which is lower than EPD's consent limit of 200mg/Nm^3. IGCC will produce the lowest amount of annual SO_2 emission followed by PFBC and advanced PC with CFBC having the highest emissions. The variations are mainly due to differences in the net plant efficiencies. However, it should be noted that the claimed high sulphur removal efficiency of 95% for IGCC, PFBC and CFBC is normally quoted for coals with high sulphur contents in the range of 2 - 4 % by wt. For HEC's case of burning coal with sulphur content less 1% by wt., it has yet to be proved whether such high removal efficiency can be achieved. On the other hand, for Advanced PC, proven track record of over 95% removal efficiency for low sulphur coal has been demonstrated for the wet limestone-gypsum FGD plant.

NO_x Emissions:

NO_x is present in the flue gas emissions from the combustion process as nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x is formed in two ways:

- Thermal NO_x results from nitrogen in the air supplied for the combustion process which combines with oxygen at high combustion temperatures.
- Fuel NO_x results from the fuel bound nitrogen in coal which is converted to NO_x during combustion.

The formation of NO_x is sensitive to high temperature and other factors such as excess air to fuel ratio and burner design.

Advanced PC: The unmitigated NO_x emission level for a conventional coal-fired boiler is around 1,000mg/Nm^3. With the adoption of advanced low-NO_x combustion systems, the emission level can be reduced by about 60% to 370mg/Nm^3. This is equivalent to an annual NO_x emission of around 15,500 tonnes for a 1800MW power station. The NO_x emissions can be further reduced to 5,400 tonnes/year by installing a 65% removal efficiency De-NO_x plant downstream of the boiler.

IGCC: The formation of NO_x in IGCC plant is suppressed by introducing nitrogen from the air separation plant to the gas turbine to lower the combustion temperature. Based on a typical NO_x emission level of 150mg/Nm^3, a 1,800MW IGCC plant will emit about 5,800 tonnes of NO_x per year. While a De-NO_x plant can in principle be fitted to the IGCC plant, it should be noted that all the IGCC plants currently in operation or under construction worldwide are not fitted with De-NO_x plant. It is because IGCC plant can already achieved very low NO_x emission levels which meet stringent regulatory requirements.

PFBC: Due to the low combustion temperatures of PFBC, very little thermal NO_x is formed. The major emissions are those emanating from the nitrogen in fuel and this is the main reason for the inherently low NO_x emissions from PFBC. Depending on the load, about 5 - 20% of the nitrogen in fuel can be converted to NO_x. Based on a NO_x emission level of 250mg/Nm^3, a 1,800MW PFBC plant will emit about 10,000 tonnes of NO_x annually. As PFBC plant will emit a low NO_x level, De-NO_x facility is not considered necessary. Only those PFBC plants burning low quality fuels and operating at higher bed temperatures will be required to install De-NO_x plant to reduce NO_x emission level.

CFBC: Similar to PFBC, the low combustion temperatures of CFBC results in low NO_x emissions of about 250mg/Nm^3. A 1,800MW CFBC plant will therefore emit about 11,600 tonnes of NO_x annually. Similar to PFBC, De-NO_x facilities is not considered necessary.

Comparison: All the four technologies can achieve a low NO_x emission level well below EPD's consent limit of 670mg/Nm^3. While the NO_x emissions from Advanced PC is higher than other three technologies, it should be noted that APC fitted with a 65% removal efficiency De-NO_x plant can achieve a NO_x emission level which is comparable to or even lower than that of IGCC plant. De-NO_x plants have recently been fitted to APC plants in countries with very stringent emission levels in place.

Particulate Emissions:

The average content of ash in coal from HEC's approved fuel suppliers is about 11%. Depending on the plant types, various percentages of the total ash will be entrained in the flue gas and emitted to the atmosphere.

Advanced PC: Over 80% of the ash from the combustion of coal is entrained in the flue gas as fly ash. With the adoption of electrostatic precipitator (EP) of over 99% removal efficiency together with FGD plant which can further remove the fly ash through the wet scrubbing process, the particulate emission in Advanced PC Plant can be reduced to 30mg/Nm^3. This represents an annual particulate emission of about 1,260 tonnes for a 1,800MW plant. Baghouse is not proposed as EP together with FGD plant can achieve similar particulate emission level as baghouse. Based on HEC operating experience over the past 15 years, it is considered that EP together with FGD can achieve a high reliability level.

IGCC: About 90 - 95% of the ash is removed from the gasifier in the form of molten slag. Most of the remaining ash in the syngas can be removed by wet scrubbing, cyclones and ceramic filters. Based on an emission level of 20mg/Nm^3, a 1,800MW IGCC plant will discharge about 780 tonnes of particulate per year to the atmosphere.

PFBC: The fly ash entrained in the flue gas is cleaned by cyclones and ceramic filters before expanding in the gas turbine. A low particulate emission level of below 20mg/Nm^3 can be achieved which is equivalent to an annual emission of about 800 tonnes of particulate for a 1,800MW plant.

CFBC: The fly ash entrained in the flue gas is removed by electrostatic precipitator of over 99% removal efficiency. Based on an emission level of 50mg/Nm^3, about 2,300 tonnes of particulate per year will be discharged to atmosphere for a 1,800MW CFBC plant.

Comparison: Particulate emissions from all the four technologies can basically meet the EPD's consent limit of 50mg/Nm^3. By using ceramic filters, IGCC and PFBC plants can achieve lower particulate emissions than Advanced PC and CFBC. However, it should be noted that the application of cyclones and ceramic filters for gas cleaning is relatively new and its reliability has yet to be proved.

CO_2 Emission

Irrespective of the power generation technologies, the combustion of coal will produce significant amounts of carbon dioxide as coal contains about 60 - 70% by weight of carbon. At present, there is no commercially available technology that can be practically adopted to remove or capture CO_2 emissions.

Advanced PC: Based on an average carbon content of about 65% by weight in coal, the annual CO_2 emission from a 1,800MW supercritical coal-fired plant is about 10.3 million tonnes.

IGCC: About 9.5 million tonnes of carbon dioxide will be produced from a 1,800MW IGCC plant.

PFBC: About 9.8 million tonnes of carbon dioxide will be produced from a 1,800MW PFBC plant.

CFBC: About 11.4 million tonnes of carbon dioxide will be produced from a 1,800MW CFBC plant.

Comparison: The higher the plant efficiency the less amount of coal will be consumed resulting in reduced CO_2 emissions. Hence, IGCC will produce the least amount of CO_2 followed by PFBC and Advanced PC, with CFBC having the highest emission.

Summary of Comparisons

Table 2.5a shows the emission levels from different technologies and indicates that IGCC produces the lowest emissions of SO_2, particulate and CO_2. For NO_x, APC fitted with De-NO_x plant will be able to reduce the NO_x emission to a level which is comparable to or even lower than that from IGCC.

Table 2.5a *A Comparison of Emission Levels from Different Plant Types with Coal as Primary Fuel*

Pollutant	APC Without De-NO_x	APC With De-NO_x	IGCC	PFBC	CFBC
SO_2 (t/yr)	4300	4,300	4000	4100	4800
NO_x (t/yr)	15500	5,400	5800	10000	11600
Particulate (t/yr)	1260	1,260	780	800	2300
CO_2 (million t/yr)	10.3	10.3	9.5	9.8	11.4

2.5.2 *Water Quality*

Power plants utilising coal as a primary fuel will produce water pollution of two main types: cooling water and plant effluents. Each of these is discussed separately below.

Cooling Water Discharge

For a steam cycle power plant, cooling water is required to condense steam from the steam turbine to water in a condenser. An once-through cooling water system extracting sea water from one side of the site and discharging it back to sea after passing through the condensers is normally adopted for coastal power plants. The designed temperature rise of cooling water is about 8 - 10°C above the intake temperature. The quantity of cooling water discharged and hence the heat released into the sea depends on the capacity of the steam power plant. For HEC's existing Lamma Power Station, a cooling water flow rate of 12.9m^3/sec is required for each 350MW unit.

Advanced PC: Based on the amount of heat rejected by steam exhausted to the condenser after passing through the steam turbine, about 66m^3/sec of cooling water is required for a 1,800MW steam power plant. Detailed calculations of the cooling water flow rate are given in the *Annex B*.

IGCC: For a 1,800MW IGCC plant, about 45% of the power is generated from the condensing steam turbine. Hence, the quantity of cooling water required is about 30m^3/sec.

PFBC: About 53m^3/sec of cooling water is required for a 1,800MW PFBC plant as 80% of the power is generated from the condensing steam turbine.

CFBC: Similar to the Advanced PC, about 66m^3/sec of cooling water is required for a 1,800MW CFBC plant as all the power is generated from the steam turbine.

Comparison: Advanced PC and CFBC will have higher cooling water discharge and hence higher heat released into the sea than PFBC and IGCC. However, for all the cases, it is believed that through proper engineering and design of the outfall and cooling water system (for example, diverting the discharge point away from the sensitive receivers, lowering the discharge velocity and temperature, etc) thermal impact of the cooling water discharge on the receiving water can be controlled to an environmentally acceptable level.

Plant Effluents

Some of the plant effluents are common to all four power generation technologies. These include:

- site surface drainage which is a direct discharge;
- coal yard run-off(where a coal storage yard is provided) which will be collected in settlement basin for coal yard water spraying to suppress fugitive dust; and
- various domestic effluents which will be discharged off site after suitable treatment.

Other plant effluents specific to the power generation technologies are described below:

Advanced PC: Plant effluents are generated from boiler startup discharge, water treatment plant, equipment drain, ash handling system, plant washing and FGD waste water. Quality of boiler startup discharge is comparable to town water and can be discharged to sea after quenching with sea water. With the exception of FGD waste water, all the other plant effluents can be collected in the recycle basin and can be fully utilised in the FGD system as well as for limestone slurry preparation for the FGD plant. The FGD waste water containing high levels of chloride, suspended solid, total nitrogen and heavy metals; these can be treated in an advanced waste water treatment plant in which heavy metals are removed by sulphide precipitation and total nitrogen by biological treatment process to meet the current regulatory requirements. It should be noted that while the technology of nitrogen removal by biological treatment process is relatively new, the development of such technology has received considerable attention in recent years particularly in Europe and Japan. Promising results have been obtained from a pilot plant for treating FGD effluent at the Averdore Power Station in Denmark which demonstrated that concentration of in-organic nitrogen can be reduced to 8mg/l under various conditions. HEC is actively seeking the latest technological advances in the biological nitrogen removal process in order to counter the technical challenges currently being addressed at the existing Lamma Power Station. The solutions developed will be applied to the new power station.

IGCC: Plant effluents from the steam cycle unit are generated from boiler blowdown, water treatment plant, equipment drain and plant washing. These effluents can either be reused or discharged after treatment to meet TM limits. Apart from the typical effluents from the steam cycle unit, waste water is generated from the syngas cleanup system consisting of a series of chemical treatment systems including the wet scrubbing unit, the hydrolysis unit, absorption and regeneration plants for removal of chemical pollutants such as H_2S, COS, HCl, NH_3 and HCN. Waste water generated from these chemical treatment systems normally contains suspended solids, heavy metals, ammonia and other toxic metals. An advanced waste water treatment plant can be provided to treat the waste water by means of chemical precipitation and ammonia stripping methods to meet TM limits before discharge.

PFBC: Plant effluents mainly come from the steam cycle unit which include boiler blowdown, water treatment plant effluent, equipment drains and plant washing. These effluents can either be reused or discharged after treatment to meet TM limits.

CFBC: Type of plant effluents are similar to that of PFBC but of larger quantities due to larger steam cycle unit.

Comparison: The four power generation technologies will produce various quantities of plant effluents with different compositions. However, mitigation measures can practically be applied to either recycle or treat the effluents to meet TM limits prior to discharge, thereby minimising their impacts on water quality.

Summary of Comparison

For a 1,800MW plant, both Advanced PC and CFBC require about 66m^3/sec of cooling water while 30m^3/sec and 53m^3/sec are required for IGCC and PFBC respectively. Hence, Advanced PC and CFBC will have higher impact on thermal discharge followed by PFBC and with IGCC having the least impact. However, for all the plant types, the cooling water discharge can practically be controlled to minimise the size of the mixing zone to an environmentally acceptable level.

For plant effluents, effluent management schemes can be formulated for all the four plant types to minimise the surplus effluents and treatment of effluents will ensure compliance with the TM limits prior to discharge.

2.5.3 *Solid Wastes*

Ash exists as a mineral matter in coal which results in an incombustible residue when coal is burned. The total amount of ash generated would therefore depend on the total amount of coal burned irrespective of the type of power generation technology being adopted. Another major source of solid waste is the generation of solid chemical byproduct as a result of chemical treatment for reduction of SO_2 emissions.

Advanced PC

Pulverized fly ash (PFA) and furnace bottom ash (FBA) are produced from the burning of pulverized coal. PFA will be carried through the furnace with the flue gases while FBA will fall to the bottom of the furnace where it sinters to form a coarser material. Based on an ash content of 11% by weight, the annual production of ash from a 1,800MW Advanced PC plant is about 426,000 tonnes for PFA and 47,000 tonnes for FBA. As demonstrated through the strategy adopted at HEC's existing Lamma Power Station, both PFA and FBA are in demand for use in the construction industry. PFA is used in the production of cement and PFA concrete while FBA can be used as a filling material and for various industrial uses. As all FBA will be rinsed with fresh water, it can also be used for cement production.

The anticipated PFA and FBA productions from the whole HEC System including the existing Lamma Power Station and the new power station in 2012 are 697,000 tonnes and 77,000 tonnes respectively. The FBA systems of the new units will be fresh water based. Based on the discussion with one of the cement companies, their consumption of ash in cement and PFA concrete production will be in the order of 1 million tonnes in 2012. Hence, it is anticipated that all the PFA and

FBA produced from HEC power generation system could be fully taken up by this company alone. However, to allow for fluctuations in demand cycles, it is considered prudent to include an ash lagoon of 11 ha for the contingency storage of about two years ash production from the 1,800MW plant to ensure an efficient and uninterrupted operation of the power station.

About 270,000 tonnes of gypsum per year will also be produced as a by-product of the FGD plant when all the three 600MW units are operational. The gypsum produced will be of high quality industrial grade. Similar to ash, the gypsum has good commercial value and can be delivered off site for manufacturing of cement and wallboard/plaster. The success of this strategy has been demonstrated in HEC's existing Lamma Power Station. Based on discussions with local and overseas potential gypsum recipients and in view of the high demand for cement and wallboard/plaster manufacture in China and South East Asia region, it is anticipated that all gypsum produced from the new power station could be easily absorbed by industry.

IGCC

Depending on the coal properties and gasifier operating mode, more than 90% of ash in coal ultimately leaves the gasifier as bottom slag. It is reported that most of the trace elements present in the coal are removed in a fixed form in both the bottom slag and fly slag. The leaching characteristics of the slag are claimed to be well within acceptable environmental limits and many of the elements are even below the detection limits. For the existing installations, the slag is normally used off site as a filling material and material for construction industry. Based on an ash content of 11% by weight, a 1,800MW IGCC plant will produce about 440,000 tonnes of slag per year. Whether or not the local industrial market can accept the quality of the slag and absorb the estimated quantity of slag will have to be further explored. Initial discussions with the PFA/FBA recipient indicated that slag might possibly be used in cement production since its chemical composition is similar to PFA. However, as there is no local experience in using IGCC slag for cement production or other uses, trial tests of the product have to be conducted prior to commercial application. Based on experience in the adoption of PFA by the construction industry, it may take upto 10 years to establish the acceptability of the use of slag for various industrial uses. It is estimated that only one-third of the total amount of slag over the 30 years plant life can be used for concrete production and reclamation. Therefore, about 6,800,000 m^3 of slag will need to be stored in the ash lagoon which is equivalent to an ash lagoon area of about 60 ha depending on the depth of the lagoon.

In the IGCC plant, the sulphur in coal is removed from the gas cleanup system through a series of chemical reactions. Depending on the process, either solid sulphur or sulphuric acid will be produced. These by-products may be saleable for use in the chemical industry, although no such immediate demand exists in the Region. For a 1,800MW IGCC plant, the amount of sulphur generated is estimated to be 40,000 tonnes per year. Although there is lack of chemical plants in Hong Kong for commercial outlets of these sulphur products, it is reckoned that all the sulphur produced can be sold to overseas countries and hence no additional storage requirement is required.

PFBC

Residues from a PFBC plant comprises three streams: granular bed material (20-50%), fly ash captured by the cyclones (45-75%) and filter catch from the final back-end filter (2%). These streams vary in size but are similar in composition.

The PFBC ash consists of three main components: coal ash, anhydrous calcium sulphate (water free gypsum) and sorbent which is normally limestone. As a Ca/S ratio of 2.0 is normally adopted for optimum sulphur removal efficiency, the PFBC ash therefore consists of 60% coal ash, 22% calcium sulphate, 16% unreacted limestone plus 2% impurities.

A number of leaching tests have been made with PFBC ash. Due to the self-hardening (pozilanic) qualities of the PFBC ash resulting in the formation of concrete-like materials, test results show that the permeability is normally less than 10^{-10}m/sec. The extremely low permeability of PFBC means that leaching is controlled more by diffusion rather than by convective flow. It is generally reported that PFBC ash will cause only limited impact on the environment and is comparable with many conventionally used materials such as concrete. Various trial applications for the PFBC ash have been carried out including the production of synthetic gravel, land filling, reclamation and use as building material, with promising results.

The total PFBC ash produced from a 1,800MW plant is estimated to be 750,000 tonnes per year. Detailed assessment on the environmental impacts of PFBC ash will be required before it can be accepted for industrial applications in Hong Kong. Similar to IGCC, it will take upto 10 years to demonstrate the acceptability of the PFBC ash for industrial uses. Hence, about one-third of the total amount of PFBC over the 30 years plant life will have commercial outlets and the remaining 16,300,000 m^3 of ash will need to be stored in the ash lagoon. Depending on the depth of the lagoon, an area of about 160 ha will be required.

CFBC

The composition of CFBC ash is similar to that of PFBC. Due to lower plant efficiency, the CFBC ash produced from a 1,800MW plant will be more than that from PFBC and is estimated to be 870,000 tonnes per year. CFBC ash is similar to PFBC ash and hence it is assumed that two-thirds (about 19,000,000 m^3) of the CFBC ash will need to be stored in the ash lagoon which is equivalent to an area of about 190 ha.

Comparison

Due to differences in efficiencies, the four power generation technologies will generate various amount of ash in different forms. The markets for FBA and PFA generated from Advanced PC plant are well established. For the slag from IGCC and the ashes from PFBC and CFBC, extensive trial tests are required to gain acceptance of the construction industry. As a result, the ash lagoon for APC will be much smaller than that required for the other three technologies.

As demonstrated in HEC's existing Lamma Power Station, commercial markets exist for gypsum while for the sulphur produced in IGCC plant, the industrial outlets have yet to be examined due to lack of local experience. For $CaSO_4$ produced by PFBC and CFBC, they have to be handled together with the ash.

2.5.4 *Construction Impact*

Construction of a power station would involve considerable civil and E&M works. As the construction period for the four plant types would be similar, the construction impact is expected to be similar for all cases. Through proper management and establishing good practices for environmental control, construction impacts are unlikely to be a key differential in the selection process.

2.5.5 *Noise*

Operational noise is unlikely to cause any major problems as long as proper noise mitigation measures are incorporated in the plant and equipment design.

2.5.6 *Decommissioning*

Irrespective of the different technologies, the generating units are anticipated to have an operational life of 30 years, and the plant equipment and materials involved are similar, consisting of mainly concrete structures, pipework, ductwork, vessels, metallic equipment, insulation materials, etc which are common for all fossil fuel power stations. Hence, the techniques employed for the decommissioning process, the disposal/reuse of the materials produced, and the statutory requirements relating to them are likely to be equally applicable to the various technologies. The impacts arising from the decommissioning of different plant types are therefore anticipated broadly similar.

2.5.7 *Overall Comparison*

Table 2.5b summarises the environmental impacts of the four power generation technologies using coal as the primary fuel.

IGCC will have the lowest emissions of SO_2, particulate and CO_2. For NO_x, APC with De-NO_x can achieve a very low NO_x emission level which is comparable to or even lower than that from IGCC, and much lower than from PFBC and CFBC. From air quality point of view, IGCC and APC with De-NO_x are therefore considered to have the least impacts compared with PFBC and CFBC.

For water quality, it is believed that the impacts arising from the four technologies can practically be mitigated to environmentally acceptable limits.

All the four technologies with coal as primary fuel will inevitably produce a considerable quantity of ash. Commercial outlets for the PFA and FBA generated from APC are well established. For IGCC, PFBC and CFBC, it is anticipated that it will take upto 10 years to establish the acceptability of the use of the slag or ash in construction industry. As a result, size of the ash lagoon required for APC will be much smaller than that for IGCC, PFBC and CFBC. APC therefore requires the least overall power station landtake comparing with the other three technologies.

Detailed calculations and mass and energy flow diagrams illustrating the amount of coal, energy values, emission levels and solid wastes from each of the power generation technologies are shown in the *Annex A*. From environmental point of view only, it is concluded that both IGCC and APC with De-NO_x will have the least environmental impacts.

Table 2.5b *Summary of Environmental Impacts of Advanced PC, IGCC, PFBC and CFBC*

Impact	APC Without De-NO_x	APC With De-NO_x (Note 1)	IGCC	PFBC	CFBC
Air Quality	Medium	Low	Low	Medium	High
Water Quality	High	High	Medium	Low	Low
Solid Waste	Low	Low	Medium	High	High
Noise	Low	Low	Low	Low	Low
Others	Low	Low	Low	Low	Low
Overall	2	1	1	3	4

Note 1: Based on a modern De-NO_x plant with 65% removal efficiency

3 PIPELINE GAS FUEL OPTION

3.1 INTRODUCTION

3.1.1 Overview

During the past decade, natural gas production world-wide has increased much faster than the production of oil or coal. This is largely due to the environmental benefits of gas compared with other fossil fuels used for power generation. Markets for pipeline natural gas are well developed in North America and Europe, but have been hampered in Asia by the lack of transport infrastructure. Nevertheless, natural gas in Asia is emerging as the fastest growing source of primary energy.

The use of gas for power generation has environmental merits over other fossil fuels. The stack emissions from gas-firing plant are free of sulphur dioxide and particulates nor is solid waste, such as ash and gypsum, generated during gas firing. However, one of the drawbacks of a pipeline natural gas plant is that the location of the gas field is critical to the decision on whether transportation of the gas by pipeline to the power plant site is technically feasible and economically justified.

3.1.2 Power Generation Technologies

New gas-based power generation technologies include magnetohydrodynamics and fuel cells. However, these technologies are still in a very early stage of development under testing and research, and hence they are not worth to be considered in this Study. For large scale power generation, the generation technologies that are commercially proven with natural gas as the primary fuel can be broadly classified as:

- Combined Cycle Plant
- Conventional Gas-firing Steam Cycle Plant

Each of these is examined and compared in the sub-sections below.

3.2 GAS-FIRING COMBINED CYCLE PLANT

3.2.1 General

A combined cycle plant is one which combines the gas cycle and steam cycle for power generation. The common configuration is to have one or more gas turbines coupled with a steam turbine. Using gas or liquid distillates as the primary fuel, the gas turbines will produce electricity. The waste heat energy from the hot gas exhaust (more than 500°C) discharging from the gas turbine is passed through a heat recovery steam generator to produce steam for driving a steam turbine for secondary electricity generation. A schematic representation of a combined cycle gas-firing plant is illustrated in *Figure 3.2a*.

A combined cycle module usually consists of two to three gas turbines coupled with one steam turbine. However, recent gas turbine development produces single train modules whereby one single gas turbine is bolted to the steam turbine together with one generator on one shaft. For large capacity power stations, gas turbine combined cycle modules is usually of 350MW class or 600MW class.

Recent advances in gas turbine technology has significantly improved the efficiency of combined cycle power plants. Based on gas firing, the highest gross efficiency achievable is close to 60%. These efficiency improvements have been due to improved gas turbine performance resulting primarily from higher firing temperatures.

Many gas turbine manufacturers can now produce models that operate with inlet gas temperatures close to 1,300°C, which gives a simple cycle efficiency of about 36% and a combined cycle efficiency (gross) of more than 55%. Refinements to the technology to further increase the inlet temperature to over 1,400°C, with the objective of achieving a combined cycle efficiency of 60% or higher, are currently under way.

3.2.2 *Generating Unit*

Gas Turbine

Gas turbines are internal combustion engines and comprise an air compressor, a combustion system, where fuel is injected for combustion to take place at essentially constant pressure, and a turbine where the heat energy of the hot gas from combustion is converted into mechanical work and electrical energy.

Over the last ten years, there have been major improvements to gas turbines in terms of both efficiency and unit size. Gas turbines of unit capacity of 200MW or above are commonly adopted today in large capacity combined cycle units to get maximum benefits of economy of scale and high efficiency.

The advances in gas turbine technology have also resulted in the emergence of low-NO_x combustion technology. NO_x emission level of 25-50 vppm can be achieved by using a dry, or a steam/water injection, low-NO_x combustion system.

Heat Recovery Steam Generator (HRSG)

The HRSG provides a heat transfer surface to generate steam by using the remaining useable heat in the exhaust gas from the gas turbine. Like the boiler of a coal-firing plant, the HRSG consists of a large number of tube panels forming a flow path for the exhaust gas which is then discharged to the atmosphere through a stack. Several pressure levels and reheat stages are used in modern HRSG steam circuits in order to optimise cycle efficiency.

Steam Turbine

Steam from the HRSG is used to drive a steam turbine which is connected to a generator for further power generation. About one third of power generated by the combined cycle block is from the steam turbine.

3.2.3 *Ancillary Plant*

Submarine Gas Pipeline

A submarine gas pipeline system will be required to supply natural gas from a

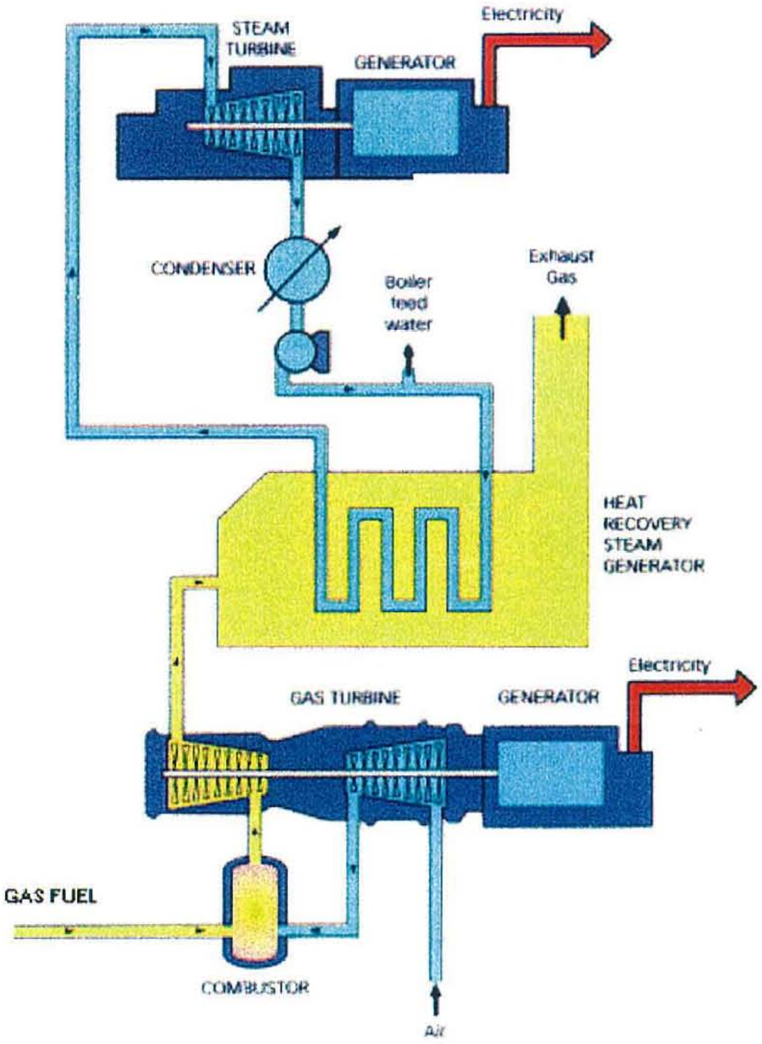

FIGURE 3.2a - A SCHEMATIC REPRESENTATION OF A COMBINED CYCLE GAS-FIRING PLANT

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regional gas field. The sections of pipeline within Hong Kong waters will need to be buried under the seabed. There are two scenarios for the submarine gas pipeline for the new power station, including installing a new pipeline from the new gas field all the way to the new power station site, or installing only that short section of pipeline connecting a new gas field to the existing submarine pipeline from Hainan to CLP's Black Point Power Station. For installing a pipeline from a new gas field, the upstream facilities including drilling and gas processing facilities will have to be installed. If the existing pipeline is to be shared, a compression station will be required to boost the pressure in the trunkline and a pipeline tee-off from the existing main trunkline will be required.

Gas Receiving Station (GRS)

To receive natural gas delivered from a regional gas field through a pipeline, a gas receiving station is required. The received natural gas is processed in the GRS and subsequently delivered to the plant for combustion. Major equipment requirements of the GRS include shut-off valves, pig receiver, slug catcher, filter, gas heater, pressure regulator, metering device, vent stack and protection system.

Cooling Water System

A once-through cooling water system would be adopted to condense steam exhaust from the steam turbine. Sea water would be extracted from one side of the site and discharged to the other side after passing through the condensers. The cooling water flow required for a 1,800MW combined cycle plant taking into account of the heat rejected from gas turbine generators, lube oil systems and other auxiliaries will be around $33m^3/sec$. For CLP's Black Point Power Station, a cooling water flow rate of $6.2m^3/sec$ is required for each 320MW combined cycle unit.

Fuel Oil System

Unlike coal where reserve stocks can be maintained at the power station to cater for any supply interruption, it is impractical for pipeline gas to have reserve stock on site. As a countermeasure, the gas combined cycle plant will be designed for dual firing with light gas oil as an alternative fuel. A fuel oil supply and storage plant consisting of a berth, oil tanks, fuel oil pumps and a piping system for the unloading, storage and transferring of fuel oil will have to be installed.

Raw Water Supply System

Major water consumption in a combined cycle plant includes water supply for the steam cycle make-up, maintenance use, plant washing, fire services system, air-conditioning system and potable water system. The water consumption of the plant will be supplied from a raw water reservoir with adequate storage capacity. To cater for 7 days consumption, the capacity of the reservoir for a 1,800MW combined cycle plant is estimated to be $12,500m^3$. Depending on the site location, a submarine water pipeline may have to be installed for the supply of raw water.

3.2.4 *Environmental Control Facilities*

NO_x Control

NO_x emissions from a combined cycle plant mainly come from the burning of fuel in the combustion chamber of the gas turbine. There are a number of methods available to reduce NO_x emissions from the gas turbine including dry low-NO_x combustion systems and steam and water injection. In the dry low-NO_x combustion system, NO_x control is performed in two ways: by short flame length, and through a carefully controlled fuel to air ratio for low flame temperatures with premix and diffusion sections within the combustor elements. The advanced dry low-NO_x combustion system can achieve a low NO_x emission level of about 25 - 50 vppm. For water and steam injections, the main purpose is to lower the combustion temperature and hence reduce the formation of NO_x.

SO_2 and Particulate Control

Due to the absence or minute quantity of sulphur and solid residual in natural gas, SO_2 and particulate control is not required for the combustion of natural gas.

Waste Water Treatment Plant

The quantity of waste water from a gas-fired combined cycle plant is small. The effluent derives mainly from plant washing, plant drains and floor drains. The effluent collected in the plant would be treated to meet regulatory requirements prior to before discharge.

Solid Waste Handling

There will be no major sources of solid waste produced by the combustion of natural gas, and hence solid waste handling is not required.

3.3 GAS-FIRING STEAM CYCLE PLANT

3.3.1 General

Due to the obvious advantages of gas-firing combined cycle plants over gas-firing conventional plant in terms of efficiency and capital costs, there are only a limited number of conventional gas-firing power plants constructed in recent years. Gas-firing conventional power plant will normally be preferred in situations where the supply of natural gas is likely to be on a relatively short term basis and hence there is a chance of converting the boiler to oil firing in future.

A conventional gas-firing power plant comprises a gas fired boiler and a steam turbine generator similar to that of a conventional coal-firing plant. The major differences arise from the ancillary facilities, since there is no flue gas desulphurization plant, and no coal and ash handling plant and facilities required.

3.3.2 Generating Unit

Boiler Plant

The main function of the boiler is to utilise the heat produced in the combustion of gas to convert water into steam. It consists of a large furnace made up of numerous membrane wall tubes where combustion of gas takes place. Water passing through the membrane wall tubes is heated to steam which then passes through superheaters to become superheated steam before going to the steam turbine.

The boiler is normally fitted with low-NO_x burners to reduce the NO_x emission level. *Figure 3.3a* shows a typical arrangement of a gas-fired conventional boiler plant.

Turbine Plant

Steam generated from the boiler is used to drive a turbine which is in turn connected to a generator for power generation.

After driving the turbine, the steam enters a condenser which is a large heat exchanger consisting of thousands of tubes. Through heat transfer with cooling water flowing through the condenser tubes, the steam is condensed back to water which is then pumped through a series of heaters and returned to the boiler.

A net plant efficiency (LHV) of about 40 - 43% can be achieved with the adoption of supercritical steam conditions.

3.3.3 *Ancillary Plant*

Similar to the gas-fired combined cycle plant, the following ancillary plants will be required for a 1,800MW gas-fired conventional plant:

- *Gas Receiving Station:* Similar design and capacity as that defined for the combined cycle plant.
- *Cooling Water System:* Quantity of cooling water required will be increased to $66m^3/sec$.
- *Fuel Oil System:* Similar design and capacity as that defined for the combined cycle plant.
- *Raw Water Supply System:* Similar design but of a larger capacity than that defined for the combined cycle .

3.3.4 *Environmental Control/Mitigation Facilities*

NO_x Control

Similar to the conventional coal-fired plant, low-NO_x burners can be employed to lower the NO_x emissions by means of overfired air and staged combustion. De-NO_x plant may also be installed downstream of the boiler flue gas exit to further reduce the NO_x emission level, if required.

SO_2 and Particulate Control

Due to the minute quantity of sulphur and solid residual in natural gas, SO_2 and particulate control is not required for the combustion of natural gas.

Waste Water Treatment Plant

Similar to the combined cycle plant, a waste water treatment plant will be required to treat the plant effluent to comply with the regulatory requirements prior to discharge.

Solid Waste Handling

There will be no major sources of solid waste produced by the combustion of natural gas; hence solid waste handling is not required.

3.4 ENVIRONMENTAL ASSESSMENT

3.4.1 *General*

The environmental assessment of the two power generation technologies with natural gas as primary fuel are based on typical design currently adopted as below:

Gas-fired Combined Cycle:	Net plant efficiency of 53% (LHV) Low-NO_x combustion gas turbine to reduce NO_x emission to 60mg/Nm^3 (based on 15%O_2)
Gas-fired Steam Cycle:	Net plant efficiency of 41% (LHV) Low-NO_x burners to reduce NO_x emission to 120mg/Nm^3 (based on 15%O_2)
Load factor:	0.8

3.4.2 *Air Quality*

Major air pollutants emitted from the stack of a gas-fired power plant are:

- Oxides of nitrogen (NO_x)
- Carbon Dioxide (CO_2)

As natural gas does not contain any sulphur or solid residue, no sulphur dioxide (SO_2) or particulates will be emitted. The quantities of air pollutants generated from different power generation technologies are compared below whilst their effects on ground level pollutant concentrations (for the preferred technology) will be assessed during Phase III of the Stage 1 EIA study when the shortlisted sites are identified.

NO_x Emission

Similar to coal-firing, NO_x is formed due to oxidation of nitrogen in air as well as nitrogen in fuel.

Combined Cycle: With the adoption of low-NO_x combustion technology, emission level of less than 60mg/Nm^3 can be achieved. For a 1,800MW, this represents an annual NO_x emission of 5,300 tonnes.

Steam Cycle: By adopting low-NO_x burners, NO_x emission can be reduced to 120mg/Nm^3. This represents an annual NO_x emission of about 14,000 tonnes for a 1,800MW plant.

Comparison: Due to the advances in combined cycle gas turbine technology, the NO_x emission is much lower than the steam cycle plant.

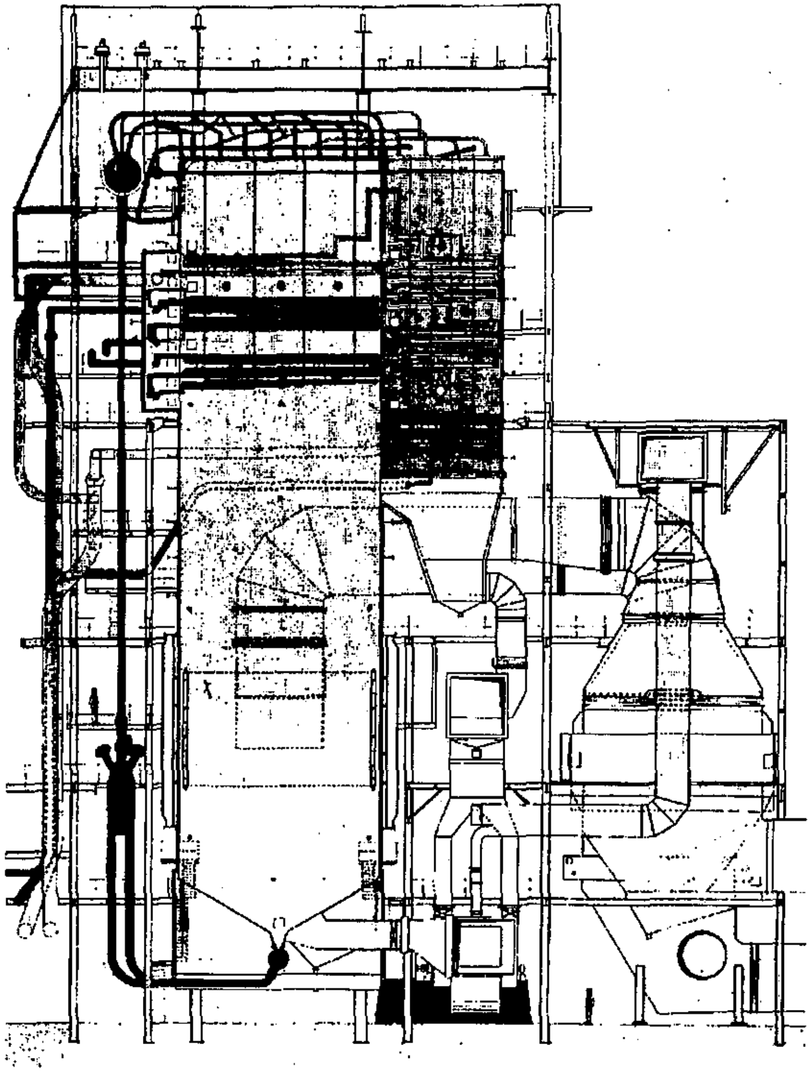

FIGURE 3.3a - A TYPICAL ARRANGEMENT OF A GAS-FIRED CONVENTIONAL BOILER PLANT

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CO_2 Emission

Natural gas contains about 70% by wt. of carbon which will be converted to carbon dioxide during the combustion process.

Combined Cycle: About 5.2 million tonnes per year of CO_2 is produced from a 1,800MW plant.

Steam Cycle: About 6.7 tonnes per year of CO_2 is produced from a 1,800MW plant.

Comparison: Due to higher efficiency, the combined cycle technology produces less CO_2 than steam cycle plant.

Summary of Comparison

For a 1,800MW plant, the annual pollutant emissions for both plant types are summarised in *Table 3.4a*.

Table 3.4a ***Summary of Emissions from Combined Cycle and Steam Cycle Plants***

Pollutant	Combined Cycle	Steam Cycle
NO_x (t/yr)	5,300	14,000
CO_2 (million t/yr)	5.2	6.7

It can be seen that both NO_x and CO_2 emissions for the combined cycle plant are lower than that of the steam cycle plant.

3.4.3 *Water Quality*

Gas-fired power plants will produce water pollution of two main types: cooling water and plant effluents.

Cooling Water Discharge

As described above, cooling water is mainly required for the steam cycle unit for condensing the steam to water.

Combined Cycle: As only one-third of the total output is generated from the condensing steam turbine, the quantity of cooling water required for a 1,800MW combined cycle plant is about $33m^3$/sec taking into account of the cooling water requirements for the gas turbine generators, bearings and other auxiliaries .

Steam Cycle: About $66m^3$/sec of cooling water is required for a 1,800MW plant as all the power is generated from the steam turbine.

Comparison: Combined cycle plant will have less cooling water discharge and hence less heat release into the sea than steam cycle plant. However, for both cases, it is considered that through proper engineering and design of the outfall and cooling water system, thermal impact of cooling water discharge on the receiving water can be controlled to an environmentally acceptable level.

Plant Effluents

Some of the plant effluents are common to both power generation technologies. These include site surface drainage which is a direct discharge and various domestic effluents which will be discharged after suitable treatment.

Other plant effluents specific to the power generation technologies are described below:

Combined Cycle: Plant effluents mainly come from the steam cycle unit which include boiler blowdown, water treatment plant effluent, equipment drains and plant washing. These effluents can either be reused or discharged after treatment to meet TM limits

Steam Cycle: Plant effluents are similar to that of combined cycle plant but of greater quantity due to larger capacity of the steam cycle units.

Comparison: Both power generation technologies will produce various quantities of plant effluents but of similar compositions. Mitigation measures can practically be applied to either recycle or treat the effluents to meet TM limits prior to discharge.

Summary of Comparison

It can be concluded that combined cycle plant has less water quality impacts than steam cycle plant in terms of cooling water and plant effluent discharges.

3.4.4 *Solid Waste*

As natural gas has been purified and filtered at source, there is no ash content in the gas and, as a result, no solid waste would remain after combustion of the gas using either of the compared technologies. Other solid wastes from the plant include domestic refuse, drum screen rejects and sewage sludge. the quantity of these solid wastes would be broadly similar for both technology options.

3.4.5 *Construction Impact*

Construction of a power station would involve considerable civil and E&M works. As the construction period for the combined cycle and steam cycle would be similar, the construction impact is expected to be similar for both cases. Through proper management and establishing good practices with regard to environmental control, construction impacts are unlikely to be of concern.

3.4.6 *Noise Impact*

The gas receiving station is the main source of potential noise and is common to both technologies. The noise potential exists through intermittent jet noise produced when high pressure steam is vented to the atmosphere; this would be mitigated through the incorporation of silencers in the plant and equipment design.

With the installation of adequate mitigation measures, it can be concluded that the noise impact for the two power generating technologies would be broadly the same.

3.4.7 *Overall Comparison*

Table 3.4b summarises the environmental impacts of the two gas-fired power generation technologies.

From an environmental viewpoint, it can be concluded that combined cycle plant will have the least environmental impacts in terms of less air pollutant emissions and less cooling water and plant effluent discharges. Detailed calculations of the emissions are given in the *Annex B*.

Table 3.4b *Summary of Environmental Impacts of Combined Cycle Plant and Steam Cycle Plant*

Impact	Combined Cycle	Steam Cycle
Air Quality	Low	Medium
Water Quality	Low	Medium
Solid Waste	Low	Low
Noise	Low	Low
Others	Low	Low

4 SUMMARY AND CONCLUSIONS

4.1 OVERALL COMPARISON OF TECHNOLOGIES

Table 4.1a presents an overall comparison of the environmental issues associated with each of the coal and gas fired technologies reviewed in this Technical Paper.

The conclusions of the environmental review of coal and gas fired technologies are presented separately in the sub-section that follow. A comprehensive comparison of generation technologies will be undertaken as part of the Site Search Study and will be reported in Technical Report No. 1 to be submitted to the Site Search Steering Group in early May. Technical Report No. 1 will include the findings of this Technical Paper and will include an evaluation of available technologies on the basis of a wider range of factors including non-environmental considerations, such as cost, developmental maturity and efficiency.

4.2 COAL FUEL OPTION

Integrated Gasification Combined Cycle (IGCC) is considered the most environmental friendly power generation technology, particularly in terms of the lower levels of NO_x compared with conventional coal-fired technologies without De-NO_x facilities. However, it should be noted that there are less than five large capacity IGCC plants currently in operation worldwide and the largest of these plants is only about 250MW. All these installations are under demonstration programmes in order to generate more actual operating data in a further pursuit for full commercialisation. It is evident that IGCC technology is still under development with a number of technical problems yet to be resolved. It is likely that this will take at least a decade before it can be widely recognized as a proven technology for large capacity power generation.

Similarly, whilst Pressurised Fluidised Bed Combustion (PFBC) has a number of environmental advantages over conventional technologies, it is also at pilot plant operation stage with a limited number of small units of about 80MW capacity currently installed for trial purposes.

Circulating Fluidised Bed Combustion (CFBC) provides few environmental advantages and is most suited to burning low grade coals. Comparatively speaking, it is the least attractive from an environmental viewpoint.

Advanced Pulverised Coal-firing is an extensively tried and tested technology for power stations of the scale and reliability required by HEC to meet the operation requirements. With the adoption of De-NO_x plant, NO_x emission can be substantially reduced to a level which is comparable to or even lower than that of IGCC and this brings the environmental impact of APC on a par with IGCC.

4.3 PIPELINE GAS OPTION

Both combined cycle and conventional gas-fired steam cycle plant are proven and reliable power generation technologies having long track records of operation. However, combined cycle technology is considered the most environmental acceptable of the two gas-firing technologies.

Table 4.1a *Comparative Environmental Performance of Coal & Gas Firing Technology*

Impact	APC Without De-NO_x (see Note 1)	APC With De-NOx (see note 2)	IGCC (see note 3)	PFBC	CFBC	Combined Cycle (SEE NOTE 3)	Steam Cycle
	Coal Fired Technologies					Gas Fired Technologies	
SO_2 (t/yr)	4,300	4,300	4,000	4,100	4,800	None	None
NO_x (t/yr)	15,500	5,400	5,800	10,000	11,600	5,300	14,000
Particulate (t/yr)	1,260	1,260	780	800	2,300	None	None
CO_2 (million t/yr)	10.3	10.3	9.5	9.8	11.4	5.2	6.7
Solid waste: (t/yr)							
PFA	426,000	426,000				No combustion related wastes	No combustion related wastes
FBA	47,000	47,000					
Gypsum	270,000	270,000					
Slag			440,000				
Sulphur			40,000				
FBC Ash				750,000	870,000		
Cooling Water (m^3/sec)	66	66	30	53	66	33	66

Note (1) : These figures are for the case with only low NO_x combustion technology but without de-NO_x plants. Modern de-NO_x plant can further reduce NO_x emission substantially.

Note (2): Based on a modern De-NO_x Plant with 65% removal efficiency.

Note (3): De-NO_x plant has not been applied to IGCC and Combined Cycle installations worldwide as such application is not considered to be cost effective due to the inherent low NO_x emission level from these technologies.

Annex A

Mass and Energy Flow Diagram

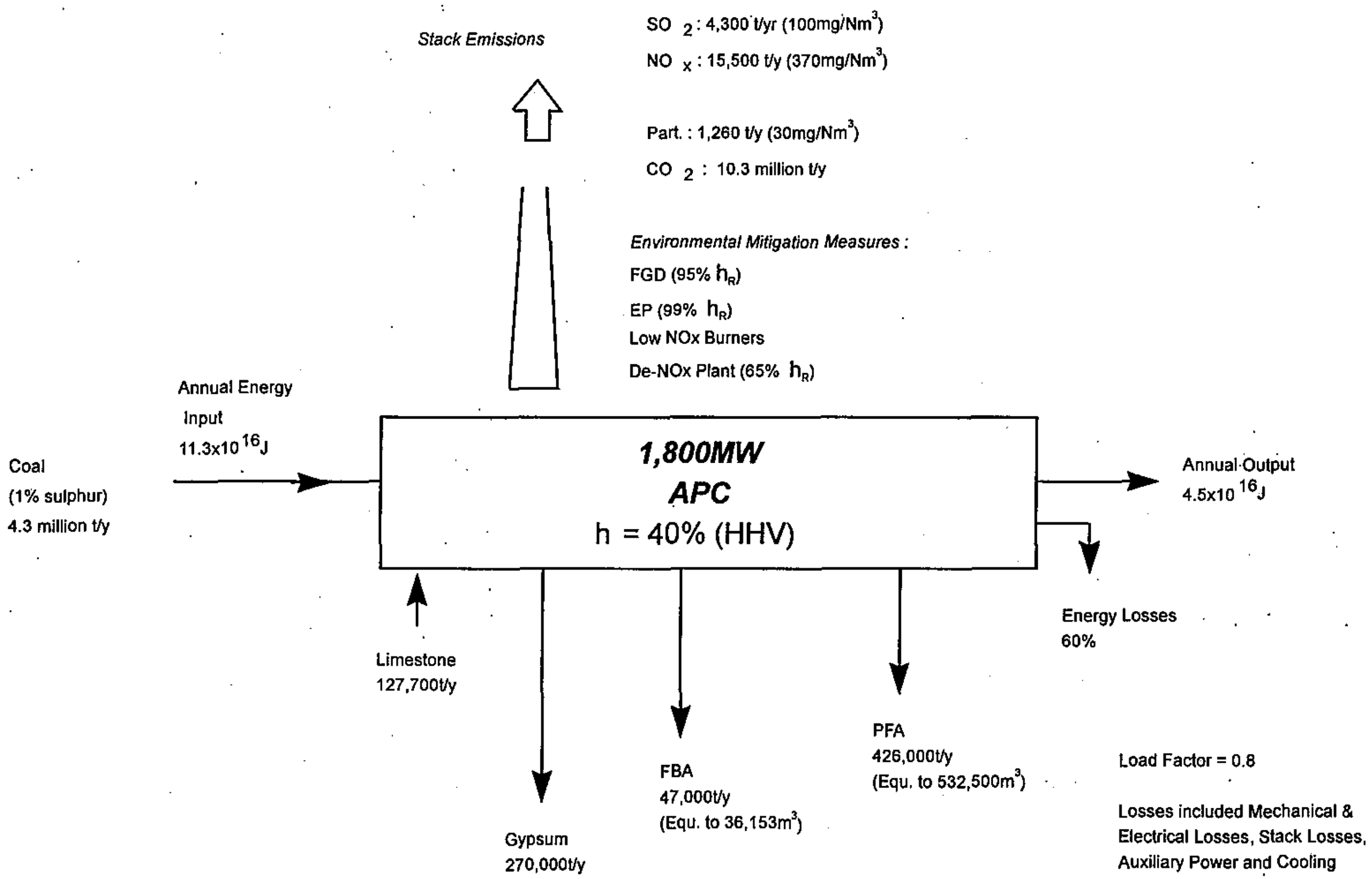

FIGURE A.1 - MASS AND ENERGY FLOW DIAGRAM FOR APC

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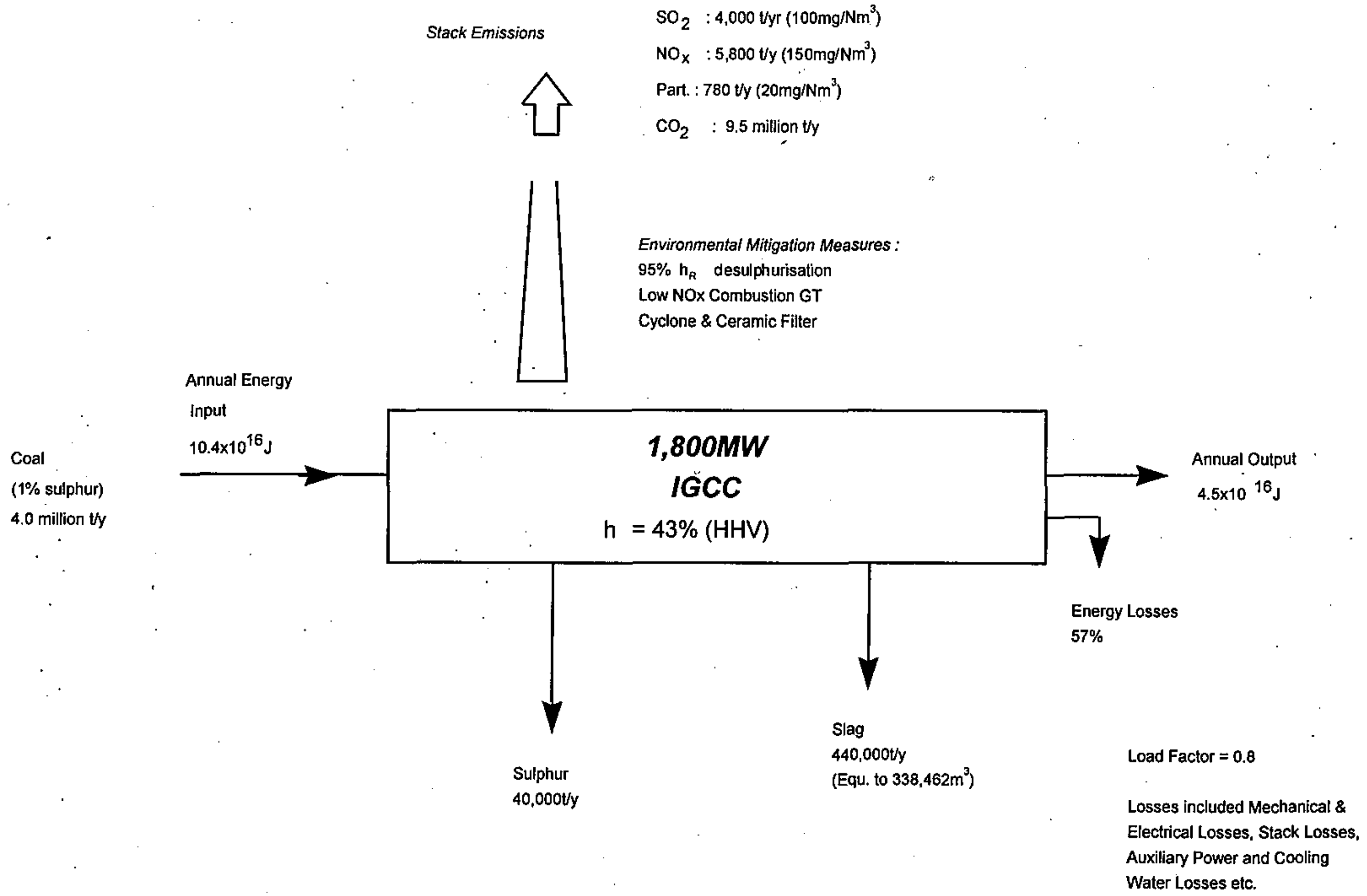

FIGURE A.2 - MASS AND ENERGY FLOW DIAGRAM FOR IGCC

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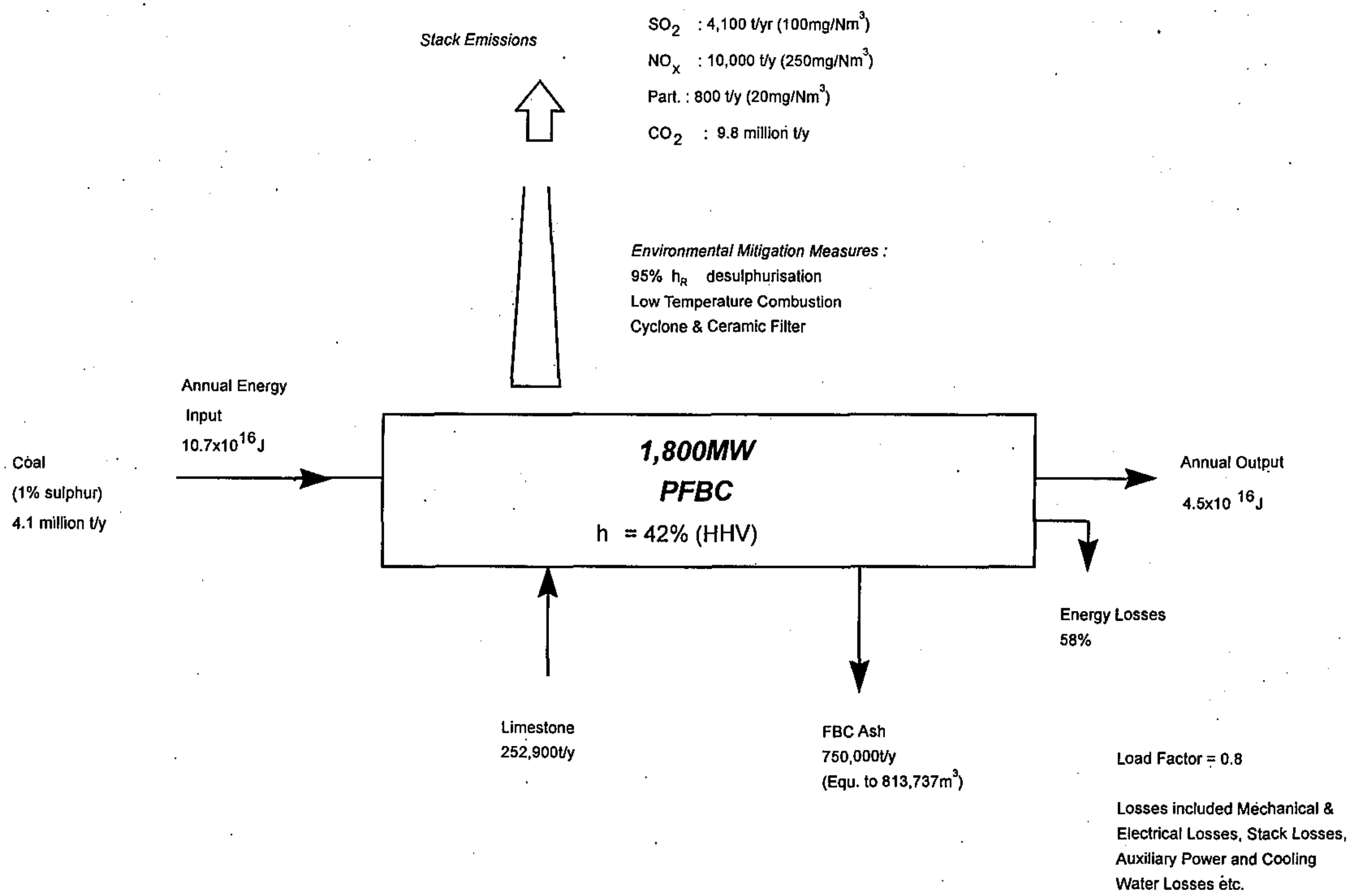

FIGURE A.3 - MASS AND ENERGY FLOW DIAGRAM FOR PFBC

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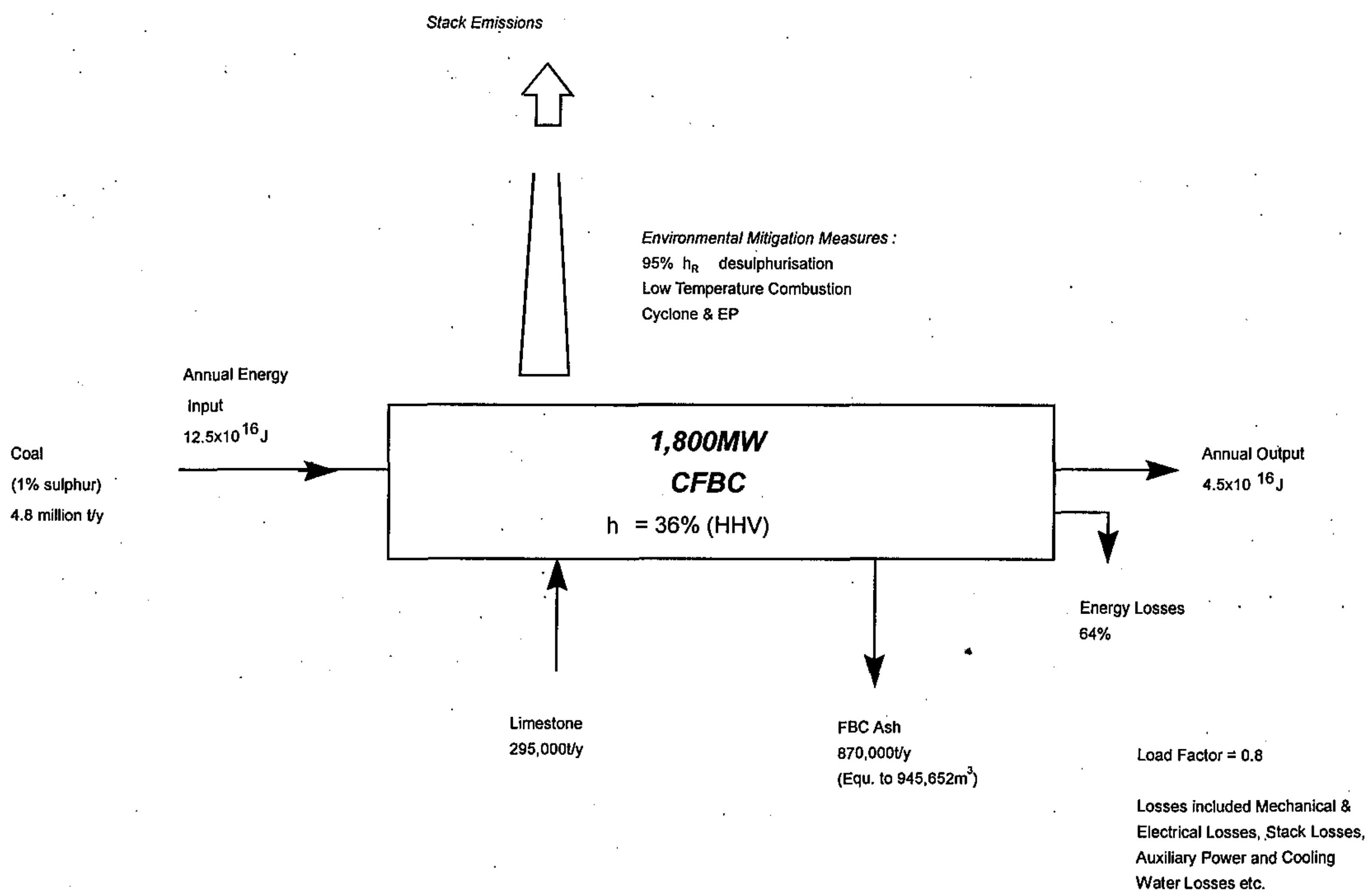

FIGURE A.4 - MASS AND ENERGY FLOW DIAGRAM FOR CFBC

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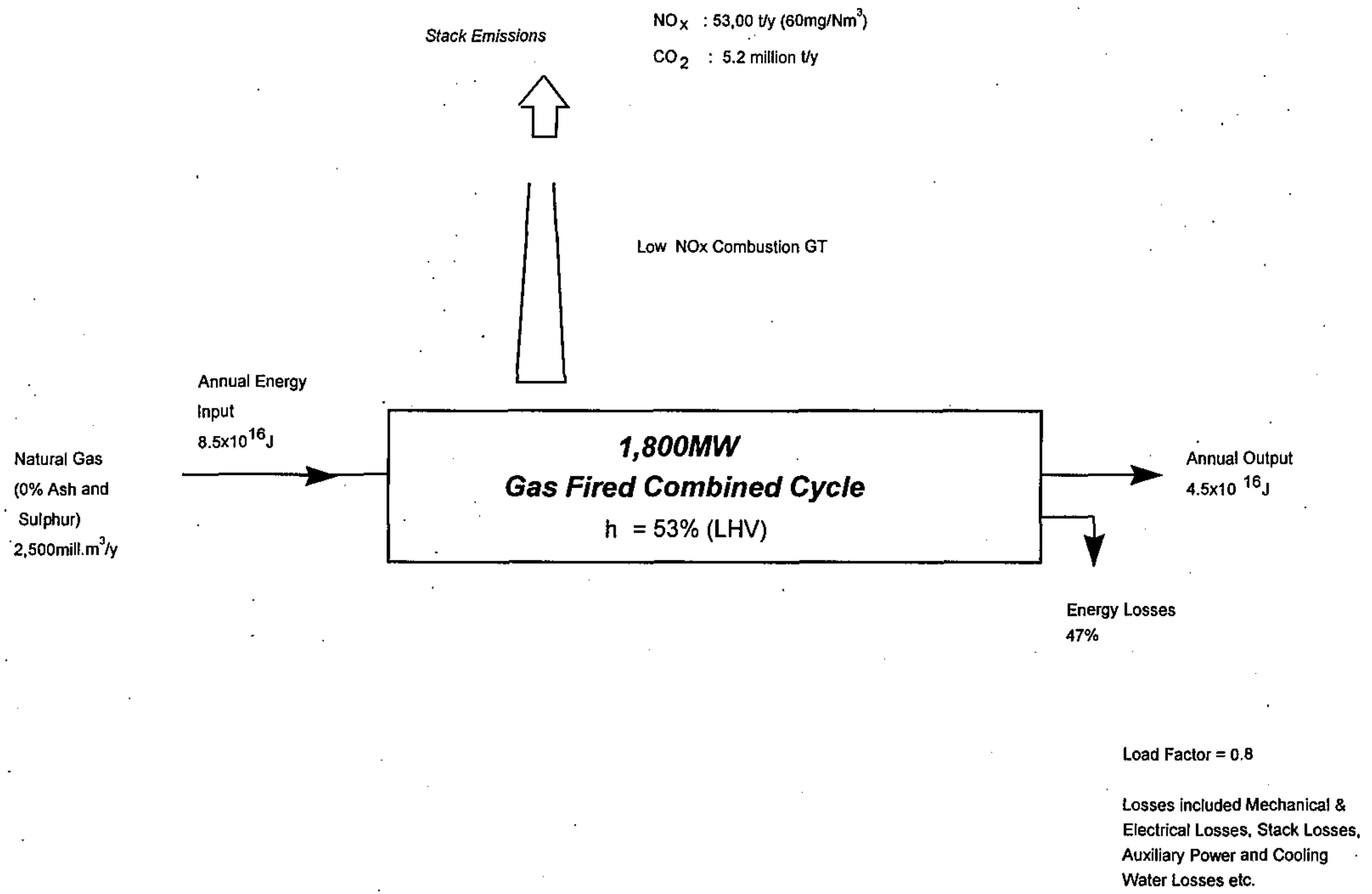

FIGURE A.5 - MASS AND ENERGY FLOW DIAGRAM FOR GAS FIRED COMBINED CYCLE

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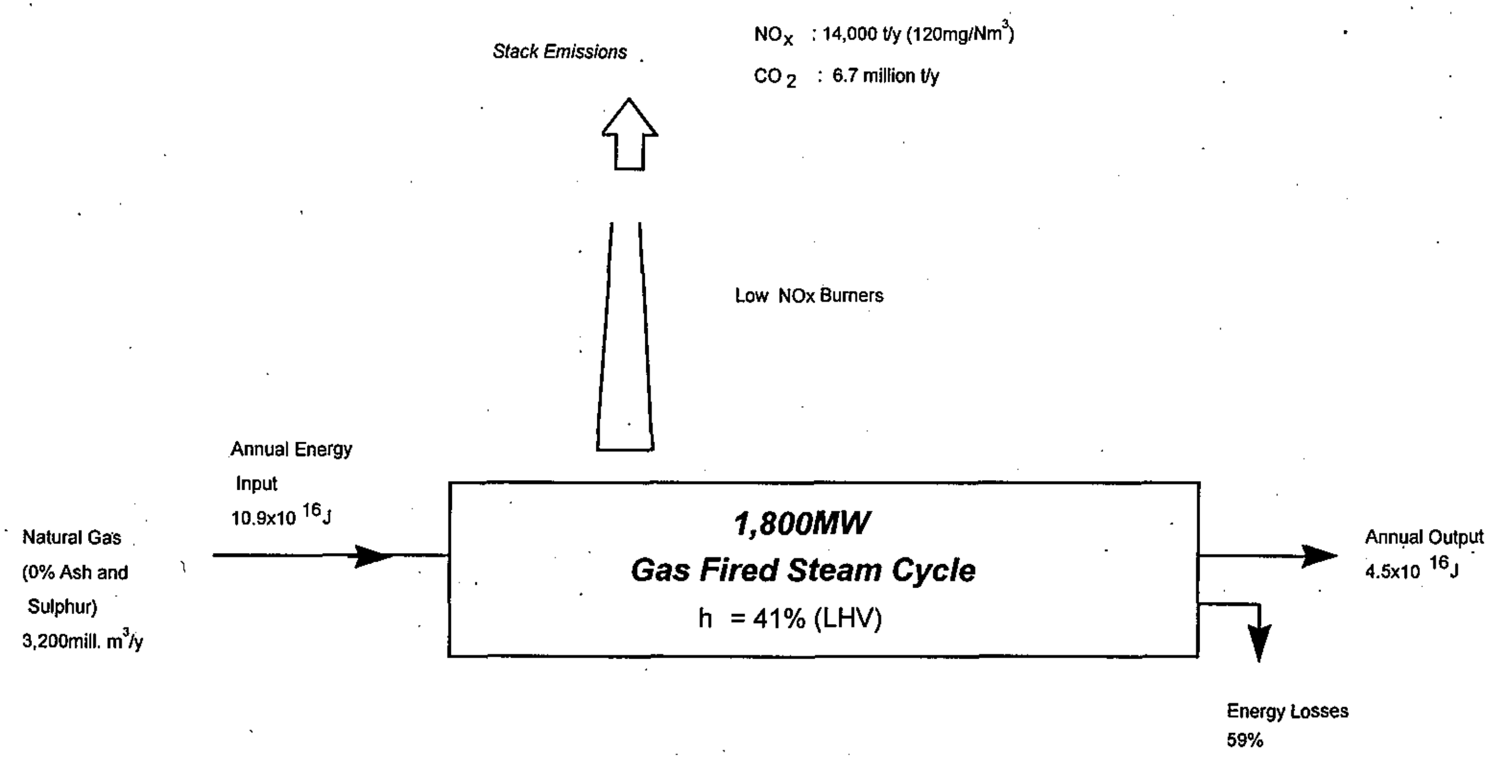

Load Factor = 0.8

Losses included Mechanical & Electrical Losses, Stack Losses, Auxiliary Power and Cooling Water Losses etc.

FIGURE A.6 - MASS AND ENERGY FLOW DIAGRAM FOR GAS FIRED STEAM CYCLE

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Annex B

Supplementary Calculation

B1 ADVANCED PULVERISED COAL PLANT

B1.1 ASSUMPTIONS

- plant capacity = 1,800MW
- calorific value of coal (HHV) = 6,300 kcal/kg
- 1 kcal = 4186.8 J
- net efficiency of Advanced Pulverized Coal Plant = 40%
- load factor = 0.8
- ash content by mass = 11%
- ratio of pulverized fly ash to furnace bottom ash = 90 : 10
- sulphur content in coal by mass = 1%
- FGD sulphur removal efficiency = 95%
- carbon content by mass = 65%
- NO_x concentration (with Advanced Low NO_x burner) = 370 mg/Nm^3 (based on 6% O_2)
- particulate concentration (with EP & FGD) = 30 mg/Nm^3 (at 6% O_2)
- flue gas temperature at exit = 80°C
- flue gas volume for 600MW APC unit = 1,992,833 Nm^3/h (at 6% O_2)
- bulk density of PFA = 0.8 tonne/m^3
- bulk density of FBA = 1.3 tonne/m^3

B1.2 CALCULATIONS

B1.2.1 *Mass of Coal Consumed Per Year*

= (Total energy consumed per year) ÷ (Energy value per kilogram of coal)
= (1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh) ÷ 40%÷ (6,300 kcal/kg x 4,186.8 J/kcal)
= 4,304,139 tonnes/yr

B1.2.2 *Mass of Ash Produced Per Year (PFA + FBA)*

= (Mass of coal consumed per year) x (Ash content by mass)
= 4,304,139 tonnes/yr x 11%
= 473,455 tonne/yr

Mass of PFA produced per year
= 473,455 tonnes x 90%
= 426,000 tonnes/yr (approx.)

Volume of PFA produced per year
= 426,000 tonnes ÷ 0.8 tonne/m^3
= 532,500 m^3/yr

Mass of FBA produced per year
= 473455 tonnes x 10%
= 47,000 tonnes/yr (approx.)

Volume of FBA produced per year
= 47,000 tonnes ÷ 1.3 tonnes/m^3
= 36,153 m^3/yr

B1.2.3 *Annual SO_2 Emission*

= Coal consumption x Sulphur content in coal x MWt ratio of SO_2 to S x (1 - FGD sulphur removal eff.)
= 4,304,139 tonnes/yr x 1% x 2 x (1 - 0.95)
= 4,300 tonnes/yr (approx.)

B1.2.4 *Annual NO_x Emission*

= 1,992,833 Nm^3/h x 370 mg/Nm^3 x 8760 hr/yr x 0.8 x 3 units
= 15,500 tonnes/yr (approx.)

Annual NO_x emission with 65% removal efficiency De-NO_x plant
= 15,500 tonnes/yr x (1 - 65%)
= 5,400 tonnes/yr (approx.)

B1.2.5 *Annual Particulate Emission*

= 1,992,833 Nm^3/h x 30 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 1,260 tonnes/yr (approx.)

B1.2.6 *Annual CO_2 Emission*

= 4,304,139 tonnes/yr x 0.65 x 44/12
= 10.3 million tonnes/yr (approx.)

B1.2.7 *Gypsum Production*

Molecular weight of gypsum, $CaSO_4.2H_2O$ = 172.17 g
Molecular weight of sulphur, S = 32.06 g
Gypsum purity = 90% of dry gypsum
Moisture content = 10% of wet gypsum

$CaCO_3 + SO_2 + ½O_2$ ---> $CaSO_4 + CO_2$

Mass of wet gypsum produced per year
= 4,304,139 tonnes/yr x 1% x 95% x 172.17 ÷ 32.06 x 1.1 ÷ 0.9
= 270,000 tonnes/yr (approx.)

B1.2.8 *Cooling Water Requirements*

Heat reject = Q x T x d x c
where Q is cooling water flow rate
T is temperature rise of cooling water
d is density of sea water
c is specific heat of sea water

For a 600MW Advanced Pulverized Coal Plant, total heat reject to the cooling water system = 710,000 kJ/sec

710,000 kJ/sec = Q x 8.5°C x 1000 kg/m^3 x 4.2 kJ/kg°C

Q = 20 m^3/sec (say 22 m^3/sec)

Total volumetric flowrate for 1,800 MW
= 22 m^3/sec x 3 units
= 66 m^3/sec

B2 IGCC PLANT

B2.1 ASSUMPTIONS

- plant capacity = 1,800 MW
- net efficiency of IGCC Plant = 43% (HHV)
- load factor = 0.8
- ash content by mass = 11%
- sulphur content in coal by mass = 1%
- carbon content by mass = 65%
- desulphurization plant efficiency = 95%
- NO_x concentration (Low NO_x combustion Gas Turbine) = 150 mg/Nm^3 (based on 6% O_2)
- particulate concentration (with Cyclone & ceramic filter) = 20 mg/Nm^3
- flue gas conditions same as APC
- bulk density of slag = 1.3 tonnes/m^3

B2.2 CALCULATIONS

B2.2.1 *Mass of Coal Consumed Per Year*

= Total energy consumed per year ÷ Energy value per kilogram of coal
= 1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh ÷ 43%÷ (6,300 kcal/kg x 4,186.8 J/kcal)
= 4,003,852 tonnes/yr

B2.2.2 *Mass of Slag Produced Per Year*

= Mass of coal consumed per year x Ash content by mass
= 4,003,852 tonnes/yr x 11%
= 440,000 tonnes/yr (approx.)

B2.2.3 *Volume of Slag Produced Per Year*

= 440,000 tonnes/yr ÷ 1.3 tonnes/m^3
= 338,462 m^3/yr

B2.2.4 *Annual SO_2 Emission*

= Coal consumption x Sulphur content in coal x MWt ratio x (1 - FGD sulphur removal eff.)
= 4,003,852 tonnes/yr x 0.01 x 2 x (1 - 0.95)
= 4,000 tonnes/yr (approx.)

B2.2.5 *Flue Gas Volume*

Flue gas volume is inversely proportional to the efficiency
= 1,992,833 Nm^3/h x 40 ÷ 43
= 1,853,798 Nm^3/h

B2.2.6 *Annual NO_x Emission*

= 1,853,798 Nm^3/h x 150 mg/Nm^3 x 8,760 hr/yr x 0.8 x 3 units
= 5,800 tonnes/yr (approx.)

B2.2.7 *Annual Particulate Emission*

= 1,853,798 Nm^3/h x 20 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 780 tonnes/yr (approx.)

B2.2.8 *Annual CO_2 Emission*

= 4,003,852 tonnes x 0.65 x 44/12
= 9.5 million tonnes/yr (approx.)

B2.2.9 *Cooling Water Requirement*

For a 1,800 MW IGCC Plant, total heat reject to the cooling water system = 958,500 kJ/sec

958500 kJ/sec = Q x 8.5°C x 1000 kg/m^3 x 4.2 kJ/kg°C

Volumetric flowrate Q = 27 m^3/sec (say 30 m^3/sec)

B3 PFBC PLANT

B3.1 ASSUMPTIONS

- plant capacity = 1,800 MW
- net efficiency of PFBC Plant = 42% (HHV)
- load factor = 0.8
- ash content by mass = 11%
- sulphur content in coal by mass = 1%
- carbon content by mass = 65%
- in furnace desulphurization efficiency = 95%
- NO_x concentration (Low temperature combustion) = 250 mg/Nm^3 (based on 6% O_2)
- particulate concentration (with Cyclone & ceramic filter) = 20 mg/Nm^3
- flue gas conditions same as APC
- bulk density of FBC ash= 0.92 tonnes/m^3

B3.2 CALCULATION

B3.2.1 *Mass of Coal Consumed Per Year*

= Total energy consumed per year ÷ Energy value per kilogram of coal
= 1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh ÷ 42%÷ (6,300 kcal/kg x 4,186.8 J/kcal)
= 40,099,181 tonnes/yr

B3.2.2 *Annual SO_2 Emission*

= Coal consumption x Sulphur content in coal x MWt ratio x (1 - FGD sulphur removal eff.)
= 4,099,181 tonnes x 0.01 x 2 x (1 - 0.95)
= 4,100 tonnes (approx.)

B3.2.3 *Flue Gas Volume*

Flue gas volume is inversely proportion to the efficiency
= 1,992,833 Nm^3/h x 40 ÷ 42
= 1,897,936 Nm^3/h

B3.2.4 *Annual NO_x Emission*

= 1,897,936 Nm^3/h x 250 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 9.9756 x 10^{12} mg/yr
= 10,000 tonnes/yr (approx.)

B3.2.5 *Annual Particulate Emission*

= 1,897,936 Nm^3/h x 20 mg/Nm^3 x 8760 hr/yr x 0.8 x 3 units
= 800 tonnes/yr (approx.)

B3.2.6 *Annual CO_2 Emission*

= 4,099,180.515 tonnes/yr x 0.65 x 44/12
= 9.8 million tonnes/yr (approx.)

B3.2.7 *Gypsum Production*

Molecular weight of gypsum, $CaSO_4$ = 136 g
Molecular weight of limestone, $CaCO_3$ = 100.09 g
Molecular weight of sulphur, S = 32.06 g
4% impurity in limestone
Ca to S ratio = 2 : 1

$2CaCO_3 + SO_2 + \frac{1}{2}O_2$ + impurities ---> $CaCO_3 + CaSO_4 + CO_2$ + impurities

Mass of gypsum, limestone and impurities mixtures produced per year
= 4,099,181 tonnes/yr x 1% x 95% x [(100.09/32.06)(1 +2 x 0.04) + (136/32.06)]
= 296,496 tonnes/yr

Mass of gypsum, limestone and ash mixture produced per year
= Mass of coal consumed per year x Ash content by mass
= (4,099,181 tonnes/yr x 11%) + 296,496 tonnes/yr
= 750,000 tonnes/yr (approx.)

Volume of FBC ash produced per year
= 750,000 tonnes/yr ÷ 0.92 tonnes/m^3
= 813,737 m^3/yr

B3.2.8 *Cooling Water Requirement*

For a 1,800 MW PFBC Plant, total heat reject to the cooling water system
= 1,704,000 kJ/sec

170,400 kJ/sec = Q x 8.5°C x 1000 kg/m^3 x 4.2 kJ/kg°C

Volumetric flowrate Q = 48 m^3/sec (say 53 m^3/sec)

B4 CFBC PLANT

B4.1 ASSUMPTIONS

- plant capacity = 1,800 MW
- net efficiency of CFBC Plant = 36% (HHV)
- load factor = 0.8
- ash content by mass = 11%
- sulphur content in coal by mass = 1%
- carbon content by mass = 65%
- in-furnace desulphurization efficiency = 95%
- NO_x concentration (Low temperature combustion) = 250 mg/Nm^3 (based on 6% O_2)
- particulate concentration (with Cyclone & ceramic filter) = 50 mg/Nm^3
- flue gas conditions same as APC
- bulk density of FBC ash= 0.92 tonnes/m^3

B4.2 CALCULATION

B4.2.1 *Mass of Coal Consumed Per Year*

= Total energy consumed per year ÷ Energy value per kilogram of coal
= 1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh ÷ 36%÷ (6,300 kcal/kg x 4186.8 J/kcal)
= 4,782,377 tonnes/yr

B4.3 ANNUAL SO_2 EMISSION

= Coal consumption x Sulphur content in coal x MWt ratio x (1 - FGD sulphur removal eff.)
= 4,782,377.267 tonnes/yr x 0.01 x 2 x (1 - 0.95)
= 4,800 tonnes/yr (approx.)

B4.3.1 *Flue Gas Volume*

Flue gas volume is inversely proportion to the efficiency
= 1,992,833 Nm^3/h x 40 ÷ 36
= 2,214,259 Nm^3/h

B4.3.2 *Annual NO_x Emission*

= 2,214,259 Nm^3/h x 250 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 11,600 tonnes/yr (approx.)

B4.3.3 *Annual Particulate Emission*

= 2,214,259 Nm^3/h x 50 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 2,300 tonnes/yr (approx.)

B4.3.4 *Annual CO_2 Emission*

= 4,782,377 tonnes/yr x 0.65 x 44/12
= 11.4 million tonnes/yr (approx.)

B4.3.5 *Gypsum Production*

Molecular weight of gypsum, $CaSO_4$ = 136 g
Molecular weight of limestone, $CaCO_3$ = 100.09 g
Molecular weight of sulphur, S = 32.06 g
4% impurity in limestone
Ca to S ratio = 2 : 1

$2CaCO_3 + SO_2 + ½O_2$ + impurities --->$CaCO_3 + CaSO_4 + CO_2$ + impurities

Mass of gypsum, limestone and impurities mixtures produced per year
= 4,782,377 tonnes/yr x 1% x 95% x [(100.09/32.06)(1 +2 x 0.04) + (136/32.06)]
= 3,459,126 tonnes/yr

Mass of gypsum, limestone and ash mixture produced per year
= (4,782,377 tonnes/yr x 11%) + 3,459,126 tonnes/yr
= 870,000 tonnes/yr (approx.)

Volume of FBC ash produced per year
= 870,000 tonnes/yr ÷ 0.92 tonnes/m^3
= 945,652 m^3/yr

B4.3.6 *Cooling Water Requirement*

For a 1,800 MW CFBC Plant, total heat reject to the cooling water system
= 2,130,000 kJ/sec

2,130,000 kJ/sec = Q x 8.5°C x 1000 kg/m^3 x 4.2 kJ/kg°C

Volumetric flowrate Q = 60 m^3/sec (say 66 m^3/sec)

Total volumetric flowrate for 1,800 MW
= 22 m^3/sec x 3 units
= 66 m^3/sec

B2 *IGCC PLANT*

B2.1 *ASSUMPTIONS*

- plant capacity = 1,800 MW
- net efficiency of IGCC Plant = 43% (HHV)
- load factor = 0.8
- ash content by mass = 11%
- sulphur content in coal by mass = 1%
- carbon content by mass = 65%
- desulphurization plant efficiency = 95%
- NO_x concentration (Low NO_x combustion Gas Turbine) = 150 mg/Nm^3 (based on 6% O_2)
- particulate concentration (with Cyclone & ceramic filter) = 20 mg/Nm^3
- flue gas conditions same as APC
- bulk density of slag = 1.3 tonnes/m^3

B2.2 *CALCULATIONS*

B2.2.1 *Mass of Coal Consumed Per Year*

= Total energy consumed per year ÷ Energy value per kilogram of coal
= 1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh ÷ 43%÷ (6,300 kcal/kg x 4,186.8 J/kcal)
= 4,003,852 tonnes/yr

B2.2.2 *Mass of Slag Produced Per Year*

= Mass of coal consumed per year x Ash content by mass
= 4,003,852 tonnes/yr x 11%
= 440,000 tonnes/yr (approx.)

B2.2.3 *Volume of Slag Produced Per Year*

= 440,000 tonnes/yr ÷ 1.3 tonnes/m^3
= 338,462 m^3/yr

B2.2.4 *Annual SO_2 Emission*

= Coal consumption x Sulphur content in coal x MWt ratio x (1 - FGD sulphur removal eff.)
= 4,003,852 tonnes/yr x 0.01 x 2 x (1 - 0.95)
= 4,000 tonnes/yr (approx.)

B2.2.5 *Flue Gas Volume*

Flue gas volume is inversely proportional to the efficiency
= 1,992,833 Nm^3/h x 40 ÷ 43
= 1,853,798 Nm^3/h

B2.2.6 *Annual NO_x Emission*

= 1,853,798 Nm^3/h x 150 mg/Nm^3 x 8,760 hr/yr x 0.8 x 3 units
= 5,800 tonnes/yr (approx.)

B2.2.7 *Annual Particulate Emission*

= 1,853,798 Nm^3/h x 20 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 780 tonnes/yr (approx.)

B2.2.8 *Annual CO_2 Emission*

= 4,003,852 tonnes x 0.65 x 44/12
= 9.5 million tonnes/yr (approx.)

B2.2.9 *Cooling Water Requirement*

For a 1,800 MW IGCC Plant, total heat reject to the cooling water system = 958,500 kJ/sec

958500 kJ/sec = Q x 8.5°C x 1000 kg/m^3 x 4.2 kJ/kg°C

Volumetric flowrate Q = 27 m^3/sec (say 30 m^3/sec)

B3 PFBC PLANT

B3.1 ASSUMPTIONS

- plant capacity = 1,800 MW
- net efficiency of PFBC Plant = 42% (HHV)
- load factor = 0.8
- ash content by mass = 11%
- sulphur content in coal by mass = 1%
- carbon content by mass = 65%
- in furnace desulphurization efficiency = 95%
- NO_x concentration (Low temperature combustion) = 250 mg/Nm^3 (based on 6% O_2)
- particulate concentration (with Cyclone & ceramic filter) = 20 mg/Nm^3
- flue gas conditions same as APC
- bulk density of FBC ash= 0.92 tonnes/m^3

B3.2 CALCULATION

B3.2.1 *Mass of Coal Consumed Per Year*

= Total energy consumed per year ÷ Energy value per kilogram of coal
= 1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh ÷ 42%÷ (6,300 kcal/kg x 4,186.8 J/kcal)
= 40,099,181 tonnes/yr

B3.2.2 *Annual SO_2 Emission*

= Coal consumption x Sulphur content in coal x MWt ratio x (1 - FGD sulphur removal eff.)
= 4,099,181 tonnes x 0.01 x 2 x (1 - 0.95)
= 4,100 tonnes (approx.)

B3.2.3 *Flue Gas Volume*

Flue gas volume is inversely proportion to the efficiency
= 1,992,833 Nm^3/h x 40 ÷ 42
= 1,897,936 Nm^3/h

B3.2.4 *Annual NO_x Emission*

= 1,897,936 Nm^3/h x 250 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 9.9756 x 10^{12} mg/yr
= 10,000 tonnes/yr (approx.)

B3.2.5 *Annual Particulate Emission*

= 1,897,936 Nm^3/h x 20 mg/Nm^3 x 8760 hr/yr x 0.8 x 3 units
= 800 tonnes/yr (approx.)

B3.2.6 *Annual CO_2 Emission*

= 4,099,180.515 tonnes/yr x 0.65 x 44/12
= 9.8 million tonnes/yr (approx.)

B3.2.7 *Gypsum Production*

Molecular weight of gypsum, $CaSO_4$ = 136 g
Molecular weight of limestone, $CaCO_3$ = 100.09 g
Molecular weight of sulphur, S = 32.06 g
4% impurity in limestone
Ca to S ratio = 2 : 1

$2CaCO_3 + SO_2 + ½O_2$ + impurities ---> $CaCO_3 + CaSO_4 + CO_2$ + impurities

Mass of gypsum, limestone and impurities mixtures produced per year
= 4,099,181 tonnes/yr x 1% x 95% x [(100.09/32.06)(1 +2 x 0.04) + (136/32.06)]
= 296,496 tonnes/yr

Mass of gypsum, limestone and ash mixture produced per year
= Mass of coal consumed per year x Ash content by mass
= (4,099,181 tonnes/yr x 11%) + 296,496 tonnes/yr
= 750,000 tonnes/yr (approx.)

Volume of FBC ash produced per year
= 750,000 tonnes/yr ÷ 0.92 tonnes/m^3
= 813,737 m^3/yr

B3.2.8 *Cooling Water Requirement*

For a 1,800 MW PFBC Plant, total heat reject to the cooling water system
= 1,704,000 kJ/sec

170,400 kJ/sec = Q x 8.5°C x 1000 kg/m^3 x 4.2 kJ/kg°C

Volumetric flowrate Q = 48 m^3/sec (say 53 m^3/sec)

B4 CFBC PLANT

B4.1 ASSUMPTIONS

- plant capacity = 1,800 MW
- net efficiency of CFBC Plant = 36% (HHV)
- load factor = 0.8
- ash content by mass = 11%
- sulphur content in coal by mass = 1%
- carbon content by mass = 65%
- in-furnace desulphurization efficiency = 95%
- NO_x concentration (Low temperature combustion) = 250 mg/Nm^3 (based on 6% O_2)
- particulate concentration (with Cyclone & ceramic filter) = 50 mg/Nm^3
- flue gas conditions same as APC
- bulk density of FBC ash= 0.92 tonnes/m^3

B4.2 CALCULATION

B4.2.1 *Mass of Coal Consumed Per Year*

= Total energy consumed per year ÷ Energy value per kilogram of coal
= 1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh ÷ 36%÷ (6,300 kcal/kg x 4186.8 J/kcal)
= 4,782,377 tonnes/yr

B4.3 ANNUAL SO_2 EMISSION

= Coal consumption x Sulphur content in coal x MWt ratio x (1 - FGD sulphur removal eff.)
= 4,782,377.267 tonnes/yr x 0.01 x 2 x (1 - 0.95)
= 4,800 tonnes/yr (approx.)

B4.3.1 *Flue Gas Volume*

Flue gas volume is inversely proportion to the efficiency
= 1,992,833 Nm^3/h x 40 ÷ 36
= 2,214,259 Nm^3/h

B4.3.2 *Annual NO_x Emission*

= 2,214,259 Nm^3/h x 250 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 11,600 tonnes/yr (approx.)

B4.3.3 *Annual Particulate Emission*

= 2,214,259 Nm^3/h x 50 mg/Nm^3 x 365 day/yr x 24 hr/day x 0.8 x 3 units
= 2,300 tonnes/yr (approx.)

B4.3.4 *Annual CO_2 Emission*

= 4,782,377 tonnes/yr x 0.65 x 44/12
= 11.4 million tonnes/yr (approx.)

B4.3.5 *Gypsum Production*

Molecular weight of gypsum, $CaSO_4$ = 136 g
Molecular weight of limestone, $CaCO_3$ = 100.09 g
Molecular weight of sulphur, S = 32.06 g
4% impurity in limestone
Ca to S ratio = 2 : 1

$2CaCO_3 + SO_2 + ½O_2$ + impurities --->$CaCO_3 + CaSO_4 + CO_2$ + impurities

Mass of gypsum, limestone and impurities mixtures produced per year
= 4,782,377 tonnes/yr x 1% x 95% x [(100.09/32.06)(1 +2 x 0.04) + (136/32.06)]
= 3,459,126 tonnes/yr

Mass of gypsum, limestone and ash mixture produced per year
= (4,782,377 tonnes/yr x 11%) + 3,459,126 tonnes/yr
= 870,000 tonnes/yr (approx.)

Volume of FBC ash produced per year
= 870,000 tonnes/yr ÷ 0.92 tonnes/m^3
= 945,652 m^3/yr

B4.3.6 *Cooling Water Requirement*

For a 1,800 MW CFBC Plant, total heat reject to the cooling water system
= 2,130,000 kJ/sec

2,130,000 kJ/sec = Q x 8.5°C x 1000 kg/m^3 x 4.2 kJ/kg°C

Volumetric flowrate Q = 60 m^3/sec (say 66 m^3/sec)

B5 GAS FIRED COMBINED CYCLE

B5.1 ASSUMPTIONS

- plant capacity = 1,800 MW
- heating value (HV) = 35 MJ/m^3
- net efficiency of gas-fired Combined Cycle Plant = 53% (LHV)
- load factor = 0.8
- ash content by mass = 0%
- sulphur content in natural gas = 0%
- composition of natural gas (by volume):

CH_3	87%
CO_2	10%
C_2H_6	0.75%
C_3H_8	0.75%
C_4H_{10}	0.75%
C_5H_{12}	0.75%

- molar volume = 0.0224 m^3
- NO_x emission = 30vppm (15% O_2, 0°C, 1 atm)
- oxygen in ambient air = 20% by volume
- 1 vppm = 2.054 mg/m^3 (For NO_2 gas at 0°C, 1 atm)
- volume of flue gas generated per m^3 of natural gas (corrected to 15% O_2) = 34.9 m^3

B5.2 CALCULATIONS

B5.2.1 *Volume of Natural Gas Consumed Per Year*

= Total energy consumed per year ÷ Heat value per m^3 of natural gas
= 1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh ÷ 53% ÷ 35 MJ/m^3
= 2,448,077,628 m^3

B5.2.2 *Mass of CO_2 Generated from Complete Combustion of One m^3 of Natural Gas*

= [(0.87 x 1) + (0.1 x 1) + (0.0075 x 2) +(0.0075 x 3) + (0.0075 x 4) + (0.0075 x 5)] m^3 ÷ [0.0224m^3/mole x 44 g/mole]
= 2,111.607 g

B5.2.3 *Mass of CO_2 Generated Per Year*

= 2,448,077,628 m^3/yr x 2111.607 g/m^3
= 5.2 million tonnes/yr (approx.)

B5.2.4 *Volume of NO_x Generated Per Year*

= 2,448,077,628 m^3 x 34.9 m^3/m^3 x 30 vppm x 2.054 mg/m^3
= 5,300 tonnes/yr (approx.)

B5.2.5 *Cooling Water Requirement*

Heat reject = Q x T x d x c

where Q is cooling water flow rate
T is temperature rise of cooling water
d is density of sea water
c is specific heat of sea water

For a 1,800MW Gas-fired Combined Cycle Plant, total heat reject to the cooling water system
= 1,086,300 kJ/sec

1,086,300 kJ/sec = Q x 8.5°C x 1,000 kg/m^3 x 4.2 kJ/kg°C

Volumetric flowrate Q = 31 m^3/sec (say 33 m^3/sec)

B6 GAS FIRED STEAM CYCLE PLANT

B6.1 ASSUMPTIONS

- plant capacity = 1,800 MW
- heating value (HV) = 35 MJ/m^3
- net efficiency of gas-fired Steam Cycle Plant = 41% (LHV)
- load factor = 0.8
- ash content by mass = 0%
- sulphur content in natural gas = 0%
- composition of natural gas (by volume):

	CH_3	87%
	CO_2	10%
	C_2H_6	0.75%
	C_3H_8	0.75%
	C_4H_{10}	0.75%
	C_5H_{12}	0.75%

- molar volume = 0.0224 m^3
- NO_x emission = 60vppm (15% O_2, 0°C, 1 atm)
- oxygen in ambient air = 20% by volume
- 1 vppm = 2.054 mg/m^3 (For NO_2 gas at 0°C, 1 atm)
- volume of flue gas generated per m^3 of natural gas (corrected to 15% O_2) = 34.9 m^3

B6.2 CALCULATIONS

B6.2.1 *Volume of Natural Gas Consumed Per Year*

= Total energy consumed per year ÷ Heat value per m^3 of natural gas
= 1,800 MW x 8,760 hr/yr x 0.8 x 3.6 x 10^9 J/MWh ÷ 41% ÷ 35 MJ/m^3
= 3,164,588,153 m^3

B6.2.2 *Mass of CO_2 Generated from Complete Combustion of One m^3 of Natural Gas*

= [(0.87 x 1) + (0.1 x 1) + (0.0075 x 2) +(0.0075 x 3) + (0.0075 x 4) + (0.0075 x 5)] m^3 ÷ [0.0224m^3/mole x 44 g/mole]
= 2,111.607 g

B6.2.3 *Mass of CO_2 Generated Per Year*

= 3,164,588,153 m^3/yr x 2,111.607 g/m^3
= 6.7 million tonnes/yr (approx.)

B6.2.4 *Volume of NOx Generated Per Year*

= 3,164,588,153 m^3/yr x 34.9 m^3/m^3 x 60 vppm x 2.054 mg/m^3
= 14,000 tonnes/yr (approx.)

B6.2.5 *Cooling Water Requirement*

For a 600MW Gas-fired Steam Cycle Plant, total heat reject to the cooling water system
= 710,000 kJ/sec

710,000 kJ/sec = Q x 8.5°C x 1,000 kg/m^3 x 4.2 kJ/kg°C

Q = 20 m^3/sec (say 22 m^3/sec)

Total volume flowrate for 1,800 MW
= 22 m^3/sec x 3 units
= 66 m^3/sec

Annex C

Responses to Comments

Response to Comments
Technical Paper on Power Generation Technology Review
for the Stage 1 EIA for a New Power Station

No.	Department	Reference	Comments	Consultants' Response
1.	EPD	General Comments	HEC should state clearly in the paper that is has covered all operationally acceptable and commercially available coal-fired and gas-fired power generation technologies appropriate for use in Hong Kong	All possible power generation technologies utilising coal or gas as the primary fuel have been examined. Innovative coal-based technologies including magnetohydrodynamics, fuel cells, ultra clean coal, underground coal gasification, coal diesel and external coal-fired combined cycle are still in a very early stage of development with small units of capacity ranging from several hundred kW to a few MW sizes under testing and research, and therefore are not considered as sufficiently proven to be included in this Study. For gas fuel option, new technologies including magnetohydrodynmaics and fuel cells are also considered premature to be worth for further pursuit. Therefore, the six power generation technologies presented in the Review for coal and gas fuels are all options that are under technical consideration for commercial, large scale power generation.

No.	Department	Reference	Comments	Consultants' Response
2.			The technologies should also be compared with all the best practicable pollution control measures in place in order to allow the selection of the 'most environmentally friendly technology and design'. The technical paper should estimate the environmental performance, and residual pollution level, of the typical design using each of the power generation technologies with all the best practicable pollution control and mitigation measures packages in place, including any low-NOx technologies, de-NOx facilities, desulphurisation, CO_2 reduction measures, particulates removal, wastewater treatment, waste heat recovery and solid wastes minimisation, utilisation and management measures.	The pollution control measures proposed for each technology in the Review are based on the most common practices adopted by power utilities in industrialised countries and with an objective of at least meeting the EPD's BPM emission limits for power generation. De-NO_x facilities have recently been fitted to APC plant for power generation in countries with very stringent emission limits in place. As 80% NO_x removal can be achieved, NO_x production from APC plant in Table 2.5a can be brought down to abut 3,100 t/yr which is significantly lower than that from IGCC plant. A separate column for APC equipped with De-NO_x has been added to Table 2.5a for comparison; the revised Table is appended for reference purposes. For CO_2, there is at present no commercially available technology that can be practically adopted to remove or capture CO_2 emissions. This issue will be addressed in detail in the Technical Paper on Greenhouse Gas Study. Regarding SO_2, particulates, waste water, solid wastes, etc., state-or the-art pollution control technologies have been duly employed in the Review. Further details of the aforesaid will be presented in Stage I EIA Report.
3.			It is suggested that mass and energy flow diagrams be included to illustrate the amount of raw materials, energy value, 'wastes' utilised and final emissions involved in the whole and each of the power generation and pollution minimisation processes. The local and/or regional availability of suppliers and users of the raw materials and 'wastes' required by and generated from the operation of the pollution mitigation processes should also be indicated. In addition, as space would be a critical concern if solid wastes are to be disposal of in landfills or lagoons, different types of solid wastes generated from the different power generation/pollutants removal technologies should also be expressed in volumetric terms using their likely build densities and consolidated densities.	Mass and energy flow diagrams will be included in the Stage 1 EIA Report.
4.			Based on the information provided, for the gas fuel option, it is obvious that combined cycle is the environmentally preferred power generation technology option. For the coal fuel option, IGCC should be adopted as the environmentally preferred technology in the prototype design to be considered further in the EIA.	The objective of the Technical Paper is not to determine the technology to be adopted for the prototype design. Section 1.1 of the Paper explains that the aim is to identify the environmental preferred technology for each of the fuel options. The Site Search Steering Group will consider a range of environmental and non-environmental factors in determining which technology should be adopted.

No.	Department	Reference	Comments	Consultants' Response
5.	EPD	Specific Comments	Paragraph 1, Section 1.1 - It should be noted that the Stage 1 EIA study brief does not specifically require the preparation and submission of the technical paper although this arrangement is supported. It is considered more accurate to state the paper has be prepared as part of the Stage 1 EIA.	Agreed. This Technical Paper will be incorporated in the Stage 1 EIA Report as part of the Stage 1 EIA Study.
6.			Paragraph 4, Section 1.1 - It should be noted that in the event that the environmentally preferred technology is different from the technology recommended for further consideration in the Site Search, the final Stage 1 EIA report must include both technology options in ranking the environmental preference of the fuel, sites, technology and design packages.	Since the Stage 1 EIA is an integral part of the Site Search Study, it is in our understanding that the Site Search Study 's Steering Group will undertake a consolidated evaluation taking due consideration of all major issues. The Stage 1 EIA and Site Search Studies shall be based on the technology recommended by the Site Search Steering Group. Please note that this approach was discussed at great length at the 1st SMG meeting and it was agreed that only one preferred technology option for each fuel option would be considered in assessing the site options.
7.			Various 'Environmental Control Facilities' sub-section under Section 2 - The paper should also address the option of using baghouses which are capable of reducing both particulates (in particular, fine particulates) and, though to a lesser extent, SO_2 with suitable plant design configuration. Section 2.5 on environmental assessment and comparison should be revised as appropriate.	Baghouses can achieve a particulate emission level of 20 -50mg/Nm^3 and are quite widely installed in APC plants for power generation. This equipment has a lower capital cost but there is a need for regular replacement of the filter bags which is considered a high maintenance cost item. Since ESP's (which has been proved highly reliable requiring minimum maintenance based on HEC operating experience over the past 15 years) together with FGD plant can achieve a very low particulate emission level of 20-30 mg/Nm^3 which is comparable to Baghouse, it is therefore proposed in the Technical Paper as the best practicable particulate control facilities for APC plant. Regarding SO_2, it is unlikely that either a Baghouse or ESP's can reduce SO_2 emissions significantly.

No.	Department	Reference	Comments	Consultants' Response
8.			Section 2.3.3 - Can the ASU for IGCC be used in combination with APC to reduce the amount NOx produced from APC?	The main purpose of the ASU for IGCC is to produce "oxygen gas" required for the gasification of coal to produce syngas. The objective to supply only oxygen for coal gasification is to produce syngas with a reasonable calorific value (i.e. small gas volume with high energy content) for further combustion in gas turbine combustion chamber. During the air separation process in the ASU, nitrogen gas will be generated as a by-product which will be fed to the gas turbine combustion chamber to lower the firing temperature of syngas for suppression of NO_x formation as well as to increase the mass flow of hot gas through the gas turbine for more power output. For APC, low NO_x combustion technology by means of staging combustion of coal with strict control of air supply is adopted to reduce NO_x formation during the combustion process which takes place in the boiler furnace. Due to inherent difference in process design, ASU is not applicable to APC for NO_x reduction.
9.			Paragraph 2, Section 2.4.2 - The paragraph mentions that there are erosion problems from the ash carried along in the flue gas. Which components in the ash are causing the problems and what pollution control measures are included in the system to remove/handle them?	For CFBC, the flue gas moves at a speed of 5-8m/s carrying with it large amount of fluidized bed materials consisting of limestone, ash and coal. This material which is carried along with the flue gas stream is separated in a hot cyclone and returned to the combustion chamber. Due to high flue gas velocity and temperature and the erosive nature of aforesaid bed materials, erosion of boiler tubes in the flue gas path is inevitable and is considered a general problem for CFBC plants. The ash entrained in the flue gas will be normally removed by the ESP before discharging to atmosphere.
10.			Section 2.5, Environmental Assessment - As commented in the 'general comments' section above, the 'typical design' in the assessment should be revised to cover all feasible mitigation options with each of the generation technologies (e.g. including De-NOx plant for NOx reduction).	Please refer to response to item 2.
11.			Emission summary under section 2.5 - The residual particulate level of CFBC is quite high relative to other technologies. Is there any particular reason for this observation? Are ESP and ceramic filter interchangeable, i.e. can APC use ceramic filter instead of ESP? Which of them has a higher particulate removal efficiency?	Ceramic filters and wet scrubbing are adopted for IGCC and PFBC plants respectively to achieve very low particulate emission levels in hot gas for protection of the gas turbine blades against erosion. Very low particulate emissions can also be achieved for APC plants with the use of ESP and FGD. For CFBC, only standard particulate control facility such as ESP or Baghouse is commonly adopted. Hence particulate emission level from CFBC is higher than the other three technologies. ESP and ceramic filter are not interchangeable. Ceramic filter is normally adopted for high temperature application and therefore not for APC.

No.	Department	Reference	Comments	Consultants' Response
12.			Sections 2.5.2, 3.2.3 and 3.3.3, Cooling Water Discharge from various fuel and plant options - It will be helpful if the report can provide some elaboration to enlighten the readers on how those cooling water discharge flow figures are derived. Besides, it will also be advisable for the report to include the daily cooling water discharge rate of HEC's Lamma Power Station in relation to its power generating capacity as a sort of benchmark or reference.	The cooling water flow requirements are estimated based on the amount of heat rejected by steam exhausted to the condenser after passing through the steam turbine. Therefore, the quantities of cooling water required by different technologies would mainly depend on the amount of power generated by the steam turbine. In order to provide further clarification, we are pleased to provide an example of how the figures are derived: Heat reject = Q x T x d x c where Q is Cooling water flow rate T is Temperature rise of cooling water d is Density of sea water c is Specific heat of sea water. For a 600MW APC plant, the steam flow to the condenser is about 1,100,000 kg/hr, equivalent to 710,000 kJ/sec heat reject in condenser steam to water. 710,000 kJ/sec = Q x 8.5°C x 1000 kg/m^3 x 4.2 kJ/kg°C giving volume flowrate Q at 20 m^3/sec (say 22 m^3/sec) Therefore total volume flowrate for 1800MW is 22 m^3/sec x 3 = **66 m^3/sec.**
13.			Section 2.5.2, thermal elevation zone of less than 2°C at a distance of 1.5 km - The paper did not provide any explanation or elaboration on how it can jump to a conclusion that a 66 m^3/s (or smaller) cooling water will result in a 2°C thermal mixing zone of 1.5 km distance. Presumably, the size of mixing zone is **"site-specific"** (i.e. depends on the hydrodynamic conditions of receiving water) and will also depend on the **dilution performance of the disposal device** (e.g. outfall) being used. The paper should therefore addressed how it arrives at such conclusion and what assumptions are being made. In addition, it is important to highlight that even if the size of thermal mixing zone can be confined to 1.5 km, it will not automatically guarantee that the impact will be acceptable. The environmental acceptability of thermal impact of a major cooling water discharge will strongly hinge on factors like the presence and nature of sensitive receivers and the size and vulnerability of the receiving water.	While the size of the thermal mixing zone is site specific, it is believed that through proper engineering and design of the outfall and cooling water system, such as diverting the discharge point away from the sensitive receivers, lowering the discharge velocity and temperature, etc., thermal impact of the cooling water discharge on the receiving water can in our opinion be controlled to an environmentally acceptable level. This will be duly demonstrated in the section of Water Quality Assessment of the shortlisted sites of Stage 1 EIA Report. The reference to the elevation zone of less than 2°C at a distance of 1.5 km is taken from the experience gained at the existing Lamma Power Station; in line with the acknowledgement that the issue is determined by site specific factors and to avoid the misinterpretation of this reference, the end of the sentence, from "...so that the sea water .." to " ...a distance of 1.5km" will be deleted.

No.	Department	Reference	Comments	Consultants' Response
14.			1st sentence, paragraph 1 under heading 'Comparison', Section 2.5.3 - The sentence that all four power generation technologies generate similar amount of solid wastes is incorrect. As illustrated in Table 4.1a, the amount of solid wastes generated from the four technologies are quite different, with 480,000 ton/yr from IGCC, 662,000 ton/yr from APC, 750,000 ton/yr from PFBC and 870,000 ton/yr from CFBC. It is believed that the differences are due to the addition of catalyst or other materials during the different generation and pollution removal processes.	The 1st paragraph is basically referring to the amount of "coal ash" produced from the four coal-fired power generation technologies. However, as the four technologies will generate other solid byproducts arising from the chemical treatment processes to reduce SO_2 emissions, it is correct that the total amounts of solid wastes (ash & solid chemical byproduct) from the four technologies taking due consideration of plant efficiency are quite different.
15.			Section 2.5.3, line 8, page 21 - The paper mentions that 'it is anticipated that the quantity of ash generated from a 1,800 MW plant can be *fully* taken up by the local, commercial ash demand.' To substantiate this optimistic statement, the paper should include historical records of PFA/FBA disposal outlets for the HEC's existing power station and the anticipated ash demand in the future. The demand will surely affect the size of the lagoon required by the new power station. Similarly, the paper should also provide information to support the disposal of the 189,000 tonnes per year of gypsum.	Based on discussions with the potential recipients for PFA/FBA, we are confident that the quantity of coal ash and gypsum produced from the 1,800MW APC plant can all be fully taken up for cement manufacturing and other industrial applications. Details will be addressed in Stage I EIA Report. However, it would be expedient and prudent at the planning stage to cater for the contingency storage of a third of the total ash production of a plant life span of 30 years.
16.			Section 4.2, page 35, last line - It seems that the '*' denotes a footnote which is missing in the paper.	The "*" mark is a typing error.

No.	Department	Reference	Comments	Consultants' Response
17.			Table 4.1a - In assessing solid wastes generated by different technologies, the potential sources of reusing the wastes (e.g. making cement, reclamation, etc.) are even more important than the quantities of wastes generated. As such, the table should clearly indicate the possible reuse outlets for solid waste generated by each technology and its assumption on this estimation.	Taking into account the potential outlets for utilization of solid wastes/by-products, the amount of solid wastes/by-products which may not have secured commercial outlets and need to be stored in the ash lagoon are estimated over the 30 years plant life as below: APC: Assuming two-thirds of the total amount of PFA and FBA can be used for making cement and bricks, the quantity of ash to be dumped into the ash lagoon for storage will be around 5,700,000 m^3 Once the commercial outlets for coal ash have been secured, in which HEC has full confidence, the size of the ash lagoon can be substantially reduced. Due to high demand of FGD gypsum for making of cement and wallboard/plaster, outlets for gypsum produced from APC can be secured. IGCC: Since initial years of operation will normally be required for trail testing of slag for various industrial uses before the authority/end-users acceptance can be established, it is assumed that only one-third of the total amount of slag can be used for concrete mixing and reclamation, about 6,800,000 m^3 of slag will need to be stored in the ash lagoon. It is assumed that there are commercial outlets for all the sulphur produced. PFBC: Similar to IGCC, initial years of operation will be used to demonstrate acceptability of the PFBC solid bi-products (coal ash, gypsum, sand, etc) for industrial uses. It is assumed that one-third of the total amount of PFBC ash can be used for land fill and building material and the remaining 16,300,000 m^3 of ash will need to be stored in the ash lagoon. CFBC: CFBC ash is similar to PFBC ash and hence it is assumed that two-thirds of the CFBC ash of about 19,000,000 m^3 will need to be stored in the ash lagoon.
18.			Table 4.1 a - We believe that the unit for solid wastes is ton/year. Is this correct?	Yes, the unit for solid wastes is ton/year.

No.	Department	Reference	Comments	Consultants' Response
19.			Nitrogen removal by biological treatment process to meet TM requirements - It was mentioned in a number of places in the paper regarding the use of biological process in wastewater treatment plant associated with coal-fired plant options. The consultant is reminded to give due regard to the potential difficulty in removing nitrogen from certain special effluent arising from coal-fired power plant. Based on the experience from HEC's existing Lamma power Station, effluent like those arising from FGD plant may present some technical challenge and complications to conventional biological nitrogen removal process which is applicable and effective for municipal wastewater. This is mainly due to the very unique nature of FGD-effluent that contains high nitrate content but with little or no organic carbon. In this respect, it is expected that the forthcoming WQ assessment in this study should identify, study and evaluate the existence of reliable, robust and commercial-available treatment process/technology which can effectively deal with the excess NO_3 in such special and problematic effluent.	The development of nitrogen removal by biological treatment process for FGD effluent has received considerable attention in recent years particularly in Europe and Japan. While the technology is relatively new, results of a pilot plant for treating FGD effluent at the Avedore Power Station in Denmark demonstrated that concentration of in-organic nitrogen can be reduced to below 8mg/l under various conditions. HEC is actively seeking the latest in technological advances in the biological nitrogen removal process in order to counter the technical challenges currently being addressed at Lamma and the solutions developed will be applied to the new power station.
20.			Individual power generation and/or pollutant removal technology may generate wastewater treatment sludge and other solid wastes which are potentially highly polluting or with high pollutant concentration. Their amount and management/disposal measures should also be covered in the report.	Disposal management for ash and solid waste from chemical treatment for reduction of SO_2 has been briefly addressed in the Report, and detailed assessment would be included in the Stage 1 EIA Report. Sludge from waste water treatment is of a relatively small quantity; a common European practice is to mix such small quantities of sludge with coal and burn it in the boiler.
21.	PELB		In general the paper offers some useful descriptions of the various technology choices for each of the fuel options - coal and natural gas. However, there are some unknowns which HEC and the consultants should clarify. For example, according to section 2,2,3 sub-paragraph 3 and 4, tow alternatives for coal handling - a large coal storage yard and coal silos - are mentioned. However, how these two facilities are different in environmental and landtake terms is not addressed, though it appears that silos do have less land requirement and may result in less coal debris through the storage of coal in a closed environment.	Coal storage yards have been widely adopted for coal-fired power stations due to ease of construction, ready maintenance and low capital cost. However, the high capital and maintenance cost coal silos may be considered for an extension of the in-service power station where available area is severely constrained. Area required for coal silos will be less than half of that for coal storage yard of similar storage capacity. Due to operating in a closed environment, coal silos are in general considered more environmentally friendly.
22.			General Comment on the Coal Fired Technology Review - IGCC is comparatively the most environmentally friendly technology and should be given further consideration. Commercial value for solid waste should not be a pre-requisite for recommending a technology. Storage area could be considered within the site for disposal if market for the waste could not be found. I think that the market for PFA did not come with the APC plant when it was introduced into Hong Kong.	The Technical Paper does not make a recommendation on which technology is to be retained for further consideration. The scope and objectives of the paper are clearly stated in Section 1.1; the status of the Paper's findings are explained in para. 4 of Section 1.1.

No.	Department	Reference	Comments	Consultants' Response
23.			Section 2.2 - It would be clearer to state the size of the pulverised coal particle in AFC plant so that comparison could be made with that of IGCC plant.	Size of pulverised coal in APC plant for combustion in boiler furnace is about 0.08mm and that use in IGCC plant for coal gasification is about 0.1mm to meet the their respective objective of combustion process.
24.			Section 2.2.4, sub-paragraph on *De-NOx plant* under the section NOx Control - It is mentioned that a NOx removal efficiency of 50% to 80% can be achieved, but there is no indication on what cause(s) the variation within the 30% range which seems quite wide.	Due to high capital/running cost, removal efficiency of De-NO_x plant would normally be selected to meet the local regulations on NO_x emission level. By varying the amount of flue gas passing through the De-NO_x plant, different removal efficiencies ranging from 50% to 80% can be achieved.
25.			Section 2.3.2 - The paper should clarify whether coal could be pulverised as inn APC plant irrespective of whether it is not a common practice or costly to do so. The same question was asked during the presentation at the 2nd SMG meeting and the information obtained was that it could not be done because of something to do with the combustion. Does it refer to the 'lean combustion process' stated in the first paragraph of Section 2.3.2? Please clarify whether by adjusting the amount of oxidizing air, the coal particle could be milled to the same fineness as APC plant so that they do not have the problem of no commercial market for the slag.	The larger size of slag in IGCC plant than that of PFA in APC plant is not solely a result of the difference in fineness of the coal particles used as mentioned in response to item 23. For IGCC, the objective of Gasifier is to produce "Syn Gas" for complete combustion in gas turbine combustor. As the Gasifier operates at a temperature higher than the ash melting point, ash in the form of molten slag will be dropped to the bottom of the gasifier where it is quenched in a water bath to a glassy form. This formation process results in larger size of slag than coal ash in APC plant. According to the IGCC suppliers, the slag is substantially harder than coal ash and too hard for grinding to the required particle size for comment making.
26.			Section 2.3.2, 2nd sub-paragraph on *Coal Gasifier* under the section Generating Unit - The consultants should indicate the difference in the environmental performance of fixed bed, fluidized bed and entrained flow gasifiers.	Fixed-Bed and Fluidise-Bed Gasifiers have not been further developed for power generation purpose due to their low coal gasification efficiency compared with Entrained Flow Gasifiers.
27.			According to section 2.3.3 under the section *Other Ancillary Plants*, the cooling water flow required for an IGCC plant is approximately half of that for a PC plant and a 'smaller' capacity cooling water system will be required. According to section 2.3.4 under the section *Gas Clean-Up System*, the syngas volume of an IGCC plant is only 2% of the combusted gas volume and hence a much 'smaller' gas cleaning unit is required compared to PC plants. Could I assume that the capacity of the cooling system and the size of the gas cleaning plant for IGCC would not be proportional to the respective 50% and 2% less of these plants' cooling water flow and syngas volume with the PC plants?	The cooling water is mainly used in the condenser of a steam turbine plant for condensing the steam after passing through the steam turbine back to water. Hence, the amount of cooling water required would depend on the power output of the steam turbine and there is no direct relationship between cooling water flow and the syngas volume.
28.			Section 2.3.4 - It is inappropriate to consider disposing elemental sulphur as chemical waste in Hong Kong as there should be market for it in the world. Regarding the use of slag as land filling material or for making road paving bricks, S for W should be consulted.	In case IGCC is adopted for the new power station, trial tests and detailed assessment on the suitability of the slag and sulphur for various industrial uses would have to be carried out during the initial years of operation before the commercial outlet can be established.

No.	Department	Reference	Comments	Consultants' Response
29.			Section 2.5.1, fourth paragraph on page 17 - The amount of reduction of NOx by using the DeNOx plant should be stated.	Please refer to response to item 2.
30.			Section 2.5.3 - Solid waste arising from various types of plant is quoted in tonne while in Section 2.2.4 and 2.3.4 waste is quoted in cubic metre. Please explain the inconsistency. Also in Section 2.5.3, it stated the 'FBA could be used for landfill and various industrial use', could the same use be satisfied by bottom slag and fly slag arising from IGCC plant. Furthermore is it possible to give the annual amount of bottom slag and fly slag arising from the IGCC plant.	Solid waste is quoted in tonnes when comparing the absolute quantity generated whereas when referring to storage requirements, the solid waste is quoted in m^3. As stated in response to item 17, the properties of IGCC slag would have to be further assessed probably with trial tests to demonstrate acceptability for industrial uses. The annual amount of slag from IGCC plant is estimated to be 440,000 tonnes as mentioned in Section 2.5.3 .
31.			Section 2.5.7 - It is stated that 'industrial outlets for slag and elemental sulphur... has yet to be explored.' This should not be used as an excuse for not considering the IGCC further.	The Technical Paper does not exclude any technology. It identifies the environmentally preferred technology for each fuel; the ranking of various coal fired power generation technologies with respect to potential environmental impacts is presented in Table 2.5b.
32.			In section 2.5.7, the consultants conclude that even though IGCC plants have the least environmental impacts, there are uncertainties regarding the industrial outlets for slag and elemental sulphur produced and the technology's claim high efficiency. In this connection, would the other three power generation technologies, though seem to be less environmental, be more appropriate for Hong Kong due to reasons which the consultants have not specified in the report? A section which cross-compares the opportunities and constraints of each option or states the assumptions used by the consultants in concluding the environmental impacts of each option is necessary.	It was not the intention of Section 2:5.7 to imply that the other three technologies (APC, PFBC and CFBC) would be more appropriate for Hong Kong. A re-reading of the second paragraph of Section 2.5.7, indicates that there are elements which are strictly within the remit of the Site Search rather than the Stage 1 EIA. The last two sentences (from "However, it should be noted that..." to "...been demonstrated") are therefore deleted. A sub-section will be added to cross-compare the opportunities and constrains of each technology options. Ranking of environmental impacts of each option is given in the attached revised Table 2.5b. For completeness, the revised Table 4.1a is also attached.
33.			There should be a section on the comparison of the environmental impacts between coal a dn gas-fired power generation technologies.	Comparison of the environmental impacts between the two fuel options will be addressed in the Technical Paper on Comparative Fuel Study.
34.	EMSD		Table 2.5(a), Pg 18 and Table 3.4(a) Pg 31 - For ease of understanding the calculation of pollutant emissions, the paper should provide the calculation details including the estimated annual fuel consumption and the various pollutant emission factors for respective generation technologies in an annex.	Detailed calculation of the pollutant emissions and estimated annual fuel consumption will be included in the Stage 1 EIA Report.

No.	Department	Reference	Comments	Consultants' Response
35.			4th sentence, 1st paragraph, Section 4.2, Pg 35 - The paper should elaborate clearly what are the technical problems associated with Integrated Gasification Combined Cycle and yet to be resolved.	Non-environmental issues associated with the technologies under consideration fall outside the scope of the Stage 1 EIA Study. The technical problems associated with IGCC technology will be included in the revised *Technical Report No 1 - Fuel, Power Generation Technology and Design Option* for the overall Site Search Study.
36.	PlanD		According to para. 8.3(r) of the Study Brief, 'Other operational impact' should also be included in this study. My concern is on the environmental impact of the following items and whether they should be addressed in this paper or as hazard assessment under the Site Search Study: - the 4 million tonne coal-carrying vessel and the handling and storage of hydrogen gas, chlorine and other chemicals (para. 3.5.3 in TR1 of the Site Search Study (SS) refers); - potential gas leakage (para. 4.4.3 in TR1 of SS refers). - transmission cables (para. 6.3.4 in TR1 of SS refers).	Since these issues are site specific, they would be addressed in the Stage 1 EIA Report during assessment of the shortlisted sites.
37.	AFD		This paper did not include consideration from ecological impact point of view. It would be more appropriate for the consultants to indicated what would be the ecological impacts of the two fuel options.	The ecological impact consideration of the two fuel options will be addressed in the technical paper for Comparative Fuel Study and the Stage 1 EIA Report.
38.	TDD		No comment raised.	
39.	HyD		No comment raised.	
40.	MD		No comment raised.	
41.	CED		No comment raised.	
42.	FSD		No comment raised.	
43.	BCSB		No written response received.	
44.	ESB		No written response received.	
45.	TD		No written response received.	

TECHNICAL PAPER

The Hongkong Electric Company, Limited

Stage 1 EIA for a New Power Station : *Pearl River Delta Air Quality Assessment*

November 1997
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CONTENTS:

1 *INTRODUCTION*

The majority of this document discusses the results of numerical simulations carried out to examine the impact on regional photochemistry of an additional power station in the Hong Kong Special Administrative Region. Simulations were performed for emissions scenarios for the year 2002, before the commissioning of the new power station, and 2012 with the proposed power station operating as: a coal-fired station utilising Advanced Pulverised Coal (APC), with or without De-NO_X; or a combined cycle gas-fired station.

The air quality model used for the Study, CSIRO's Lagrangian Atmospheric Dispersion Model (LADM), is presented in *Section 2* with a description of the modelling domains and initial set-up. In the previous *Working Paper*[1], the worst-case conditions for a site in southern Hong Kong were discussed and a brief summary of the two chosen scenarios is given here in *Section 3*. The emission characteristics of the various sources were set out in the above mentioned *Working Paper*, but are also in *Section 4* of this document. Results of the modelling exercise are presented and discussed in *Section 5*. In *Section 6*, an analysis of the impact of a new power station on levels of acid deposition in the region is presented.

[1] Stage 1 EIA for a New Power Station: *Air Quality Working Paper on Emissions and Worst-Case Scenarios.* ERM-Hong Kong, Ltd.

2 THE MODELLING SYSTEM LADM

LADM (Lagrangian Atmospheric Dispersion Model) is an air pollution dispersion system that models accurately the transport and diffusion of emissions from discrete sources for impact distances of hundreds of metres to a few hundred kilometres. It is applicable to air quality studies that involve simple to very rugged terrain, time-varying conditions such as sea breezes, and the interaction of complex wind flows such as drainage winds. The system is most readily applied to larger facilities such as power stations, refinery complexes and smelters.

It is most useful for creating and analysing worst-case simulations for environmental impact assessment (EIA) studies. It is capable of predicting the impact of morning fumigation, the usual cause of highest ground level concentrations, out to large distances from tall stacks. Sea-breeze fumigation and convective mixing are equally well modelled, in both flat and complex terrain, as are plume impacts in stable conditions.

LADM consists of two main components:

- a mesoscale windfield model which predicts the diurnal cycle of winds and turbulence at many levels and gridpoints in the atmosphere; and
- a Lagrangian particle dispersion model which uses the winds and turbulence to predict the pathways and concentrations of tracer particles released from any number of locations.

The LADM also has a photochemical module to simulate photochemical smog formations.

2.1 *THE PROGNOSTIC WINDFIELD MODEL*

Given an initial synoptic state, this model predicts the mesoscale perturbations to that state generated by terrain and by the diurnal heating and cooling cycle. Such winds include sea breezes, slope flows, drainage flows, nocturnal low-level jets and those arising from blocking and channelling of the flow.

The model employs the equations of motion, the hydrostatic equation, the compressible form of the continuity equation and the thermodynamic and moisture equations in an (x,y,σ) coordinate system, where σ = pressure normalised by surface pressure. The predicted variables are the three wind components, surface pressure, temperature and specific humidity. The equations are applied at each point of a three-dimensional grid, typically consisting of 51 x 51 points at each vertical level. The first level is usually 10 m above the ground followed by 30 m and then up to 19,000m, with spacing between levels increasing towards the top of the model. Twenty five is a typical number of levels. A sophisticated boundary-layer turbulence formulation is employed as well as a vegetative canopy and soil moisture scheme at the lower boundary.

The spacing between horizontal gridpoints does not change over the domain and the value chosen is dependent upon the problem and the dominant scale of the underlying terrain. LADM is usually run in a nested manner using grid spacings ranging from 30 down to 1 km for consecutive runs. Each run takes its lateral boundary conditions from the previous run (one-way nesting). One advantage of nesting is that the smallest domain is distant from the lateral boundaries of the original domain - errors generated at artificial boundaries gradually move inwards and contaminate the interior solutions.

2.1.1 *Model Set-Up*

Five nested grids are used for this Study, with horizontal grid spacings of 20, 10, 5, 2 and 1 km respectively. They are all centred on (22.3°N, 114.05°E). The domains of the 5, 2 and 1 km nests are shown in *Figure 2.1a*. The dimensions of all grids are 51 x 51 with 24 levels in the vertical, ranging from 10 m above the ground to 19000 m at the model top. The spacing between levels increases from the ground to the top. Zero-gradient boundary conditions for wind, temperature and moisture are specified on the outer grid while all inner grids obtain their boundary conditions from the previous grid. Model runs begin at 0000 LT (local time) and run for 48 hours. A 72-hour run for the 2012 coal-fired (without De-NO_X) option under Worst-case Scenario 1 was also performed. At the initial time in all grid columns, the wind, temperature and moisture fields are set to the same specified synoptic profile, adjusted for height above the terrain. Emissions are released from 0200 LT onwards on the second day. This allows the wind and temperature fields one diurnal cycle in which to adjust to the underlying terrain and differential heating on slopes and across coastlines.

2.2 *The Lagrangian Particle Model*

This predicts the dispersion (including plume rise for buoyant emissions) from the pollutant sources using the wind and turbulence predictions from the meteorological model. A stream of tracer particles is released from each source at a rate proportional to the specified emissions. The particles can represent neutrally-buoyant gases that are relatively inert over the period of interest, such as SO_2 or NO_X, or reactive gases that take part in photochemical reactions. Ground-level concentrations (glcs) of these gases can be calculated by counting the number of particles in small "boxes" over the region of interest. The dispersion component of LADM can be run in two modes:

- *near-source mode* to determine the maximum glc, which usually occurs within 5 km of a source in convective conditions; and

- *far-field* mode to examine dispersion many kilometres from the source.

Final plume-rise height is calculated from a combination of Briggs (1975) equations for a bent-over Boussinesq plume and the plume-rise equations of Glendening (1984). This new formulation collapses to the Briggs form for a bent-over Boussinesq plume, and to the Briggs (1975) vertical plume model equations for zero ambient wind.

Further details of the numerics and parameterizations used in LADM can be found in Physick (1993) and a CSIRO Technical Report (Physick *et al.* 1994).

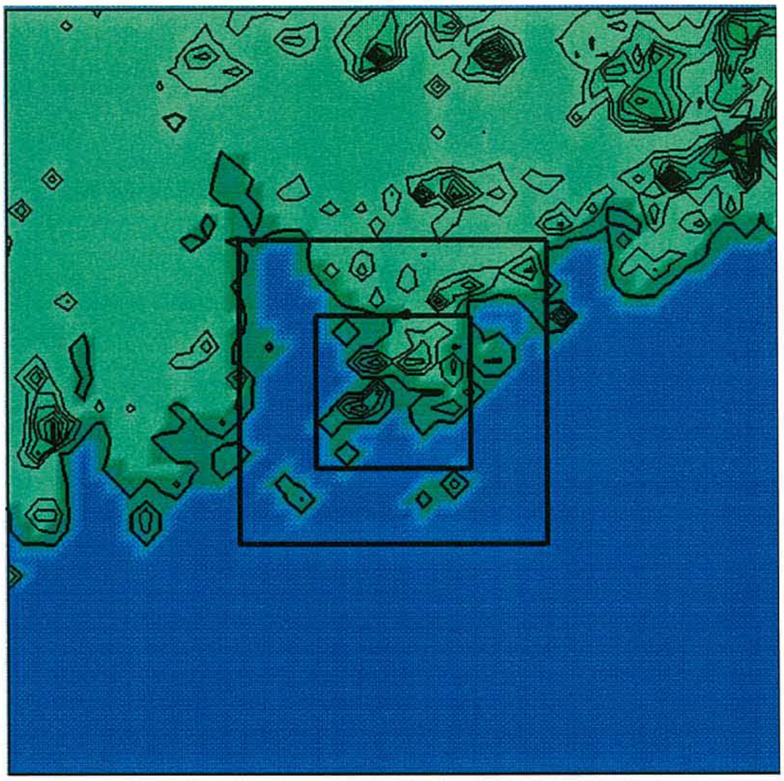


Figure 2.1a: The 5, 2, and 1 km nested domains used in simulations

2.2.1 *Photochemistry and the Approach to Modelling Local Visibility*

The Lagrangian particle model is also able to simulate photochemical smog reactions, using the Integrated Empirical Rate (IER) equations of smog formation (Johnson and Quigley, 1989), which predict concentrations of ozone (O_3) and nitrogen dioxide (NO_2) from emissions of hydrocarbons and oxides of nitrogen. Particles are assigned a mass according to the emission rate, as in the non-reactive simulations, but the mass of each particle changes with time according to the IER equations.

According to the IER procedure, there are two regimes in the formation of photochemical smog in an air parcel:

- a light-limited regime in which the smog produced is a function of the cumulative product of the rate coefficient for nitrogen dioxide photolysis, the hydrocarbon concentration, and temperature - while there is light, ozone will be produced; and

- a NO_X-limited regime in which sufficient light has been incident on the air parcel that photolysis effectively ceases - additional NO_X is needed for further ozone production.

The model uses a variable called R_{smog} (ppb) which can be derived from hydrocarbon concentration (ppbC) in terms of the molecular weight of CH_2. A value of .0067 moles smog/mole of ROC carbon/unit cumulative-light flux, is used to represent the reactivity of an urban air mass dominated by vehicle emissions (Wratt *et al.*, 1992).

In order to treat secondary formation of Fine Suspended Particulates with diameter less than 2.5 microns (FSP), we have used an extended form of the IER equations that handle sulfate and nitrate production. The IER model (*Johnson and Quigley, 1989*) estimates the concentration of Stable Non-Gaseous Nitrogen (SNGN) products, and we have assumed that these SNGN are all nitrates (a conservative estimate). Then knowing that the dominant gas-phase reaction to form both nitrates and sulfates is with the hydroxyl radical, and knowing the ratio of the reaction rates of these two processes (see e.g., *Seinfeld 1986*), we can then estimate the amount of both sulphates and nitrates from predictions of the concentration of SNGN, nitrogen dioxide and sulfur dioxide.

The FSP calculations include primary emissions and secondary sulphate and nitrate formation. These three types of FSP are major contributors to the total concentration of fine particles, based on RSP data from the EPD annual reports for Hong Kong (*EPD, 1993, 1994*). Organic carbon has similar levels to the smallest contributor of the above three (nitrates), but we have no simple way to include them in the calculations. Total particulate emissions are assumed to consist of 18.5% FSP for the coal-based power stations, 25% for the airport, and for the urban source where the particulate emissions are specified as RSP (or PM10), the factor is 50%. In these calculations, values for the $PM_{2.5}/PM_{10}$ ratio from *Cohen and Gras (1997)* and for the PM_{10}/TSP ratio from *Vedal (1997)*, have been used. With respect to FSP from the power stations, standard coal-fired technology with Electrostatic Precipitators is assumed as worst-case, since there is no data available for the more advanced design. However, it should be noted that the use of Flue Gas Desulfurisation (FGD) is able to reduce the total particulate emissions from the source.

An empirically-based estimate of visibility, the Local Visual Distance (LVD in km), can be calculated from the FSP concentration using the Koschmeider equation:

$$LVD = 3.912 \ / \ b_{est} \qquad \text{(see e.g. Seinfeld, section 7.5),}$$

where b_{est} is the light extinction coefficient
$b_{est} = b_{background} + 3.912 \ [FSP] \ / \ 1786$ (Charlson *et al.*, 1986),

and the background extinction has been set to give an LVD of 200 km.

The photochemistry simulations were performed using winds and turbulence from the meteorological run using the 5 km spacing grid, in order to follow the transport of emissions into the Pearl River Delta region. The smaller domain was used for the part of the Study concerned with the dispersion of non-reactive gases.

3 METEOROLOGICAL SCENARIOS

High ozone readings have been recorded to the west of Lantau Island on days in which surface synoptic winds are generally easterly, with winds at higher levels being from the southeast quadrant. Under this wind regime, emissions from a new power station at Lamma Island (and at sites in the general area) would be transported towards Lantau Island and probably impact on terrain and mix to the ground. There is also the potential to mix with emissions from Chek Lap Kok airport and the North Lantau Expressway. The more easterly winds at surface level are likely to advect urban emissions from the Kowloon - Hong Kong Island area to Lantau Island as well. These emissions, and the background air, contain the VOCs necessary for smog formation. While it is possible that this type of synoptic wind profile can occur in the autumn, winter and spring months, the warm temperatures and relatively cloud-free skies necessary for photochemistry are far more prevalent in the autumn.

3.1 WORST-CASE SCENARIO 1

After some preliminary test runs, the meteorology of Worst-case Scenario 1 was specified as follows: surface synoptic winds of 3 m/sec from the east (90°) turning with height to southeasterly (135°) by 500 m above ground level, also at 3 m/sec and maintaining this profile to the highest model level. For the initial potential temperature, a typical profile of 3 K/km from the surface to 1000m was specified, with 5 K/km above.

Figure 3.1a shows the model predictions for the Hong Kong windfields at a height of 10 m above the ground for 0800, 1200, 1400 and 2000 local time (LT). Extremely light winds are predicted to the west of Hong Kong and Lantau Islands at 0800 LT, although by 1200 LT sea breezes have developed at many coastlines in the region. A complex flow still exists to the west of Lantau Island at 1400 LT, although the winds are generally southeasterly by 1800 LT. *Figure 3.1b* shows the winds at a height of 300m above the ground at the same times. Emissions from the elevated power station sources are expected to be at this height or higher and it can be seen that Lamma Island emissions can be expected to cross Lantau Island and perhaps stagnate, at least in the morning hours.

An initial dispersion run with Scenario 1 meteorology showed that emissions from the urban source travelled to the northwest region of Lantau Island in the morning hours.

Figures 3.1c and *d* show the model predictions for the Hong Kong windfields on Day 3 at a height of 10 m and 300m, respectively, above the ground for 0800, 1200, 1400 and 2000 local time (LT).

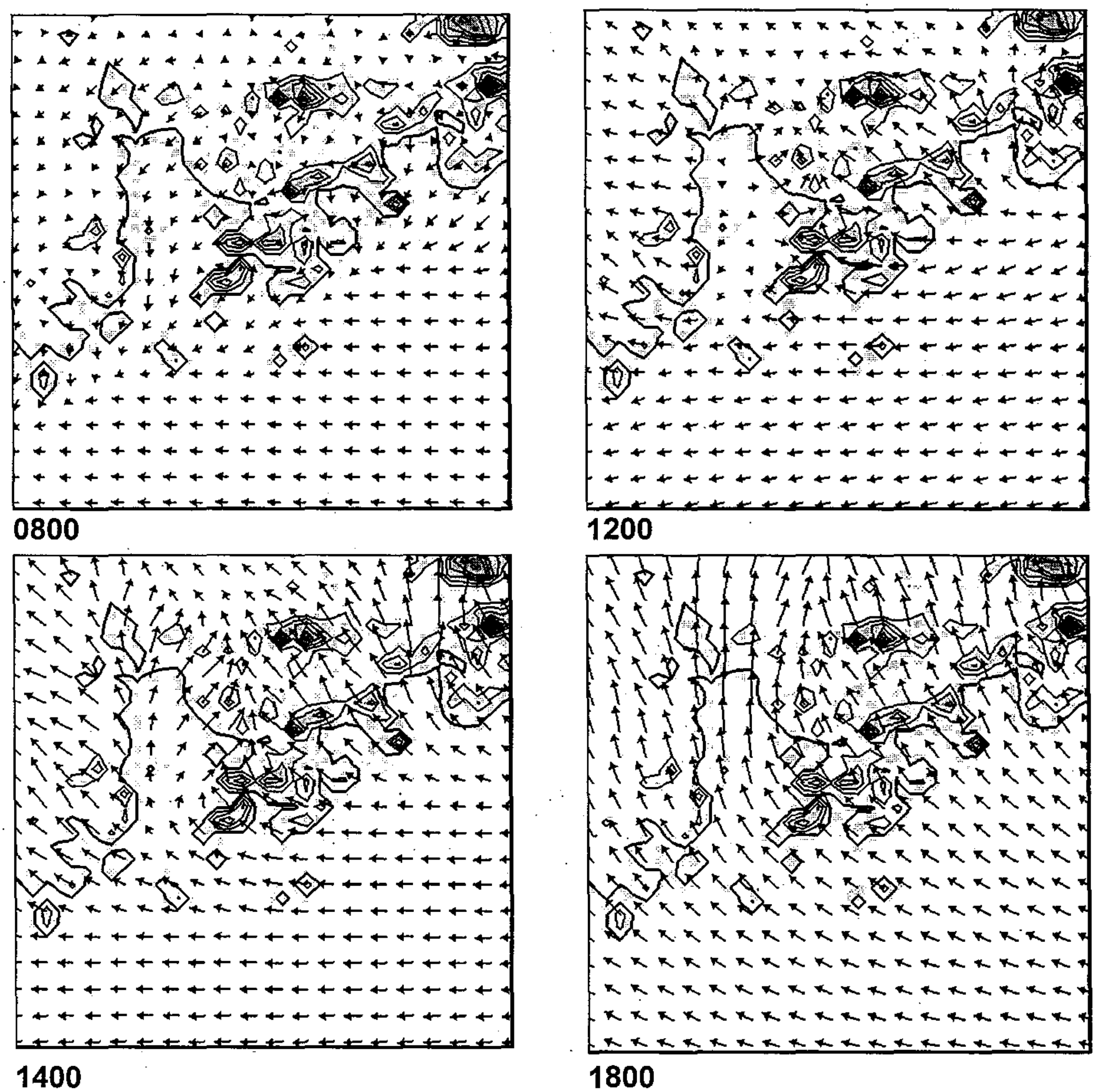


Figure 3.1a: Windfields at a height of 10 m above the ground on a 5 km domain at 0800, 1200, 1400 and 1800 LT.

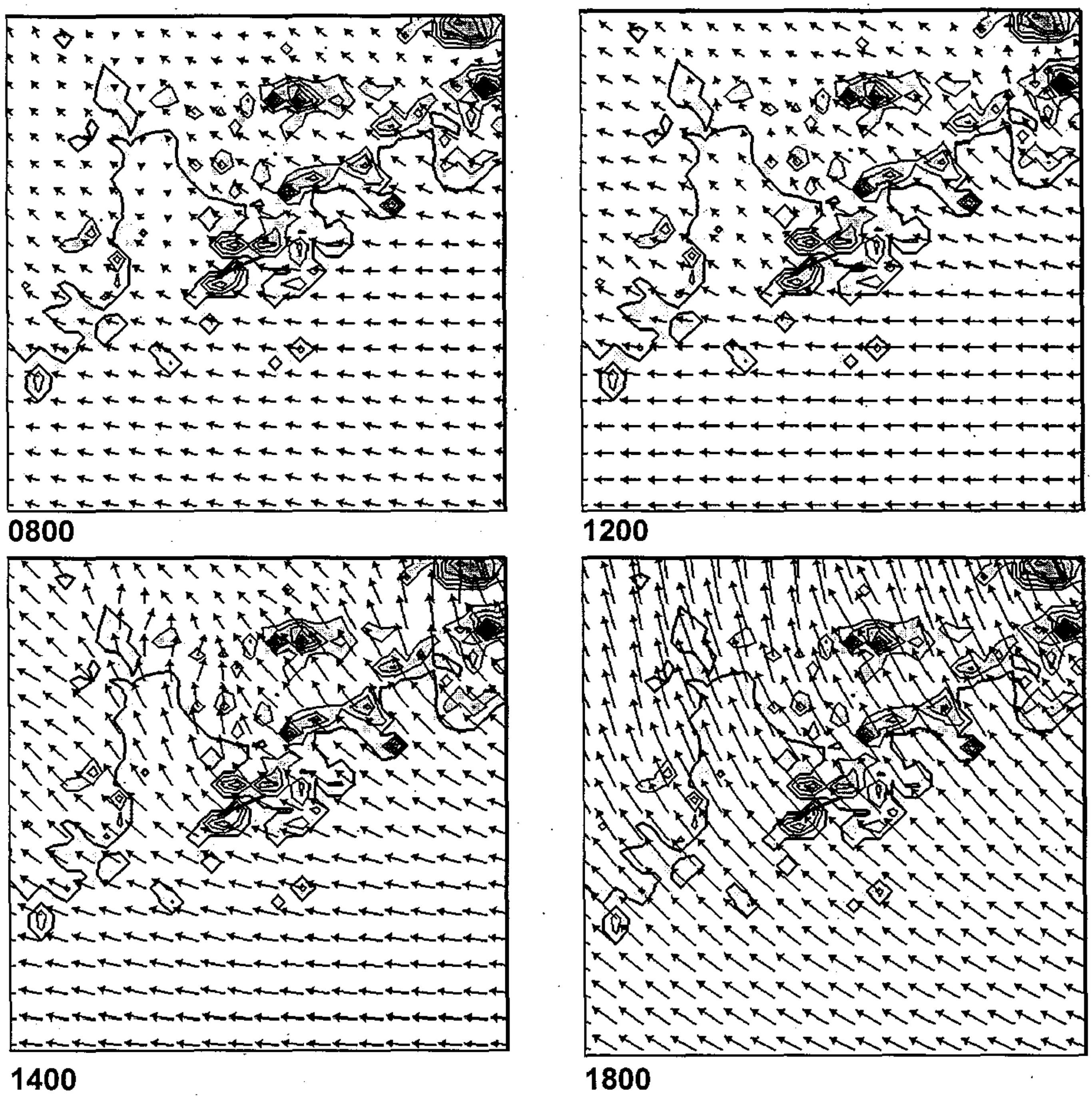


Figure 3.1b: Windfields at a height of 300 m above the ground on a 5 km domain at 0800, 1200, 1400 and 1800 LT.

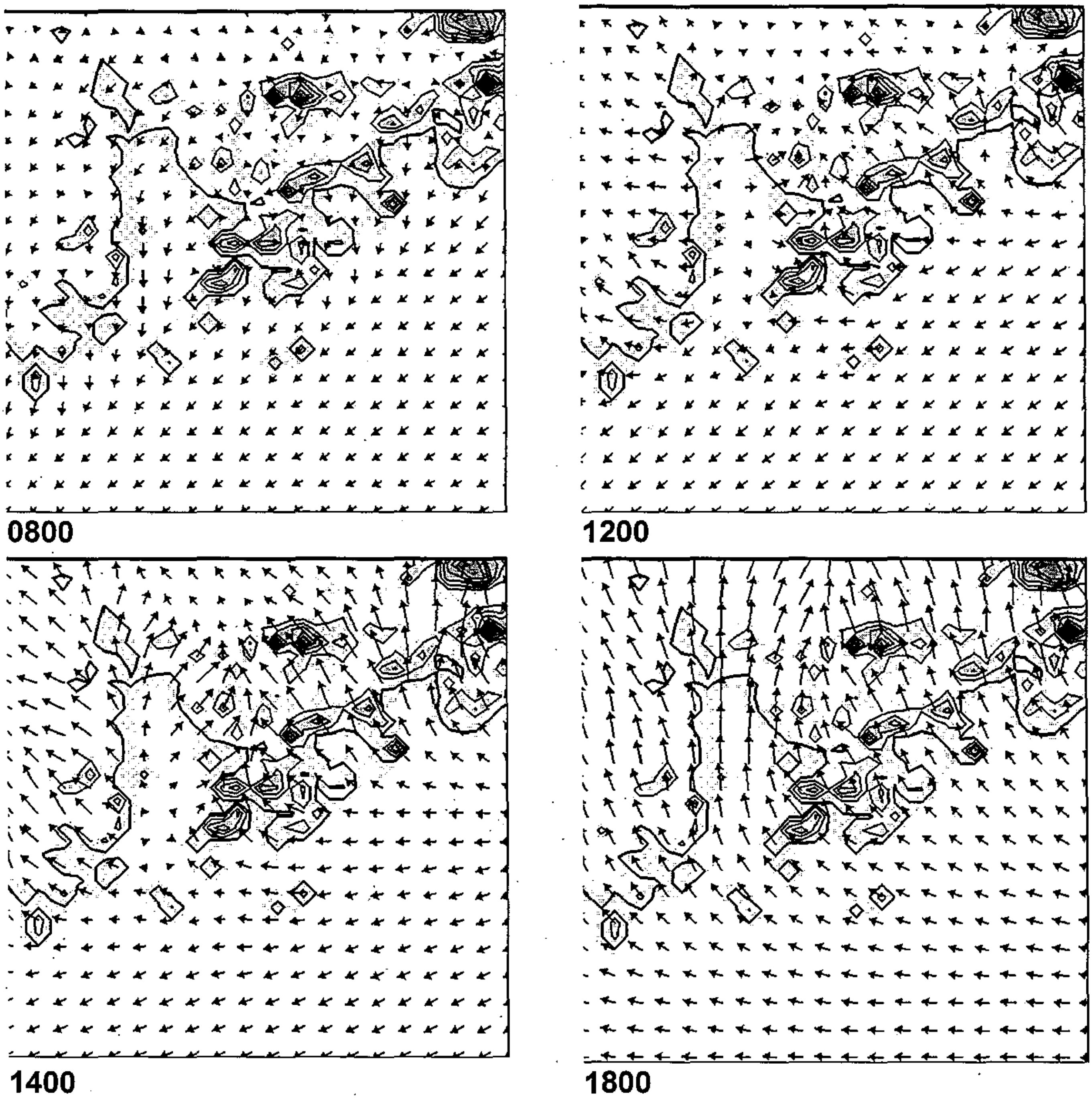


Figure 3.1c: Windfields at a height of 10 m above the ground on a 5 km domain on Day 3 at 0800, 1200, 1400 and 1800 LT.

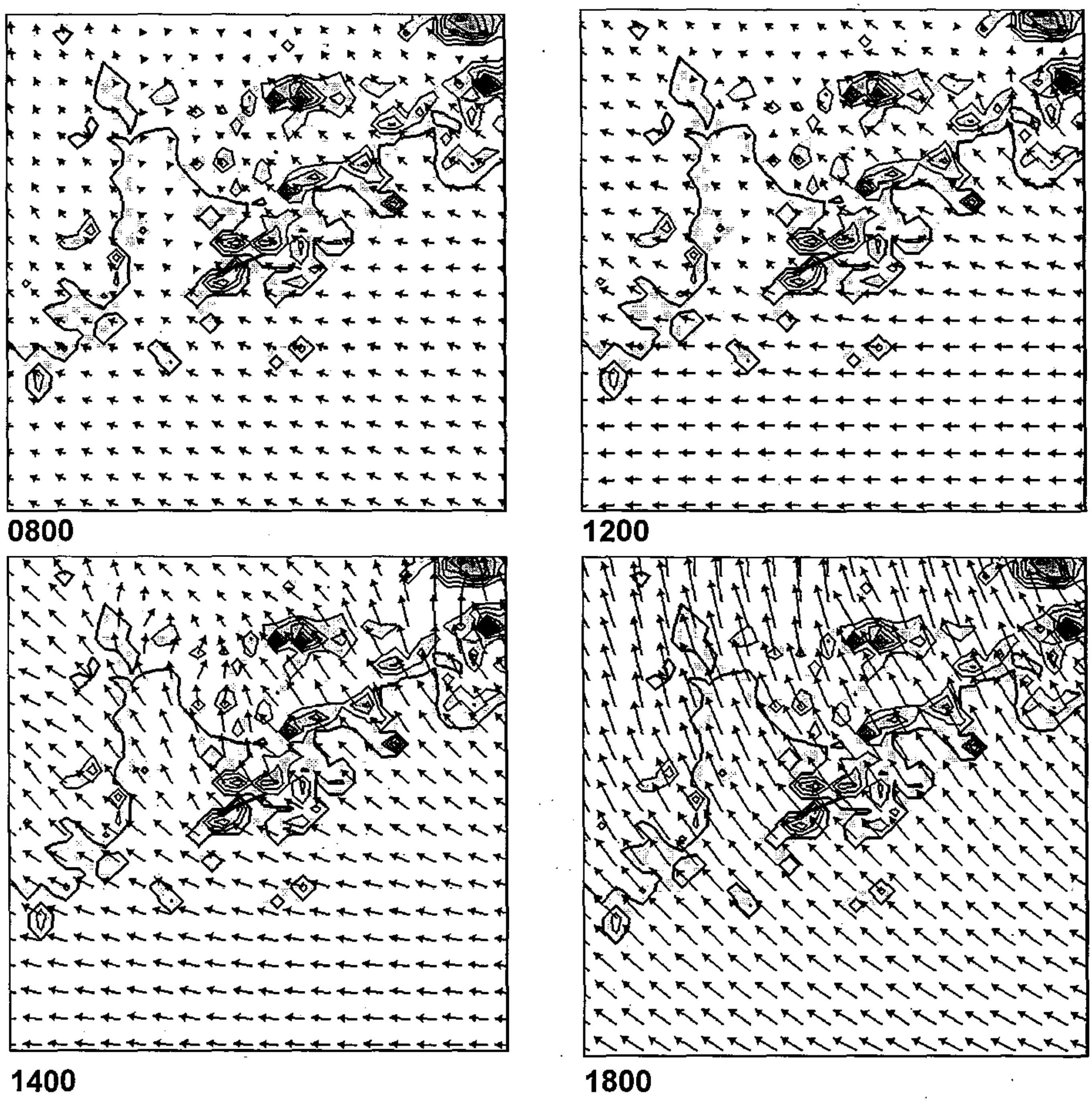


Figure 3.1d: Windfields at a height of 300 m above the ground on a 5 km domain on Day 3 at 0800, 1200, 1400 and 1800 LT.

3.2 *Worst-case Scenario 2*

For the second worst-case scenario, the consultants specified a surface wind with a small northerly component, as sometimes observed, while maintaining the upper winds and stability profile as before. In this case urban morning emissions were transported to both the northwest and southeast sides of Lantau Island, with a suggestion that those on the southeast side may travel around the lower tip to the western side later in the day. The meteorology of Worst-case Scenario 2 was specified as follows: surface synoptic winds of 3 m/sec from about east-northeast (70°) turning with height to southeasterly (135°) by 500 m above ground level, also at 3 m/sec, and maintaining this profile to the highest model level. An initial potential temperature profile of 3 K km^{-1} from the surface to 1000m was specified, with 5 K/km above.

For *Scenario 2*, surface winds during the day are more northerly and lighter around the Islands, and to the south and west, than for *Scenario 1*, suggesting that pollutants may tend to gather in those regions. The winds at 300m are also lighter in the morning than those for *Scenario 1*, although the directions are similar.

4 EMISSIONS

4.1 INTRODUCTION

The locations of the existing sources included in this Study are shown in *Figure 4.1a*. These include: the new Lantau airport, the urban source, the North Lantau Expressway, a Waste-to-Energy Incineration Facility (WEIF), the Castle Peak and Black Point power stations, and the existing Lamma Power Station. Omitted sources were not considered to be of sufficient magnitude to influence the outcome. Such sources include the Town Gas Production Plant at Tai Po, whose emissions would not overlap with the new power station anyway, and the Cement Plant at Tuen Mun, emissions from which are not large and would only overlap with the new power station emissions in late afternoon. Nor would there be any photochemical reactions between emissions from these two NO_x sources. All sources are elevated point sources except the airport on Lantau Island and the Hong Kong surface urban emissions which are treated as area sources.

4.2 POINT SOURCES

Some characteristics of the point sources are listed in *Tables 4.2a* and *b*. All values in the Tables represent the characteristics of each power station when considered as one source. The effective diameter of the source is that which gives the mean area of the source. For example, at Lamma Island No.1 chimney (units 1, 2 and 3 with diameter 5.11m), the effective diameter is 8.85m. Similarly, chimneys 2 and 3 have effective diameters of 9.73 and 7.83m respectively. When combining as one source, we have taken the effective diameter of that source to be that which gives the mean area of the 3 chimneys, ie 8.84m.

The exit temperatures and velocities used for the worst-case scenario runs in *Tables 4.2a* and *b* are minimum values. The lower resulting plume-rise height produces more interaction of the power station plumes with the surface sources, especially that from urban Hong Kong. Exit temperature is a weighted mean of each unit's temperature.

For sources with more than one chimney, the effective number of chimneys N_E (or buoyancy enhancement factor), depends on the source buoyancy flux and the chimney spacing, as well as wind direction relative to stack orientation. A methodology developed by *Briggs (1984)* for calculating N_E is discussed and applied to Latrobe Valley (Australia) power stations by *Manins (1987)*. Values of N_E for Hong Kong multi-chimney stations are shown in *Table 4.2a* and *b*. No dependence on wind direction has been used, following the data analysis of Briggs (1984) and the findings for the Latrobe Valley. The N_E values are used to multiply the initial plume buoyancy for each source.

Note that the emission rates in the Tables are those when a power station is operating at maximum capacity. Particulate rates for the point sources refer to total suspended particulates (TSP). The actual emission rates used for the Study appear in *Figures 4.2b to g*.

Table 4.2a *Source characteristics for the Coal-Fired Stations and the Proposed Waste- to-Energy Incineration Facility*

	Castle Peak	*Lamma Island*	*Proposed New Power Station*	*WEIF*
Height (m)	233	215	240	150
Exit vel. (m/sec)	17	15	15	15
Exit temp. (K)	383	373	353	393
Eff diam. (m)	12.0	8.84	11.3	4.66
SO_2 rate (g/sec) at max. capac.	8511	3206	171	89.2
NO_x rate (g/sec) at max. capac.	6467	2432	613 (215)[a]	142.8
Percentage NO_2 in emissions	5	5	5	5
Partic. rate (g/sec) at max. capac.	511	258	50	17.8
No. of stacks	2	3	1	1
Stack spacing (m)	400	200	-	-
Buoyancy enhancement factor N_E	1.1	1.2	-	-

Note: a - emission rate for APC with De-NO_x

Table 4.2b *Source characteristics for the Gas-Fired Stations*

	Black Point	*Proposed New Power Station*
Height (m)	106	110
Exit vel. (m/sec)	15	15
Exit temp. (K)	353	353
Eff diam. (m)	11.8	10.2
SO_2 rate (g/sec) at max. capac.	20.2	-
NO_x rate (g/sec) at max. capac.	378	208
Percentage NO_2 in emissions	5	5
Partic. rate (g/sec) at max. capac.	20.2	-
No. of stacks.	2	1
Stack spacing (m)	180	-
Buoyancy enhancement factor N_E	1.1	-

4.2.1 *Castle Peak A and B*

The typical daily load curves, as a percentage of daily peak, for China Light and Power Co. Ltd. (CLP) in 1996 are shown in *Figure 4.2a*. In the absence of other values, these curves are also assumed to hold for CLP emissions under the 2012 scenario.

The coal consumption estimated for 2012 by CLP under their High Coal Consumption scenario is used in the following manner to obtain the daily peak sulphur dioxide (SO_2) emissions in 2012. Assuming that the coal contains 1% sulphur, which is the maximum sulphur content allowed by the Air Pollution Control Ordinance (Fuel Restriction), the estimated 6,240,500 tonnes of coal for that year produces 62,405 tonnes of sulphur, which in turn forms 124,810 tonnes of sulphur dioxide. This is equivalent to 342 tonnes/day, and using the load curves in *Figure 4.2a* (weighted according to day of the week and season) gives an annual mean peak hourly emission rate of 17.96 tonnes/hr, or 17,960 kg/hr (4989 g/sec). This compares with an emission rate of 30,640 kg/hr for the eight units at Castle Peak A and B (four at each) operating at full capacity. The reason for this assumption is that Castle Peak Power Station is not the only source of electricity supply for CLP, as a significant portion of the projected demand will be met by

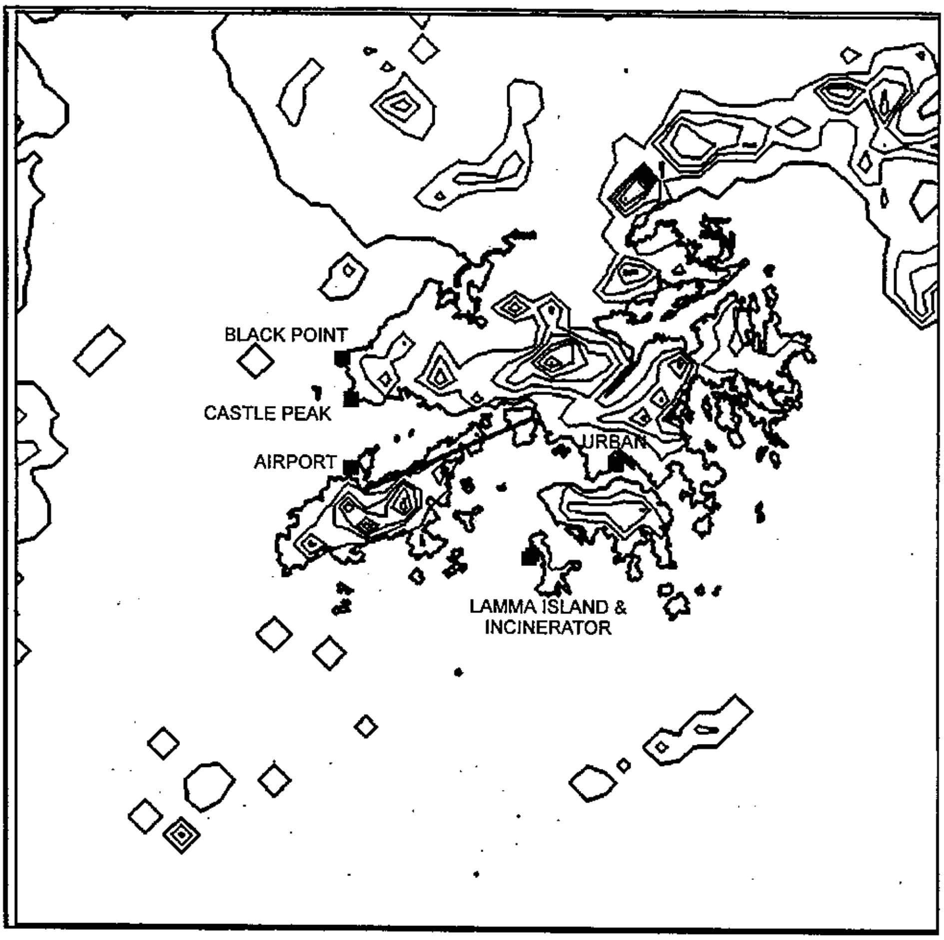


Figure 4.1a The existing sources modelled in the simulations.

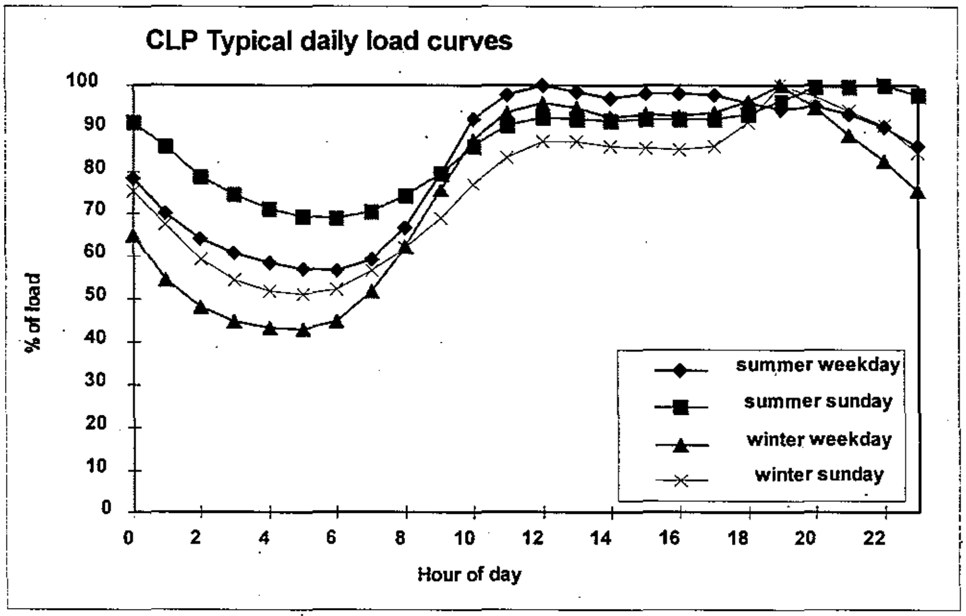


Figure 4.2a: Typical daily load curves, as a percentage of Daily Peak, for China Light and Power Co. Ltd. (CLP) in 1996.

the supply from the Daya Bay Nuclear Power Station and Back Point Power Station. The emission rates used for the model runs are based on the average daily projected fuel consumption under the high coal consumption scenario. The estimated emission rates are considered reasonable for the selected worst-case scenarios which are more likely to occur in autumn when the demand is less.

The same scaling for NO_x (full capacity rate of 23,280 kg/hr) gives a peak hourly emission rate of 13,646 kg/hr (3790 g/sec). Similarly, the peak hourly emission rate for particulates is 1078 kg/hr (299 g/sec). For all simulations, the summer weekday diurnal loading profile is applied, as this, in line with the worst-case situation, is the typical time for maximum electricity consumption. The diurnal variation of emission rate (in g/sec) for SO_2, NO_x and particulates, summed for Castle Peak A and B, is shown in *Figure 4.2b*. These sources are combined and treated as one in all simulations. The chimney height is the mean of A and B (215 and 250m) and the effective diameter is that which gives the mean area of the two chimneys.

4.2.2 *Black Point*

The 8 gas combined cycle units under CLP's High Coal Consumption scenario for 2012 are assumed to be operating at full capacity at the daily peak, leading to emissions at this time of 72.8, 1360, and 72.8 kg/hr for SO_2, NO_x, and particulates respectively. For all simulations, the summer weekday diurnal loading profile is applied, as for the Castle Peak stations. The diurnal variation of SO_2, NO_x, and particulates emission rates in g/sec is shown in *Figure 4.2c*.

4.2.3 *Waste-To-Energy Incineration Facility*

The source representing two one million ton per year waste-to-energy incinerators on Lamma Island is considered to run at full capacity throughout the diurnal cycle. The emission rate for each pollutant is shown in *Table 4.2a*.

4.2.4 *Existing Lamma Island Power Station in 2002*

The diurnal profiles of emission rates for SO_2, NO_x, and particulates calculated from the peak day generating unit loading schedule provided by HEC for 2002 are shown in *Figure 4.2d*. The effective diameter is that which gives the mean area of the three chimneys. A mean spacing between the chimneys of 200m gives a buoyancy enhancement factor of 1.2.

4.2.5 *Existing Lamma Island Power Station 2012*

The diurnal profiles of emission rates for SO_2, NO_x, and particulates calculated from the peak day generating unit loading schedule provided by HEC for 2012 are shown in *Figure 4.2e* (assuming the proposed station is coal-fired) and *Figure 4.2f* (assuming the proposed station is gas-fired).

4.2.6 *Proposed New Power Station*

The HEC loading schedule for the three units indicates almost full capacity over the diurnal cycle. This is reflected in the daily emission rate profiles for the coal-fired scenario (*Figure 4.2g*) and the gas-fired scenario (*Figure 4.2h*). In *Figure 4.2i*, emissions are shown for the coal-fired scenario when APC with De-NO_x

technology is applied. Under the latter option, NO_x emission rates are reduced by 65% while SO_2 and particulates are unchanged.

4.3 *AREA AND LINE SOURCES*

4.3.1 *Urban Emissions*

Emissions from the urban area include vehicle, domestic and industrial emissions (except for the major point sources which are treated separately). Contours were prepared by Environmental Protection Authority Victoria (EPAV) from an inventory, including vehicle kilometres travelled, supplied by Hong Kong sources, including the Environmental Protection Department. Emission factors were obtained from a preliminary analysis of the data by EPAV, and from USEPA emission factors. Time variation of the emissions is based on fleet distribution and traffic count information (personal communication, Simon Bentley, CSIRO). We have assumed that this diurnal variation information can be applied to the total urban emissions. Although there is likely to be a population increase by 2012, there is just as likely to be controls on emissions which counteract the increase or else a change in the vehicle mix or some other change as well. So in the absence of information on urban emissions for 2012, we have used the present-day emissions for the 2012 scenario emissions. These are represented in the model by a Gaussian volume source at 25 m above the ground, with standard deviations σ_x =7 km, σ_y =5 km, and σ_z =10m. It is centred on the western side of Kowloon Bay, south of the Kai Tak International Airport. The diurnal variation of NO_X, VOC and respirable suspended particulates (RSP) emissions is shown in *Figure 4.3a*. The NO_2 to NO ratio at emission is 5:95.

4.3.2 *Chek Lap Kok Airport*

The existing airport site will not be present in the year 2012, but a new airport will be in operation on the northern coast of Lantau Island at Chek Lap Kok. Emissions for this site are based on information obtained from the EPD and represent the site operating at a level approaching its maximum capacity. The airport emissions are represented by a Gaussian volume source at 50 m above the ground, with standard deviations σ_x = 2 km, σ_y =2 km, σ_z =15m. This distribution is reasonable for hydrocarbon emissions, but is conservative in terms of ground level concentrations for nitrogen oxides which are mostly emitted during the approach, take-off, and climb-out phases of flight. Emissions are assumed not to vary over the diurnal cycle and are specified as 12.7 g/sec for SO_2, 195 g/sec for NO_x, 106 g/sec for VOC, and 7.8 g/sec for particulates.

4.3.3 *North Lantau Expressway*

This expressway links the new Chek Lap Kok airport with the urban area via Tsuen Wan, and is included in the simulations as its emissions may mix with those of the urban plume as the latter is advected westward during the morning. The emissions used are those quoted for off-site vehicles in the New Airport Master Plan (Greiner-Maunsell) for a typical busy day. The expressway is represented as a line source with constant emissions of 10.5 g/sec for SO_2, 164 g/sec for NO_x, 40 g/sec for VOC and 27.6 g/sec for particulates.

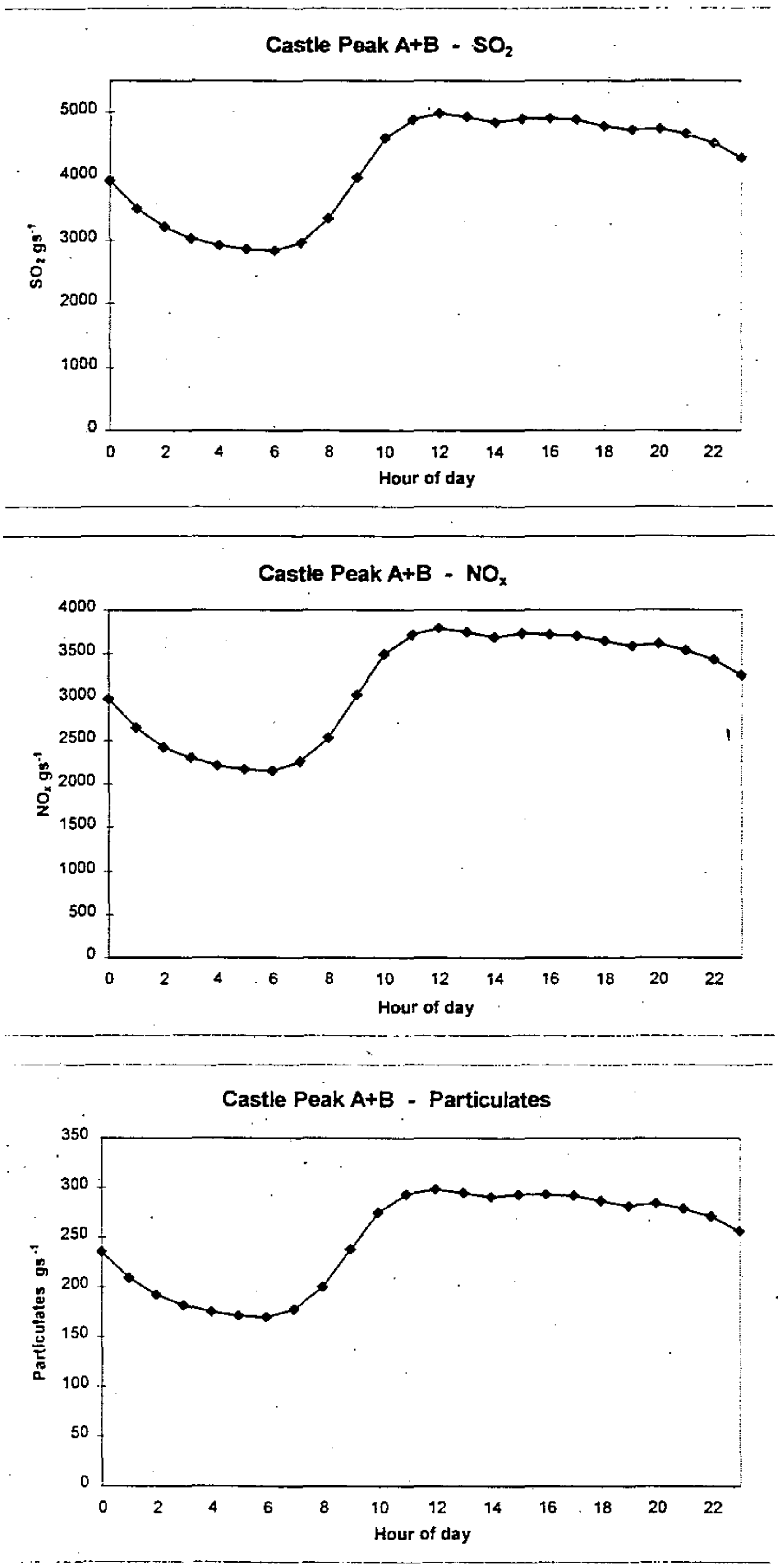


Figure 4.2b: The diurnal variation of emission rate (in g s^{-1}) for SO_2, NO_x and particulates, summed for Castle Peak A and B, for the CLP 2012 High Coal Consumption scenario.

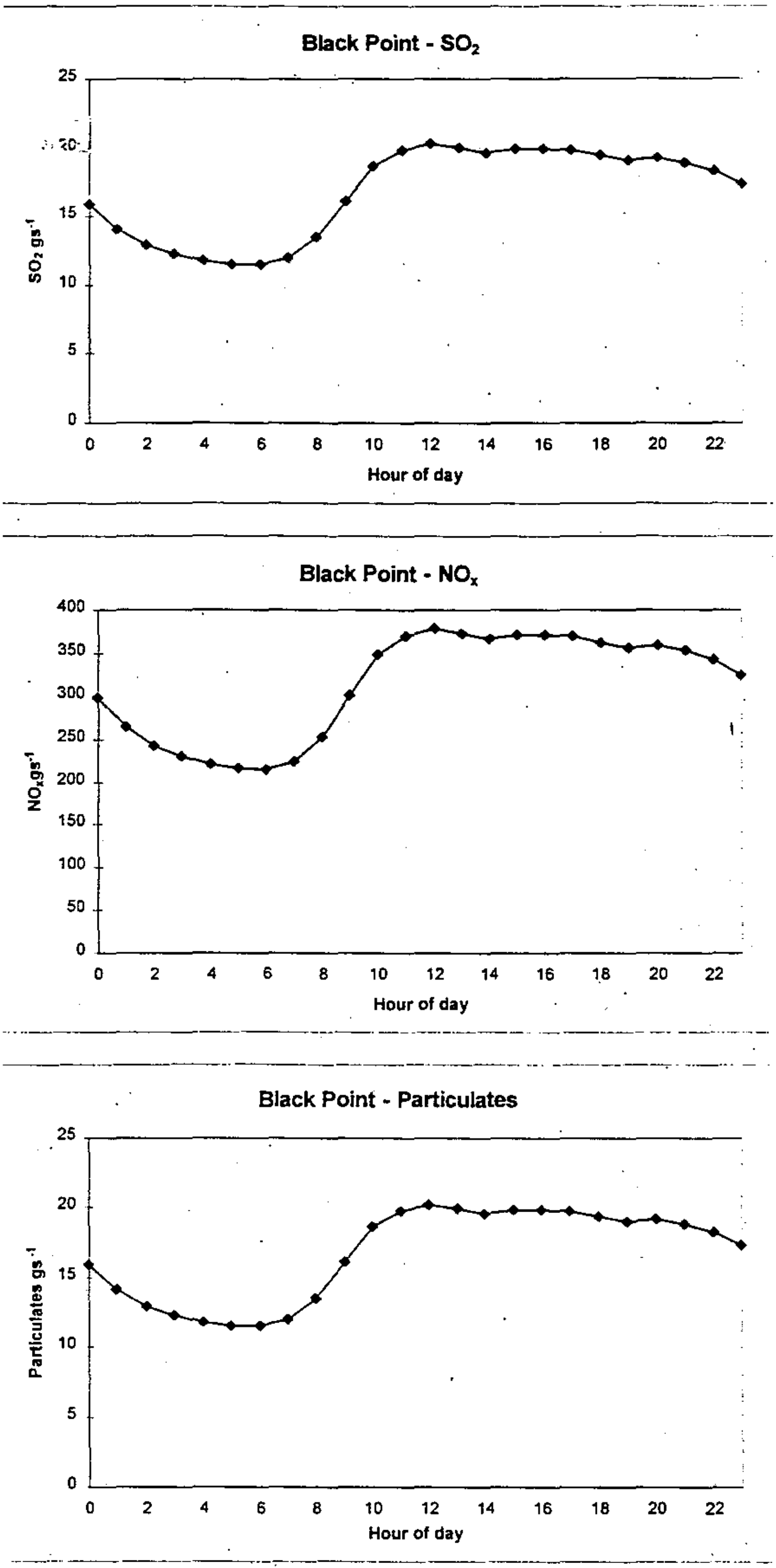


Figure 4.2c: The diurnal variation of emission rate (in g s^{-1}) for SO_2, NO_x and particulates for Black Point, for the CLP 2012 High Coal Consumption scenario.

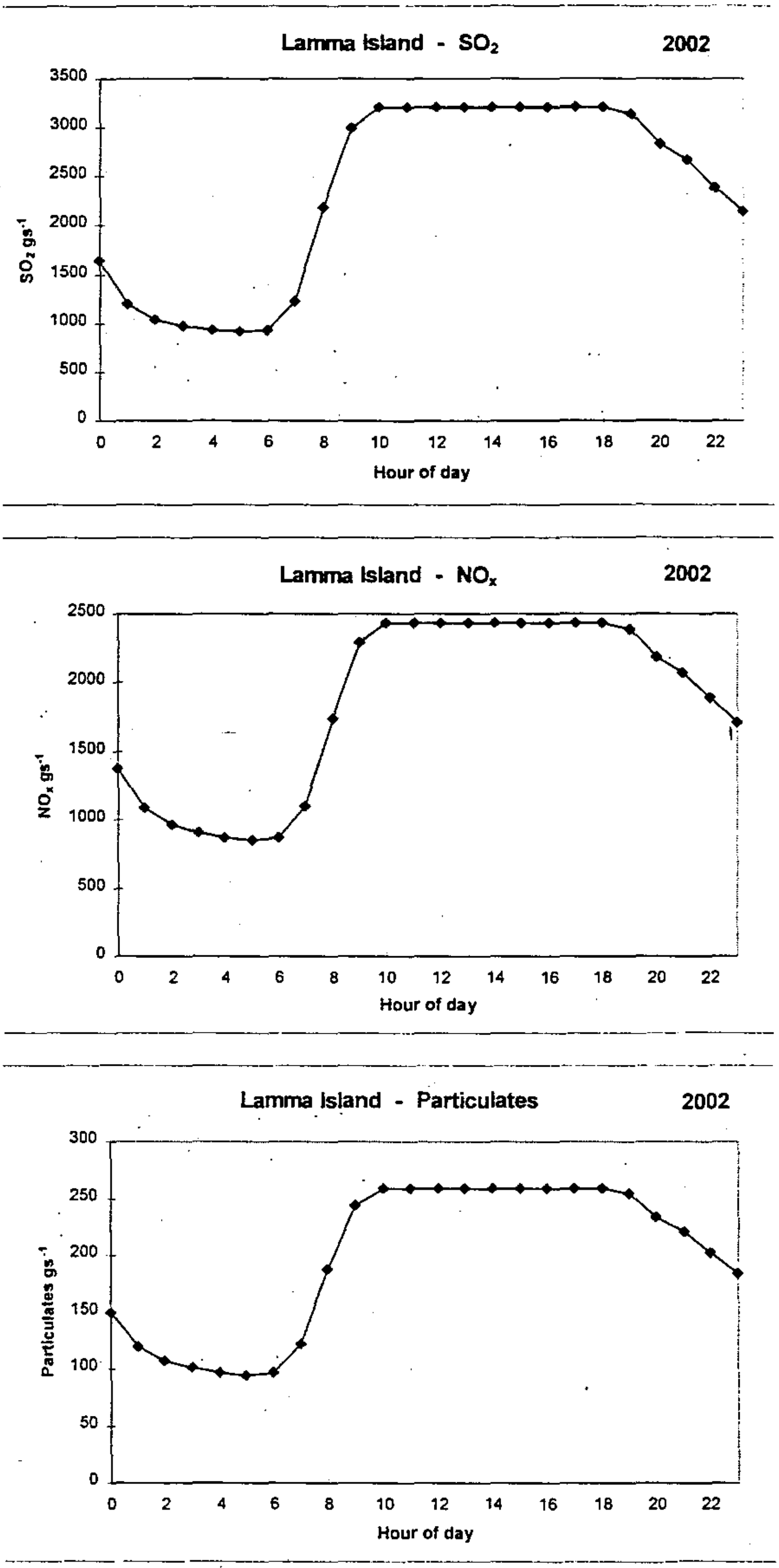


Figure 4.2d: The diurnal variation of emission rate (in g s^{-1}) for SO_2, NO_x and particulates for Lamma Island in 2002.

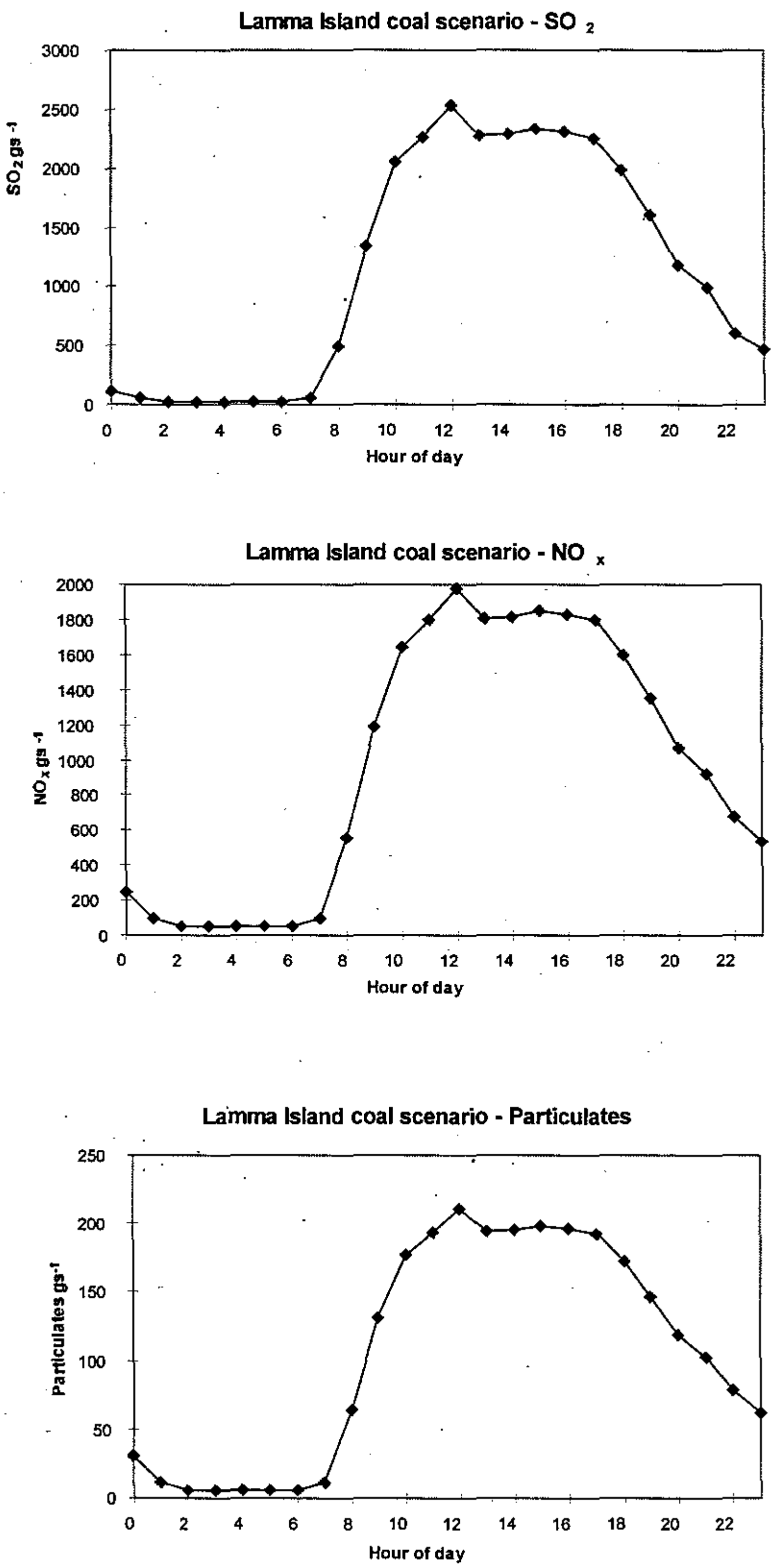


Figure 4.2e: The diurnal variation of emission rate (in g s-1) for SO2, NOx and particulates for Lamma Island, for the 2012 coal-fired scenario.

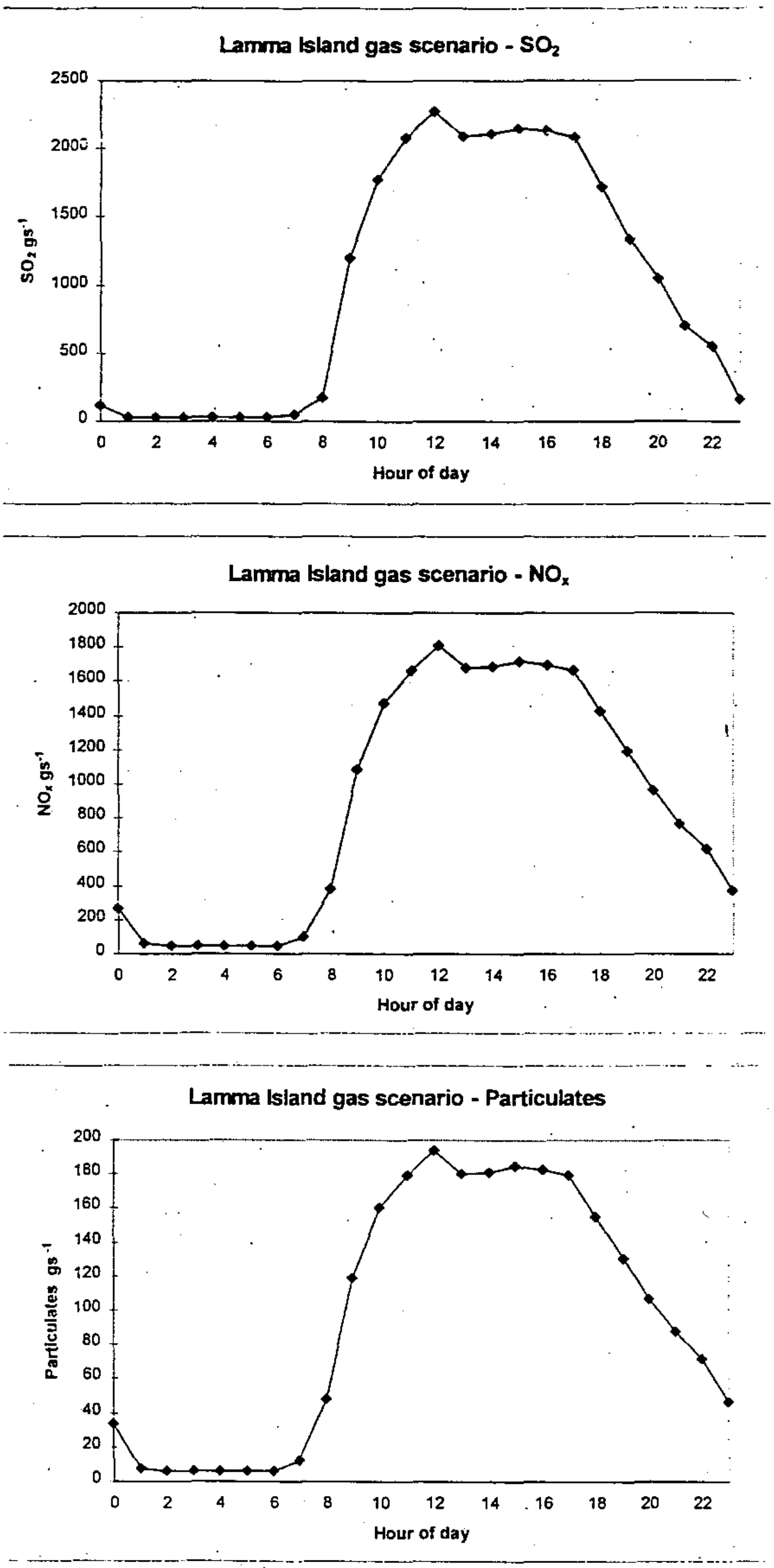
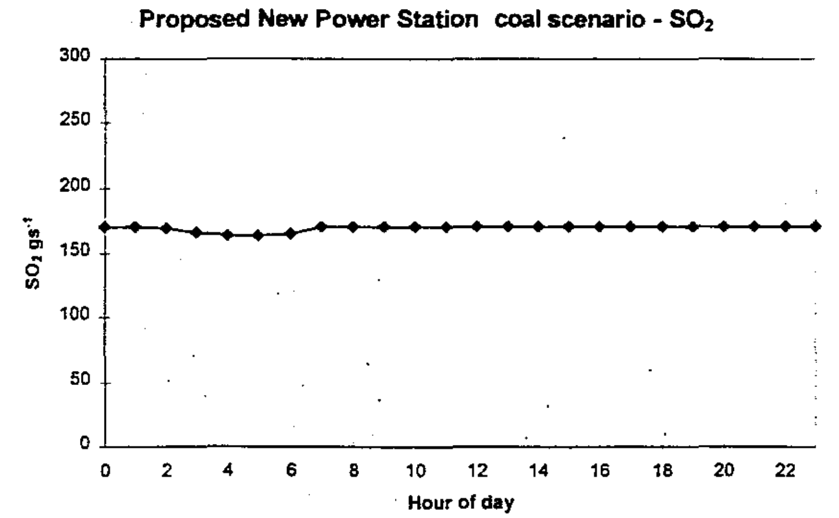
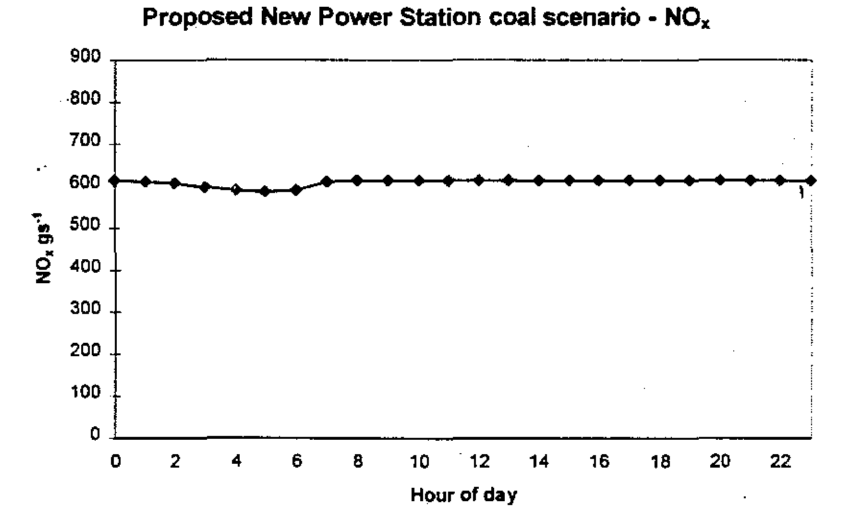


Figure 4.2f: The diurnal variation of emission rate (in g s^{-1}) for SO_2, NO_x and particulates for Lamma Island, for the 2012 gas-fired scenario.





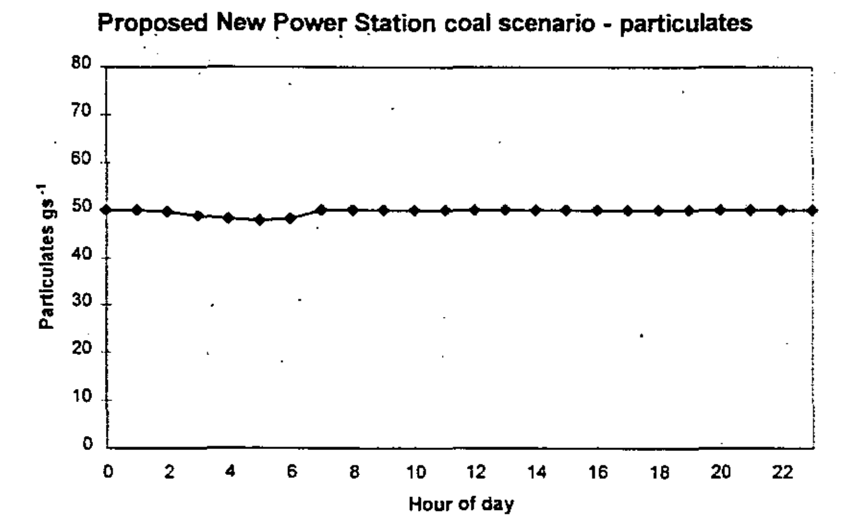


Figure 4.2g: The diurnal variation of emission rate (in g s^{-1}) for SO_2, NO_x and particulates for the proposed New Power Station, for the 2012 coal-fired scenario.

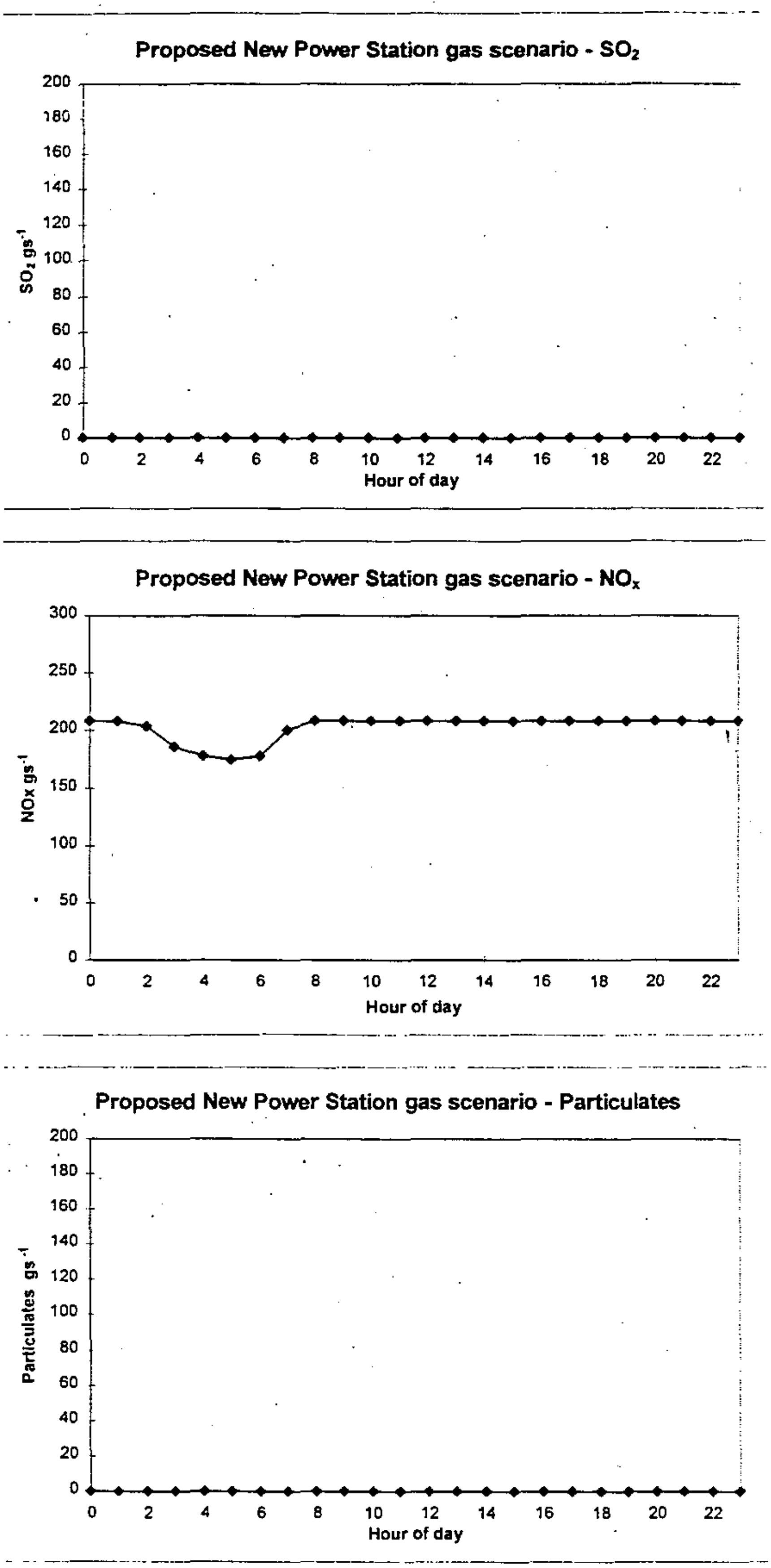


Figure 4.2h: The diurnal variation of emission rate (in g s^{-1}) for SO_2, NO_x and particulates for the proposed Lamma Island station, for the 2012 gas-fired scenario.

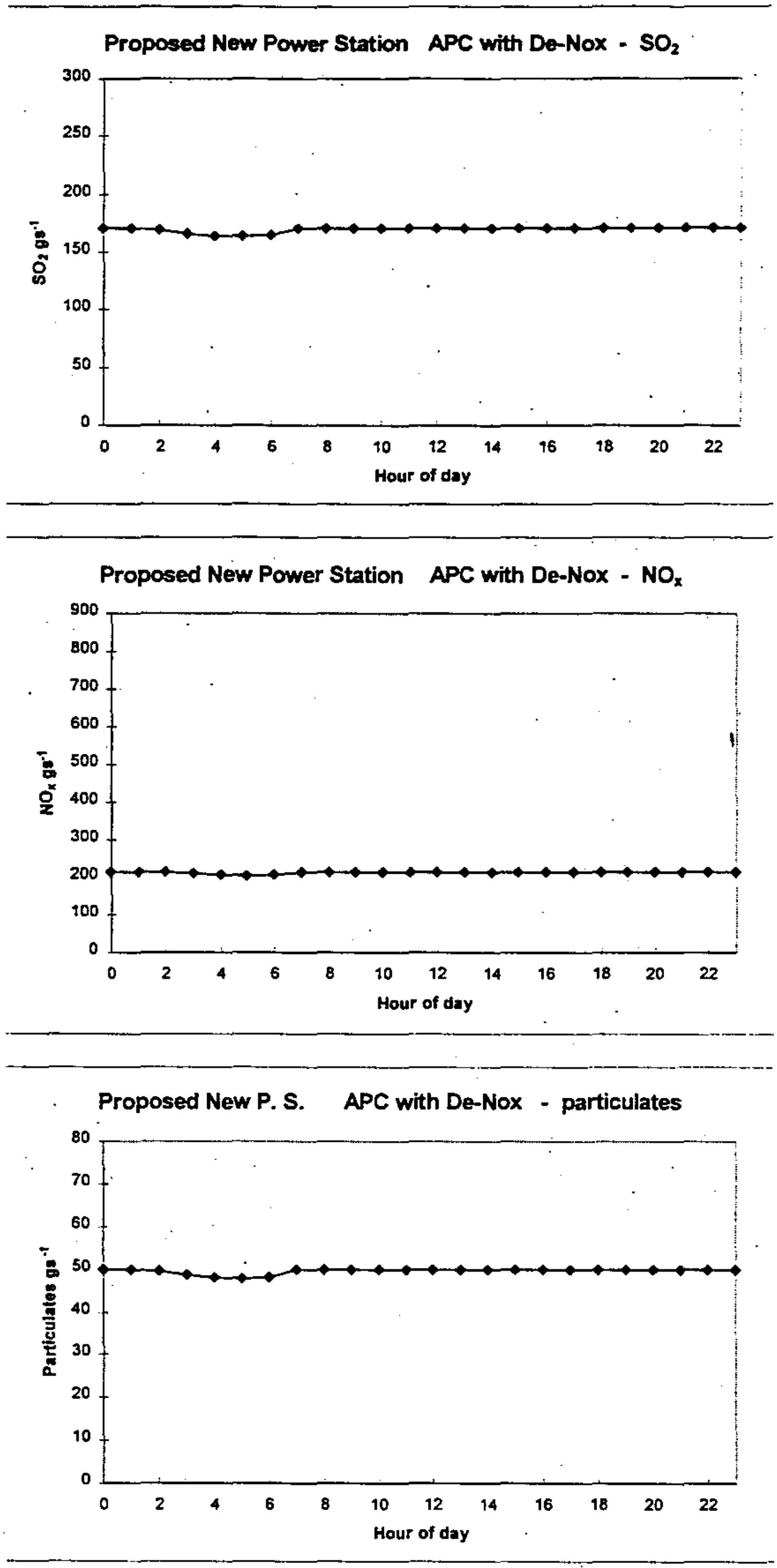


Figure 4.2i: The diurnal variation of emission rate (in g s^{-1}) for SO_2, NO_x and particulates for the proposed Lamma Island station operating under APC with De-NO_x technology in 2012.

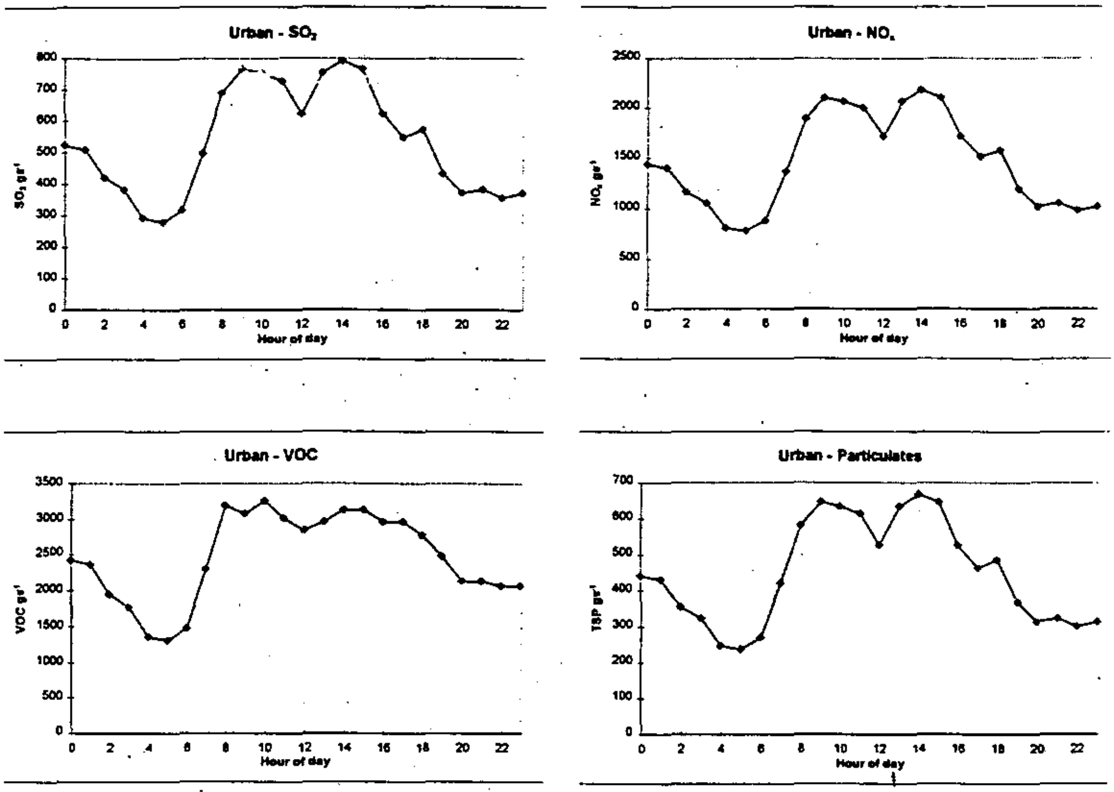


Figure 4.3a: The diurnal variation of emission rate (in g s^{-1}) for SO_2, NO_x, VOC and particulates for the urban source for 2012.

4.3.4 *Background Source*

In the absence of data for background hydrocarbon levels in Hong Kong, a value of 75 ppbC total non-methane hydrocarbons, based on typical background levels in Australian cities, was used. The background ozone value assumed was 34 ppb, based on the average background levels in Hong Kong (*Lam and Wang, 1997*).

5 RESULTS

5.1 INTRODUCTION

Simulations for four situations were carried out:

- existing sources in 2012 plus coal-fired proposed source;
- existing sources in 2012 plus coal-fired proposed source with APC with De-NO_x technology;
- existing sources in 2012 with gas-fired proposed source; and
- existing sources in 2002.

These simulations allow for a comparison of the impacts on regional photochemistry of the 2012 scenarios with a proposed gas-fired or coal-fired power station, as well as a comparison of different coal-fired technologies.

By comparing the 2012 results with a simulation for a year (2002) prior to the New Power Station coming on line, the impact of HEC's proposed station on the regional photochemistry can be assessed. For the year 2012, when the New Power Station is fully commissioned, about half of the maximum system demand will be supplied by the new units which will either be gas-fired or coal-fired with FGD, the low NO_X combustion technology or De-NO_X facilities. On the other hand, for 2012 without the new power station, HEC would need to operate all the existing units in the Lamma Power Station to full capacity and purchase the balance of the electricity power from CLP or the Guangdong grid to meet the system demand. Hence, the need to utilise a year like 2002 as the "without new power station" scenario rather than just a direct simulation of all 2012 emissions minus the proposed power station, as the latter would basically be incorrect for a baseline scenario. However, this latter scenario would be useful in helping to estimate the contributions of the New Power Station under the various options in 2012.

To assess the photochemistry component, NO_X and O_3 concentrations were the point of focus. Assessments for FSP, visibility, and SO_2 concentrations were also performed, although their importance in the regional context is relatively minor.

Although point sources are well represented in the model, it should be mentioned that the area sources are simulated in a simplified manner, both in their spatial representation and emission strengths. The quantitative results involving these sources, especially the *urban* one, should be treated with caution. However, the model is quite suitable for use in comparing different scenarios, as in this Study. The model's strength lies in its ability to predict meteorology and mixing processes, thus the potential overlap of emissions from various sources.

Simulations for the identified worst-case scenarios were carried out initially on a 2 km grid covering 100 km x 100 km. Then, in order to focus on the whole PRD region, 5 km grid runs, providing a 250 km x 250 km coverage, were performed for existing sources in 2012 plus coal-fired source, for both worst-case scenarios. Although the results for the two scenarios were similar, the slightly northerly surface wind component in *Scenario 2* was able to split the urban plume in the morning, whereby a portion travelled southwards between Lantau Island and Hong Kong Island (see *Figure 5.1a*). This suggests that *Scenario 1* has a higher potential to cause photochemical reaction in the PRD region, hence this *Paper* only discusses the modelling results from Worst-case *Scenario 1*.

It should be noted that the 2 km grid results are more accurate due to the higher resolution, hence the local (Hong Kong) values derived from the 5 km grid simulations and discussed in this *Paper* should be treated with caution. *Annex A* contains results from the 2 km grid runs, if more accurate local information is of interest. But for the purpose of consistency and the primary aim of focusing on the PRD region, only the 5 km results will be discussed in this *Paper*.

To address concerns regarding the Airport Height Restrictions (AHR) in force over the Lamma area due to a navigation beacon, and prescribed under the *Hong Kong Airport (Control of Obstructions) (No. 2 Order)*, additional simulations were performed for a stack height of 150m. The results of these simulations are presented in *Annex C*.

For puposes of reference, *Tables 5.1a* and *5.1b* show respectively, the Hong Kong Air Quality Objectives (AQO) and PRC National Air Quality Standards (NAQS). It should be noted that the PRC National Air Quality Standards are divided into three levels, targeting three landuse classifications:

- Level 1 - Preservation and conservation of natural areas
- Level 2 - Urban, residential and rural areas
- Level 3 - Industrial zones

Table 5.1a ***Hong Kong Air Quality Objectives in $\mu g/m^3$ and ppb in brackets where appropriate*** [(i)]

Pollutant	Averaging Time				
	1 Hour [(ii)]	8 Hours [(iii)]	24 Hours [(iii)]	3 Months [(iv)]	1 Year [(iv)]
Total Suspended Particulates (TSP)	-	-	260	-	80
Respirable Suspended Particulates[(v)] (RSP)	-	-	180	-	55
Sulphur Dioxide (SO_2)	800 (305)	-	350 (134)	-	80 (31)
Nitrogen Dioxide (NO_2)	300 (160)	-	150 (80)	-	80 (43)
Carbon Monoxide (CO)	30000	10000	-	-	-
Photochemical Oxidants[(vi)] (O_3)	240 (122)	-	-	-	-
Lead	-	-	-	1.5	-

Note:
(i) Measured at 298 K (25 °C) and 101.325 kPa (one atmosphere).
(ii) Not to be exceeded more than three times per year.
(iii) Not to be exceeded more than once per year.
(iv) Arithmetic means.
(v) Respirable suspended particulates means suspended particles in air with a nominal aerodynamic diameter of 10 micrometres and smaller.
(vi) Photochemical oxidants are determined by measurement of ozone only.

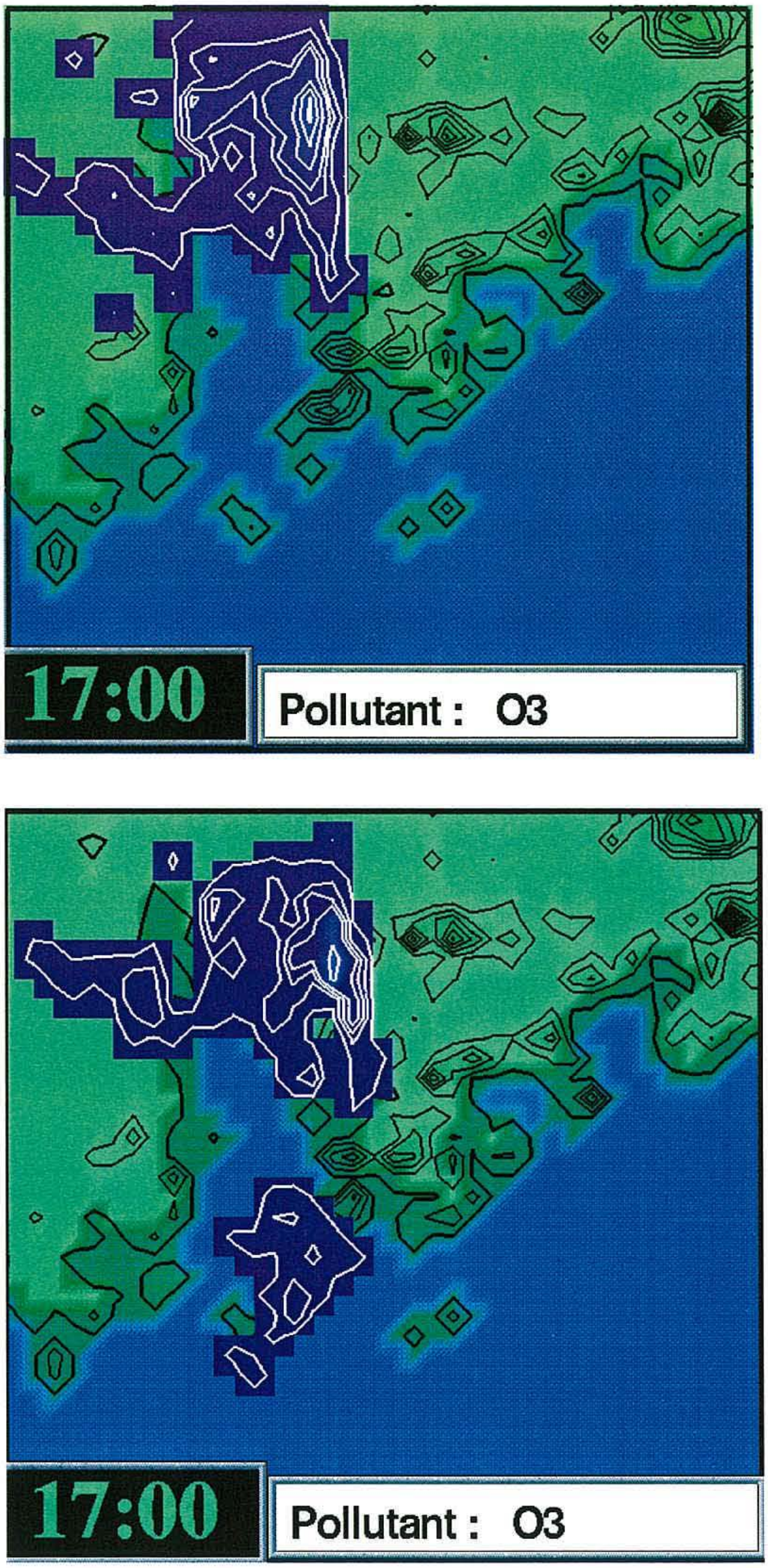


Figure 5.1a: The hourly-averaged ground-level concentrations of O3 at 1700 LT for 2012 with a Coal-fired New Power Station under Meteorological Scenarios 1 and 2 on the 5 km grid. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

Table 5.1b *PRC National Air Quality Standards (GB 3095-1996)*

Pollutant Items	Sampling Time	Concentration Limit			Concentration Units
		Level I	Level II	Level III	
SO_2	Annual mean	0.02 (8)	0.06 (23)	0.10 (38)	
	Daily mean	0.05 (19)	0.15 (57)	0.25 (95)	
	Hourly mean	0.15 (57)	0.50 (191)	0.70 (267)	
TSP	Annual mean	0.08	0.20	0.30	
	Daily mean	0.12	0.30	0.50	mg/m^3 (ppb)
PM_{10}	Annual mean	0.04	0.10	0.15	
	Daily mean	0.05	0.15	0.25	
NOx	Annual mean	0.05	0.05	0.10	
	Daily mean	0.10	0.10	0.15	
	Hourly mean	0.15	0.15	0.30	
NO_2	Annual mean	0.04 (21)	0.04 (21)	0.08 (43)	
	Daily mean	0.08 (43)	0.08 (43)	0.12 (64)	
	Hourly mean	0.12 (64)	0.12 (64)	0.24 (128)	
CO	Daily mean	4.00	4.00	6.00	
	Hourly mean	10.00	10.00	20.00	
O_3	Hourly mean	0.12 (61)	0.16 (82)	0.20 (102)	

5.1.1 *Preliminary Findings from Non-Reactive Simulations*

The photochemistry model is very time consuming to run, due to the representation of emissions by means of tracer particles. It is important therefore that the number of sources for each simulation is kept to a minimum, depending on the meteorology and grid domain. In order to identify the major sources for the two meteorological scenarios considered here for regional impacts, a simulation with photochemistry turned-off (a passive NO_x simulation) was performed. This allows for an examination of the degree of interaction and overlap between emissions from the various sources, and their contribution to ground-level concentrations.

It was found that for both worst-case scenarios (assuming that the New Power Station is situated in the southern part of Hong Kong), the buoyant emissions from the four power station sources, ie., Black Point, Castle Peak, existing Lamma and the proposed new power stations, travelled out over the sea towards the northwest and to the north-northwest later in the day. Emissions from the proposed power station and Castle Peak mix down on to the land west of the Delta from 1100 LT onwards. Mixing and interaction did not occur in the upper reaches of the PRD until the afternoon. *Figure 5.1b* shows the plumes from each of the four power stations at 1700LT, by which time they had reached the PRD region. Emissions from the airport, urban and expressway surface sources do not reach the PRD region until mid-afternoon when they are transported by a southerly sea breeze.

In conclusion, emissions from the identified sources reached the PRD region in the afternoon, where there was interaction and mixing to the ground. For the purpose of assessing the impacts on the PRD region, the hours of focus should be those in the afternoon, hence simulations at 1300, 1600, 1700 and 1800 LT are shown in this report.

5.1.2 *Dispersion of Individual Plumes*

The passive NO_X simulation allowed the dispersion of individual plumes to be examined and these are summarised in the following sections.

Emissions from the *airport* drifted slowly offshore in a west-northwesterly direction throughout the night and early morning. Fresh emissions moved southwestwards along the Lantau coast for a couple of hours from 0700 LT, but until 1400 LT they mainly stagnated around the source region or moved a little way offshore during the mid-morning. The offshore pollutants began to move towards Deep Bay with the south-westerly sea breeze in early afternoon, reaching the northern Bay coast by 1500 LT. The afternoon sea breeze also transported emissions in the vicinity of the Airport towards the north where they impacted on Castle Peak. By 1700 LT, emissions reached the PRD region and were generally beginning to disperse inland.

Between 0200 LT and 0900 LT, the emissions from the *urban* source moved westward between Lantau Island and the mainland, and into the Pearl River Estuary. A section also drifted to the southwest as it passed between Lantau and Hong Kong Islands, eventually moving across the southern tip of Lantau Island with the southeasterly sea breeze and into the Estuary. Very light winds existed between 0900 LT and 1100 LT in the region west of Kowloon and between the two main Islands, and emissions tended to stagnate here until the sea breeze moved them onto the mainland and into the New Territories. The early morning emissions drifting to the north and west of Lantau Island were brought onto the Island near the Airport at around 1100 LT by a local sea breeze/eddy system, while in the afternoon the stronger southeasterly sea breeze took most emissions to the northwest part of the Territory. Like the *airport* emissions, *urban* emissions reached the PRD region by 1700 LT and generally proceeded to disperse inland.

Expressway emissions moved slowly westward till 0900 LT, joining emissions from the *airport* and *urban* sources in the Pearl River Estuary, before moving towards Lantau Island during the morning and finally heading to the northeast towards Deep Bay at about midday. Fresh *expressway* emissions moved northwards to the New Territories with the local sea breeze from 1000 LT onwards. By 1700 LT, emissions had reached the PRD region.

Lamma Power Station emissions did not reach the surface until 0900 LT when the growing mixed layer on Lantau Island fumigated them to the ground on Sunset Peak. Typical plume heights were 460m at night and 420m during the day. Fumigation continued in this location until 1300 LT and it was only on Lantau Island that the *Lamma Island* emissions registered at ground level. At 1400 and 1500 LT, emissions were brought to ground further to the north on the Island as the sea breeze strengthened and turned more southerly. Between 1600 and 1800 LT, the plume footprint stretched from the northern tip of Lantau Island to Castle Peak, with maximum non-reactive ground-level concentrations (glcs) at this time

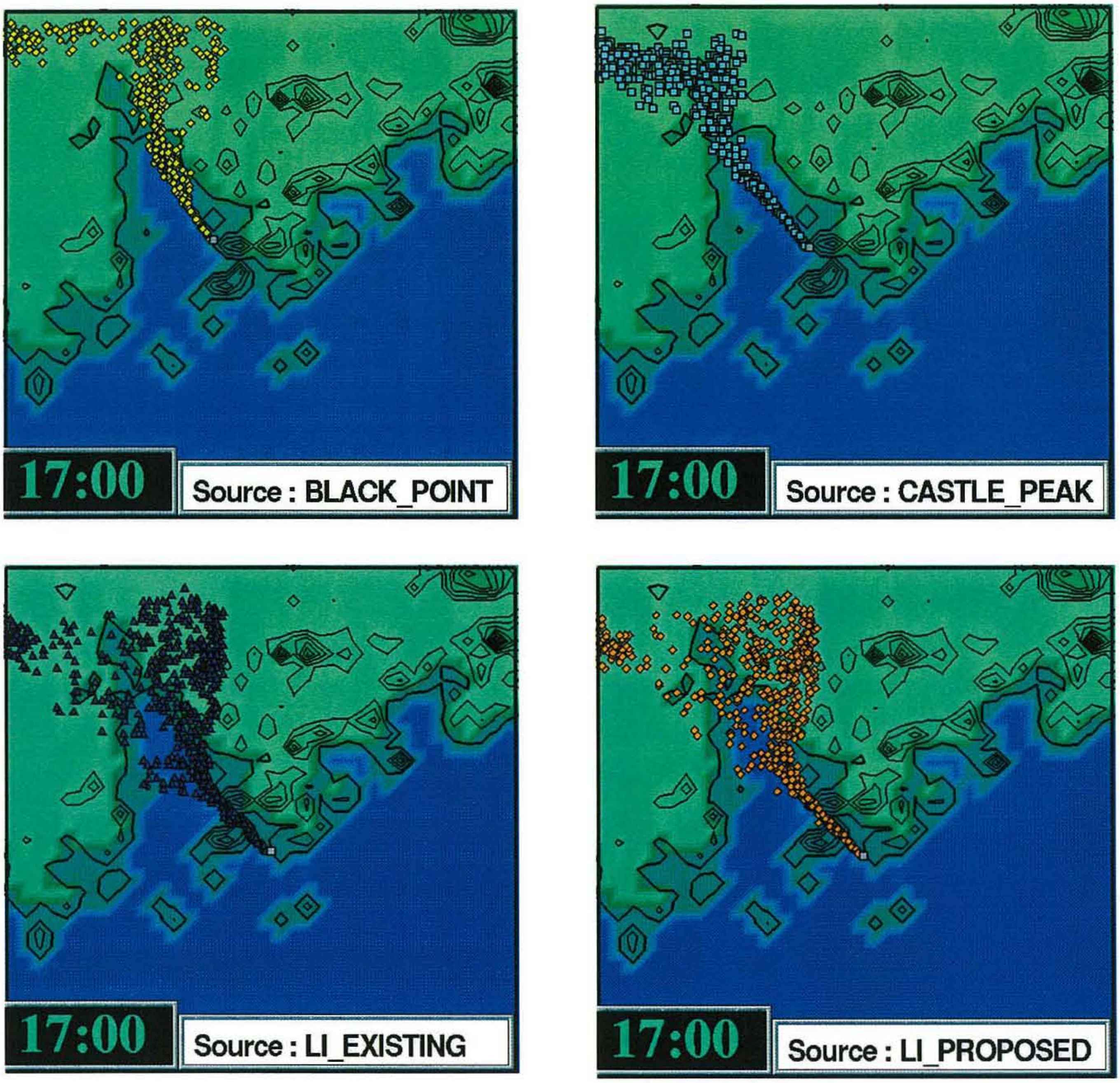


Figure 5.1b: Two-dimensional view of the distribution of emissions from Black Point, Castle Peak, existing Lamma and the New Power Station at 1700 LT under Scenario 1. The ground-level concentration contours are for NOx from a non-photochemistry simulation, and are merely to indicate where the emissions are reaching the ground. Contour values for NOx are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

(due only to the Lamma Island station) being found at the latter site. *Figure 5.1c* shows the progression of the plume from the existing Lamma Power Station at 1300, 1600, 1700 and 1800 LT.

WEIF emissions were also mixed to the ground on Lantau Island near Sunset Peak from 0900 LT but, due to a lower plume height, moved to the northern tip of the Island by 1200 LT. They also impacted on Castle Peak after 1500 LT and by 1700 LT, they had reached the PRD region.

Emissions from the *New Power Station*, sited on Lamma Island, behaved in a very similar manner to those from the current *Lamma Power Station* (see *Figure 5.1d*). Typical plume heights were 480m at night and 440m during the day. However, glcs of non-reactive gases in the mid-morning period on Lantau Island were considerably higher for the *New Station* than for the existing *Lamma Power Station*, due to the higher emission rate of the former during the night. However the situation was reversed in the afternoon with *Lamma Power Station* glcs of NO_x typically being about three times higher than those from the *New Power Station*.

Emissions from the *Black Point* power station followed a similar directional pattern to the existing Lamma power station. The major differences were that the Black Point emissions were of a much smaller magnitude and what was left of it reached the PRD region earlier than the plume from the existing Lamma power station (see *Figure 5.1e*).

Emissions from the *Castle Peak* power station behaved in a fashion similar to that of the Black Point power station, impacting on the PRD region at relatively the same time. The only major difference between the two plumes was the much larger magnitude of emissions from Castle Peak. By 1700 LT, the Castle Peak plume was impacting on the inland (see *Figure 5.1f*).

5.2 *NO_2 AND O_3 SIMULATIONS*

Tables 5.2 a and *5.2b* show the absolute maxima for NO_2 and O_3 concentrations. As some of these values occurred in the Hong Kong; maximum values for the PRD region may not be reflected in these tables. The latter is illustrated more clearly in the relevant figures.

To estimate the contributions of the proposed New Power Station to pollutant concentrations in 2012, simulations for 2012 existing sources (without the proposed station) were run. Two simulations were performed - one for the utilisation of coal and the other for using gas . The two runs were performed because the loading curves for the use of the two different fuels would be different (see *Section 4.2.5*). Values obtained from these runs (as shown in the last two columns of *Tables 5.2a* and *b*) were then subtracted from the relevant option runs (columns 3-5 in *Tables 5.2a* and *5.2b*) to yield contribution estimates (ie, the coal run was subtracted from the two coal option runs and the gas run from the gas option run).

Table 5.2a *Maximum concentrations of NO_2 (ppb).*

Time	2002	2012 coal	2012 coal with De-NO_x	2012 gas	2012 existing sources (coal)[a]	2012 existing sources (gas)[b]
0900	135	135	135	135	135	135
1000	158	158	158	158	158	158
1100	211	209	209	209	209	209
1200	262	230	213	206	204	199
1300	285	266	239	229	219	205
1400	129	121	112	105	108	101
1500	176	164	142	142	128	125
1600	201	201	180	186	167	170
1700	98	97	96	112	96	111
1800	43	42	41	40	41	39
1900	37	37	37	38	37	38
2000	38	38	38	38	38	38
2100	39	39	39	38	39	38
2200	39	39	39	38	39	38

Note: a - this simulation was run for the purpose of calculating the contributions from a new coal-fired station and is not an option scenario.
b - this simulation was run for the purpose of calculating the contributions from a new gas-fired station and is not an option scenario.

Table 5.2b *Maximum concentrations of O_3 (ppb).*

Time	2002	2012 coal	2012 coal with De-NO_x	2012 gas	2012 existing sources (coal)[a]	2012 existing sources (gas)[b]
0900	45	45	45	45	45	45
1000	88	88	88	88	88	88
1100	186	186	186	186	186	186
1200	173	173	173	173	173	173
1300	356	356	356	356	356	356
1400	359	361	361	359	361	359
1500	224	227	228	210	228	215
1600	226	230	231	234	232	235
1700	253	263	271	305	275	309
1800	105	109	110	95	111	96
1900	34	34	34	34	34	34
2000	33	33	33	33	33	33
2100	33	33	33	33	33	33
2200	33	33	33	33	33	33

Note: a - this simulation was run for the purpose of calculating the contributions from a new coal-fired station and is not an option scenario.
b - this simulation was run for the purpose of calculating the contributions from a new gas-fired station and is not an option scenario.

There were exceedances of both the Hong Kong AQO and the PRC NAQS for NO_2 and O_3. For NO_2, exceedances of the hourly AQO occurred between 1100 and 1300 LT, and at 1600 LT for all four simulations (by a maximum of 125 ppb, which occurred for the 2002 simulation). At 1500 LT, there was exceedance only by the 2002 and the 2012 coal-fired option simulations. The NAQS was exceeded

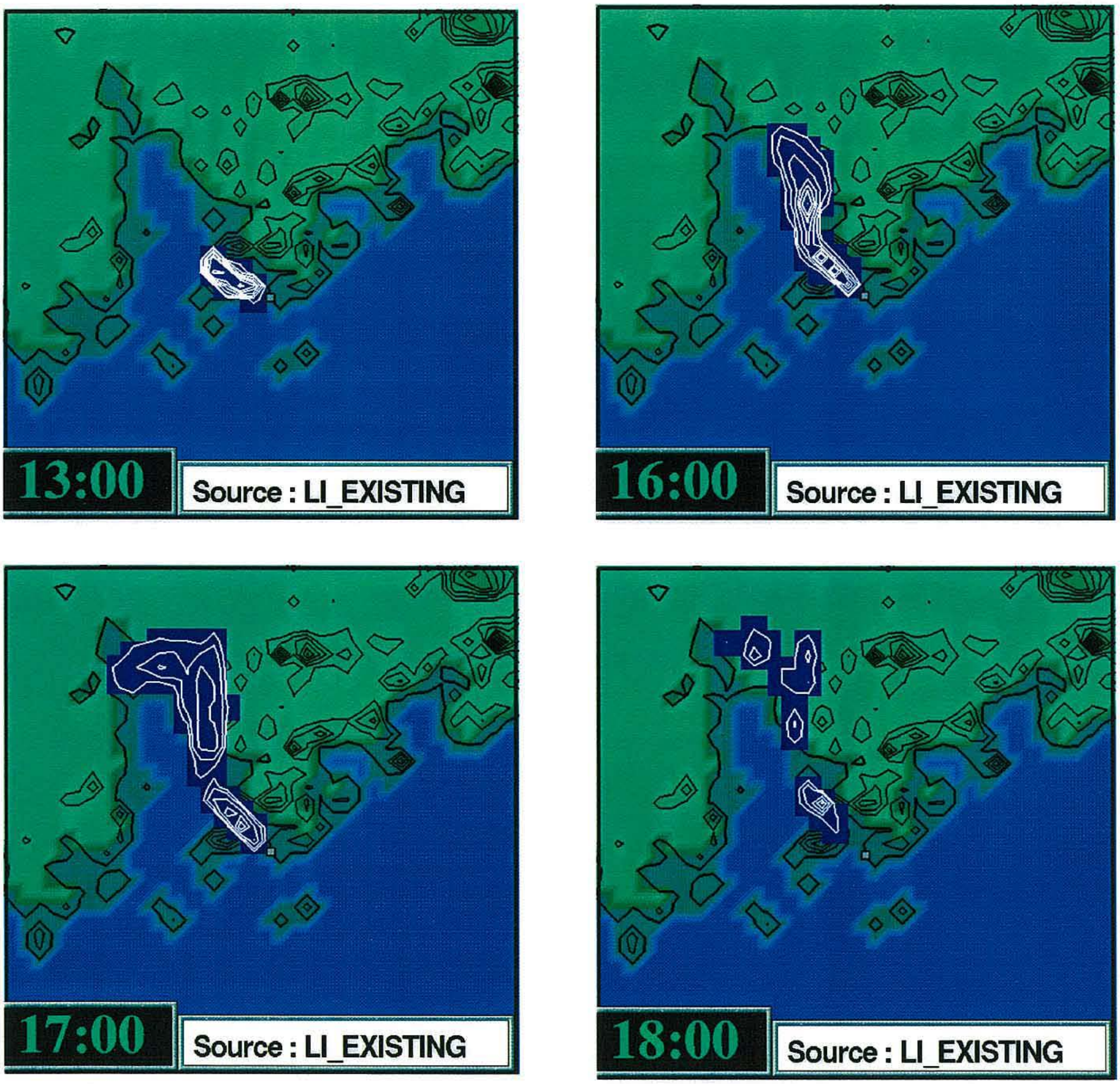


Figure 5.1c: The distribution of emissions from the existing Lamma Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. The ground-level concentration contours are for NOx from a non-photochemistry simulation, and are merely to indicate where the emissions are reaching the ground. Contour values for NOx are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

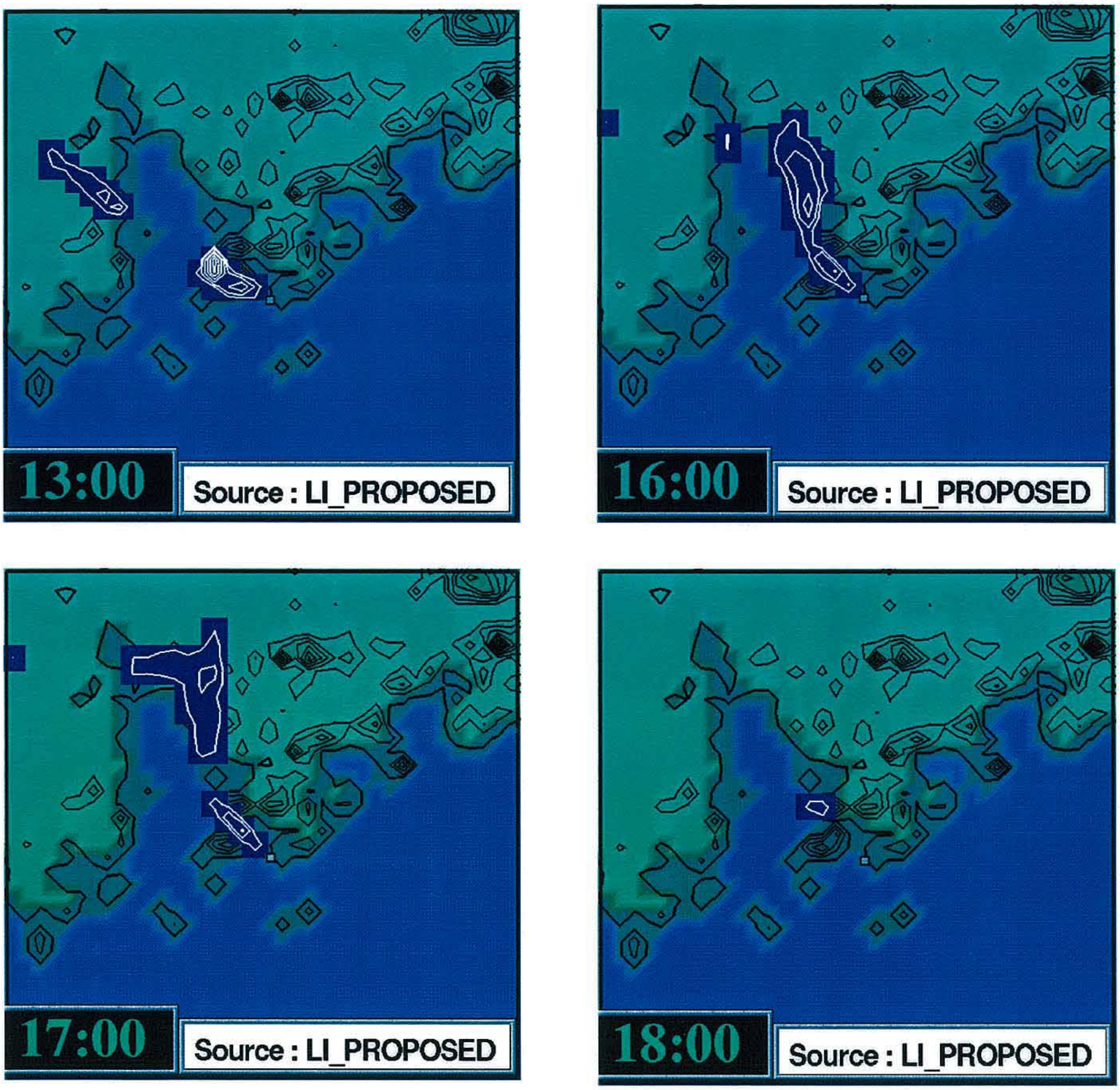


Figure 5.1d: The distribution of emissions from the Proposed New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. The ground-level concentration contours are for NOx from a non-photochemistry simulation, and are merely to indicate where the emissions are reaching the ground. Contour values for NOx are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

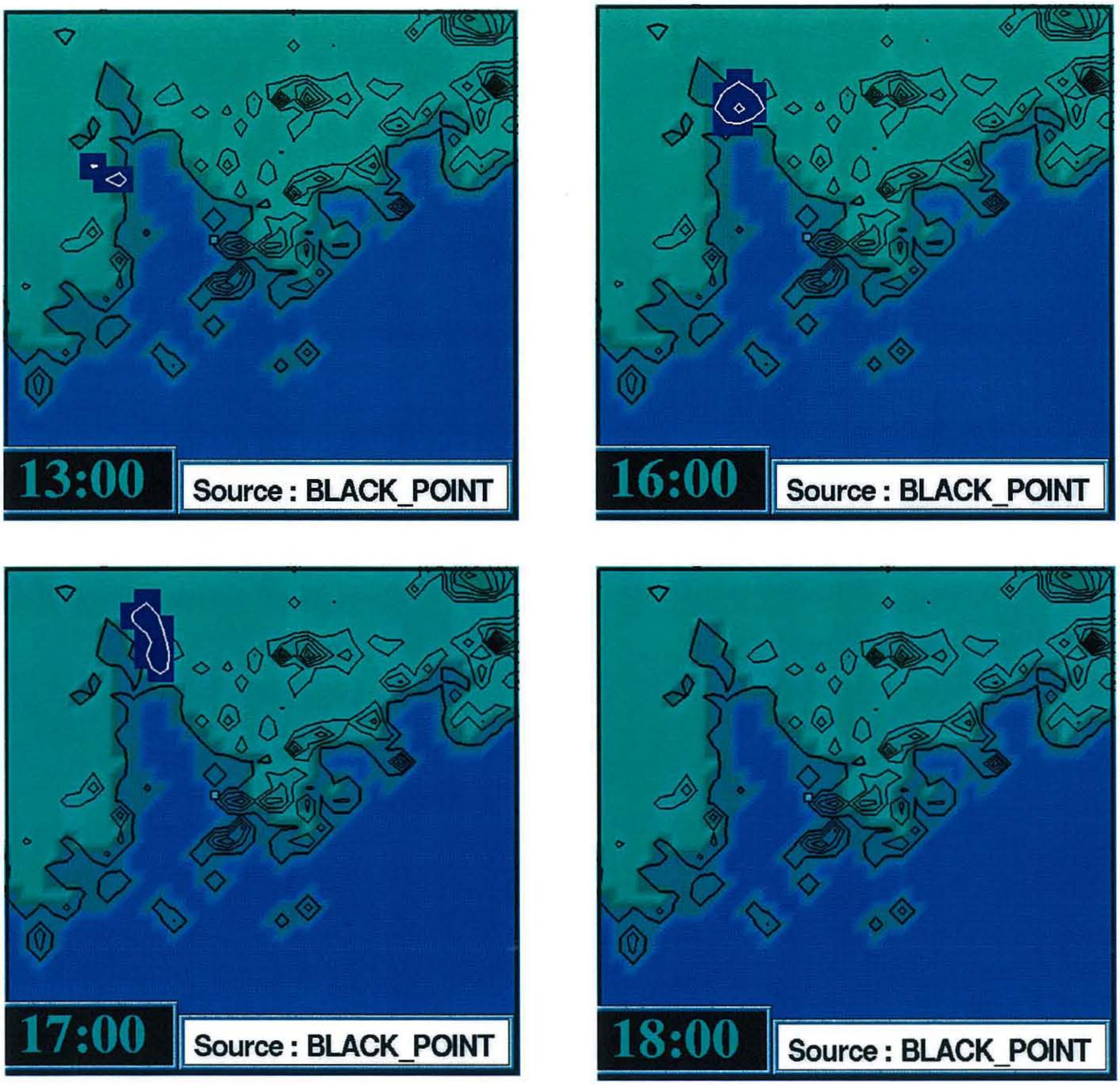


Figure 5.1e: The distribution of emissions from the Black Point Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. The ground-level concentration contours are for NOx from a non-photochemistry simulation, and are merely to indicate where the emissions are reaching the ground. Contour values for NOx are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

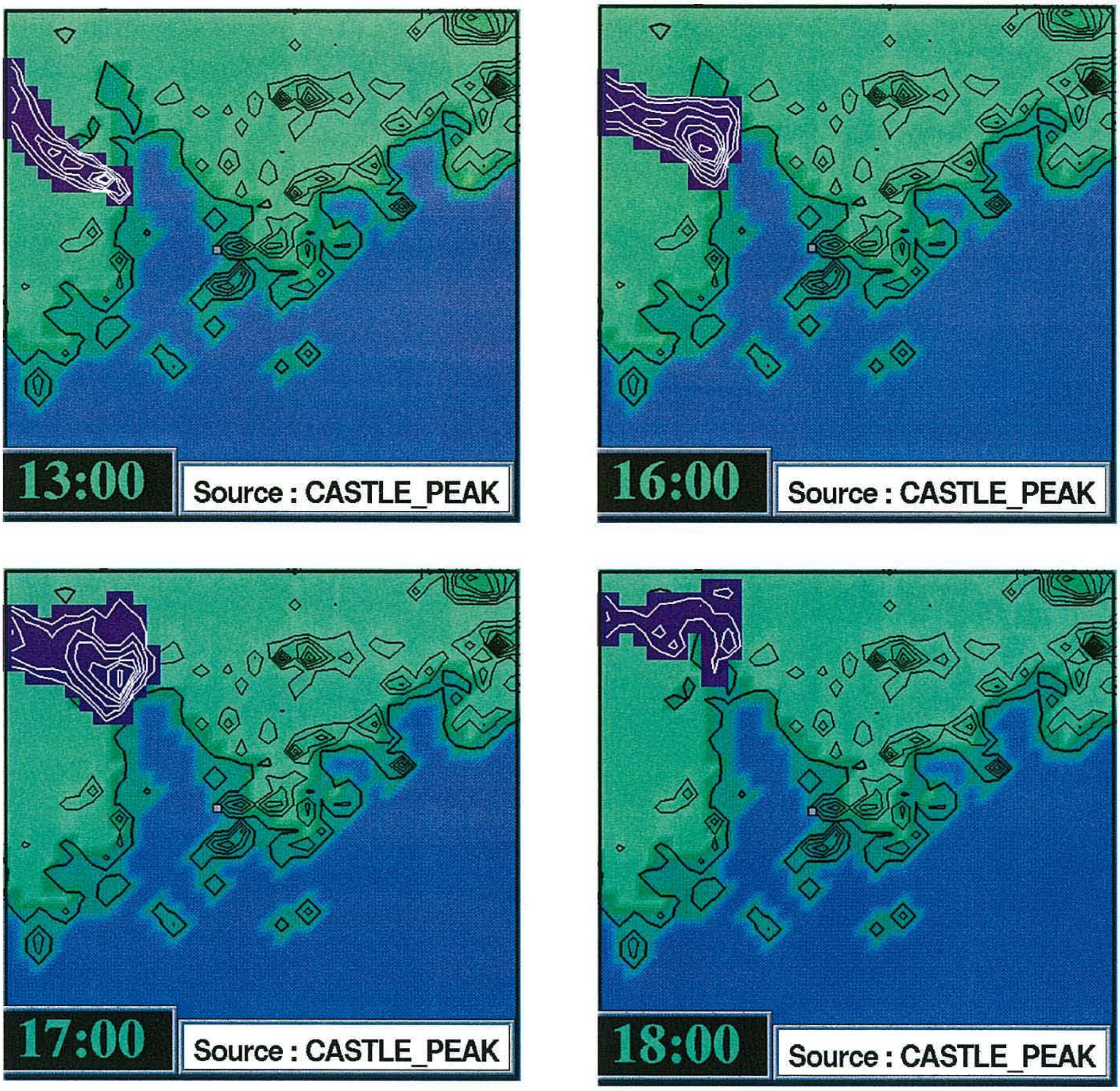


Figure 5.1f: The distribution of emissions from the Castle Peak Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. The ground-level concentration contours are for NOx from a non-photochemistry simulation, and are merely to indicate where the emissions are reaching the ground. Contour values for NOx are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

for level III (the least stringent level) from 0900 to 1600 LT for all four simulations.

Most of the NO_2 exceedances occurred in the Hong Kong and are due to existing sources (see the last two columns of *Table 5.2a*). Predicted concentrations for the three 2012 options were mostly lower than the 2002 scenario, indicating that the existence of a new power station, regardless of the technology utilised, would generally decrease total NO_2 concentrations. *Section 5.4.1* describes in more detail the potential contributions of a New Power Station.

For O_3, the hourly AQO was exceeded between the hours of 1100 and 1700 LT for all four simulations (by a maximum of 239 ppb, which occurred at 1400 LT for both coal options simulations). The NAQS was exceeded between 1100 and 1800 LT, with the exception of the gas option which was within the level III standard at 1800 LT.

It should be noted that predicted O_3 concentrations for all scenarios compared to those accounted for by just the existing sources, were generally the same in the morning and early afternoon, implying that the major contributors of O_3 were the existing sources. In fact, NO_x emission from the New Power Station slightly reduced the formation of O_3 in the late afternoon as the plume drifted towards the PRD region. Generally, the existence of a New Power Station seemed to decrease the overall concentrations of O_3, although only to a small degree. With a maximum difference of less than 5% at 1700LT between the 2012 coal scenario and the 2012 existing sources, it can be concluded that the New Power Station would have little impact on O_3 maxima (see *Section 5.4.1*).

5.2.1 *Photochemistry for 2012 with Coal-Fired New Power Station*

Up to and including 1000 LT, maximum glcs of nitrogen dioxide (NO_2) were found over the sea to the southwest of Kowloon towards Lantau Island. These were associated with the westward drift and subsequent stagnation of emissions from the urban plume. This centre of maximum NO_2 concentration moves onshore with the sea breeze at Tsuen Wan before midday and diminishes in magnitude as ozone is formed and as it is dispersed into a deeper mixed layer over the New Territories. By 1100 LT, another centre of maximum NO_2 concentration had formed about 10 kilometres west of Lantau Island. As well as pollutants from the *urban* source, this mixture consisted of *airport* and *expressway* emissions.

For ozone (O_3), by 1000 LT, centres have developed within the urban plume in similar locations to the NO_2 maxima at this time, ie over the sea west of Kowloon, and west of Lantau Island. There is also a maximum near Castle Peak, associated perhaps with impact on local terrain. The Kowloon and Castle Peak centres have combined by 1200 LT and moved inland towards Yuen Long.

By 1200 LT, the air mass to the west of Lantau Island, which consists of emissions from the *urban*, *airport* and *expressway* sources but is dominated by the *urban* emissions, has been transported to the western shore of Lantau Island, although it does not penetrate far inland due to the southeasterly sea breeze (strengthened by the synoptic wind) on the eastern side of the Island.

The low-level wind field at 1200 LT is shown in *Figure 3.1a* and it is evident that on the western side of the Island a strong convergence line exists between the local sea breeze at the west coast and the stronger synoptically-reinforced sea breeze from the east. Between the hours of 1000 LT and 1400 LT, this demarcation line largely prevents mixing of the pollutants either side, i.e. the *urban, airport* and *expressway* emissions to the west and *Lamma Island* emissions, which have been mixed down to ground level, to the east. Note from the wind field at a height of 300m (*Figures 3.1b*) that the west-coast sea breeze is quite shallow. As a consequence, some of the *Lamma Island* elevated emissions continue to be transported to the northwest beyond Lantau Island, and do not reach the surface.

Concentrations of NO_2 and O_3 at 1300, 1600, 1700 and 1800 LT are shown for the 2012 simulations with a coal-fired New Power Station, in *Figures 5.2a and 5.2b*. At 1300 LT, the O_3 plume had reached maximum concentrations of over 350 ppb, with the peak centred over the West New Territories. NO_2 concentrations were split into two plumes with one to the northwest of the Pearl River Estuary (with maximum of about 40ppb) and one impacting over the Hong Kong and Deep Bay region (with maximum concentrations of over 250 ppb). The latter plume originated mainly from the *urban* and power station sources.

By 1600 LT, the NO_2 plume had dispersed along the coast of the Pearl River Estuary reaching maximum concentrations of 200 ppb along the west coast of the Estuary. The O_3 plume proceeded to move northwards with the sea breeze and weaken by 1500 LT. By 1600 LT, the O_3 plume had dispersed over the entire Pearl River Estuary with maximum concentrations dropping to about 230 ppb.

By 1700 LT, both the NO_2 and O_3 plumes had moved inland, where concentrations decreased for NO_2 to a maximum of just under 100 ppb (north-northwest inland of the PRD region) and O_3 increasing slightly to a maximum of 263 ppb (over the northeast coast of the Pearl River Estuary.

By 1800 LT, both the NO_2 and O_3 plumes had dipersed somewhat with only maximum concentrations of about 40 ppb and 100 ppb remaining respectively. The NO_2 had by this time split into two again leaving a footprint that covered the Hong Kong (due again mainly to the *urban* emissions) and the other plume impacting the inland north of the PRD region. The O_3 plume was also, at this time, impacting on the inland to the north of the Pearl River Estuary.

A run for the third day (under *Scenario 1*) was performed for the 2012 coal-fired option, the results of which are shown in *Figures 5.2c* and *5.2d*. This run showed that by 1000 LT of that day, maximum NO_2 concentrations (of approximately 200 ppb) were centred in the Hong Kong area with two separately located peaks - one over Lantau Island and the other near the West Kowloon coast. In the PRD region, there was some NO_2 (approximately 10- 40 ppb) impacting along the east coast of the inland north of the Pearl River Estuary. By 1300 LT, the NO_2 concentrations in the PRD had moved to the west coast of the inland and the majority of the concentrations still centred in Hong Kong (maximum of about 250 ppb over Lantau Island). At 1600 LT, the Hong Kong and PRD NO_2 plumes had begun to merge, covering the whole coastal stretch from Hong Kong across to the north of the Pearl River Estuary, and over the region northwest of the PRD. By 1700 LT, the same general dispersion pattern continued but the maximum concentrations had declined (to approximately 100 ppb) as compared to those at 1600 LT (approximately 150 ppb).

By 1000 LT of the third day, the O_3 plume covered the entire east coast of the PRD region, extending from the south of Lantau Island. Maximum concentrations were approximately 80 ppb. By 1300 LT, the plume had expanded across to cover the entire PRD region with a maximum of 250 ppb over the northwest New

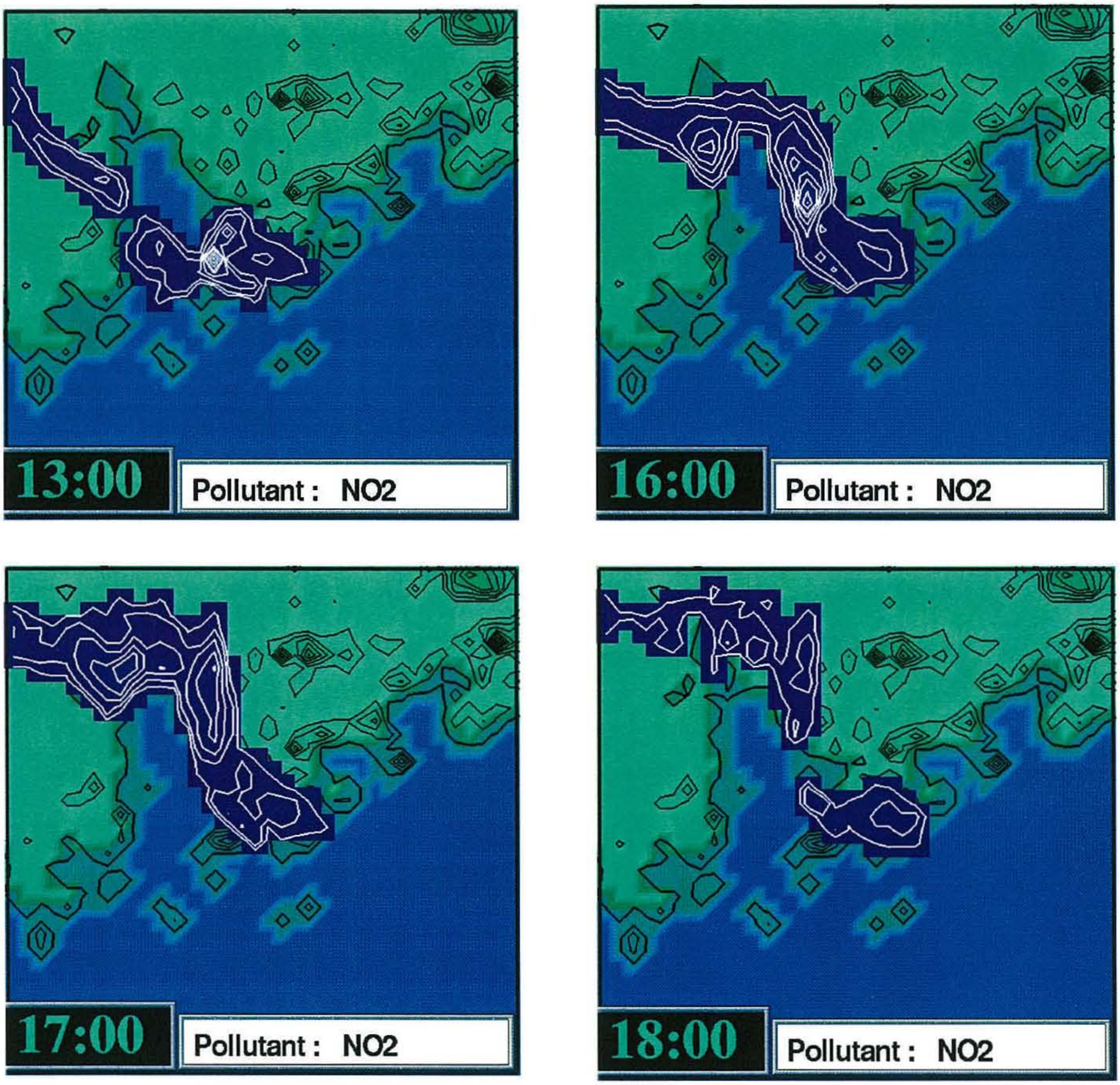


Figure 5.2a: The distribution of NO2 emissions in 2012 with a Coal-fired New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for NO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

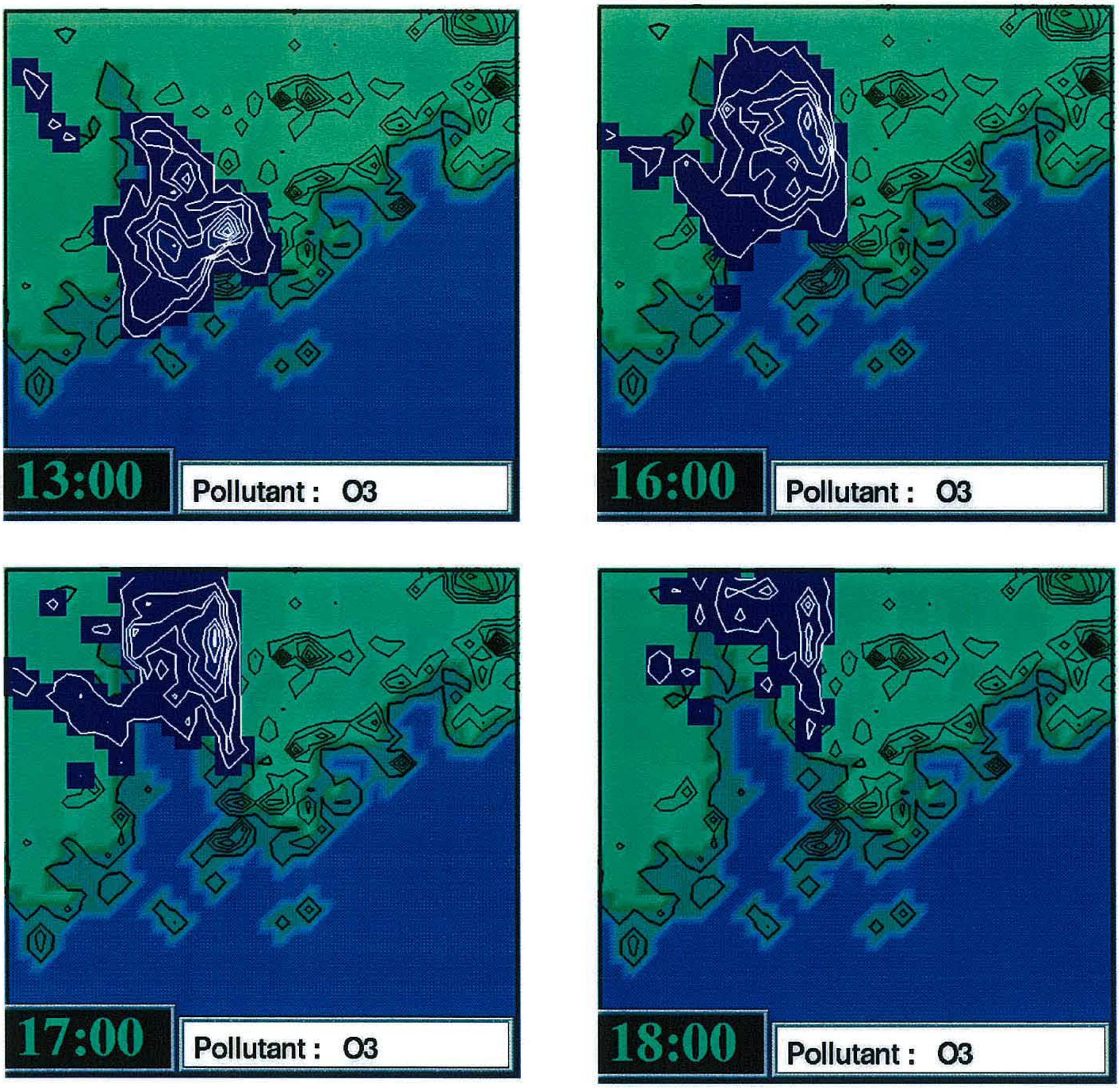


Figure 5.2b: The distribution of O3 emissions in 2012 with a Coal-fired New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

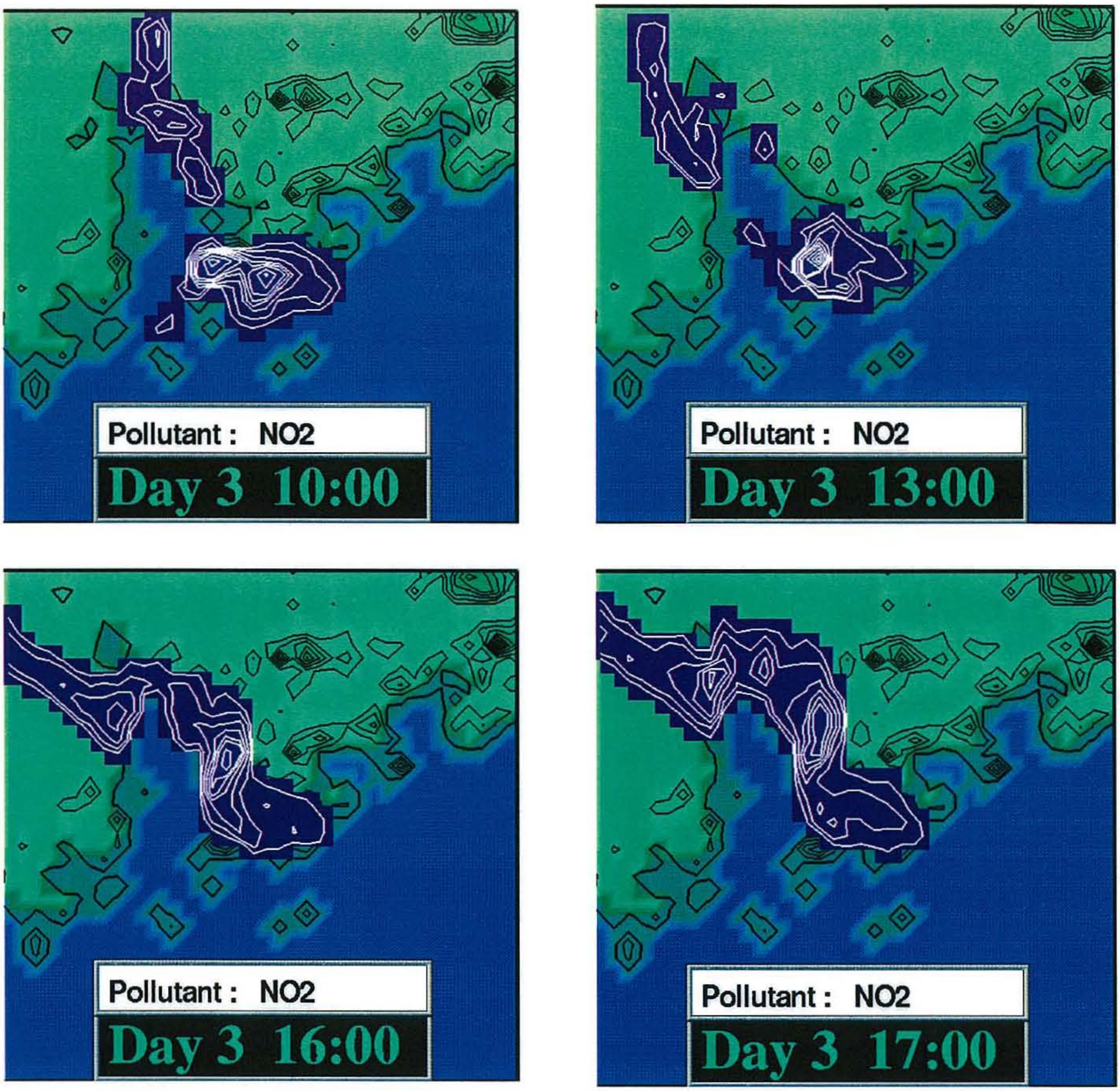


Figure 5.2c: Day 3. The distribution of NO2 emissions in 2012 with a Coal-fired New Power Station at 1000, 1300, 1600 and 1700 LT under Scenario 1. Contour values for NO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

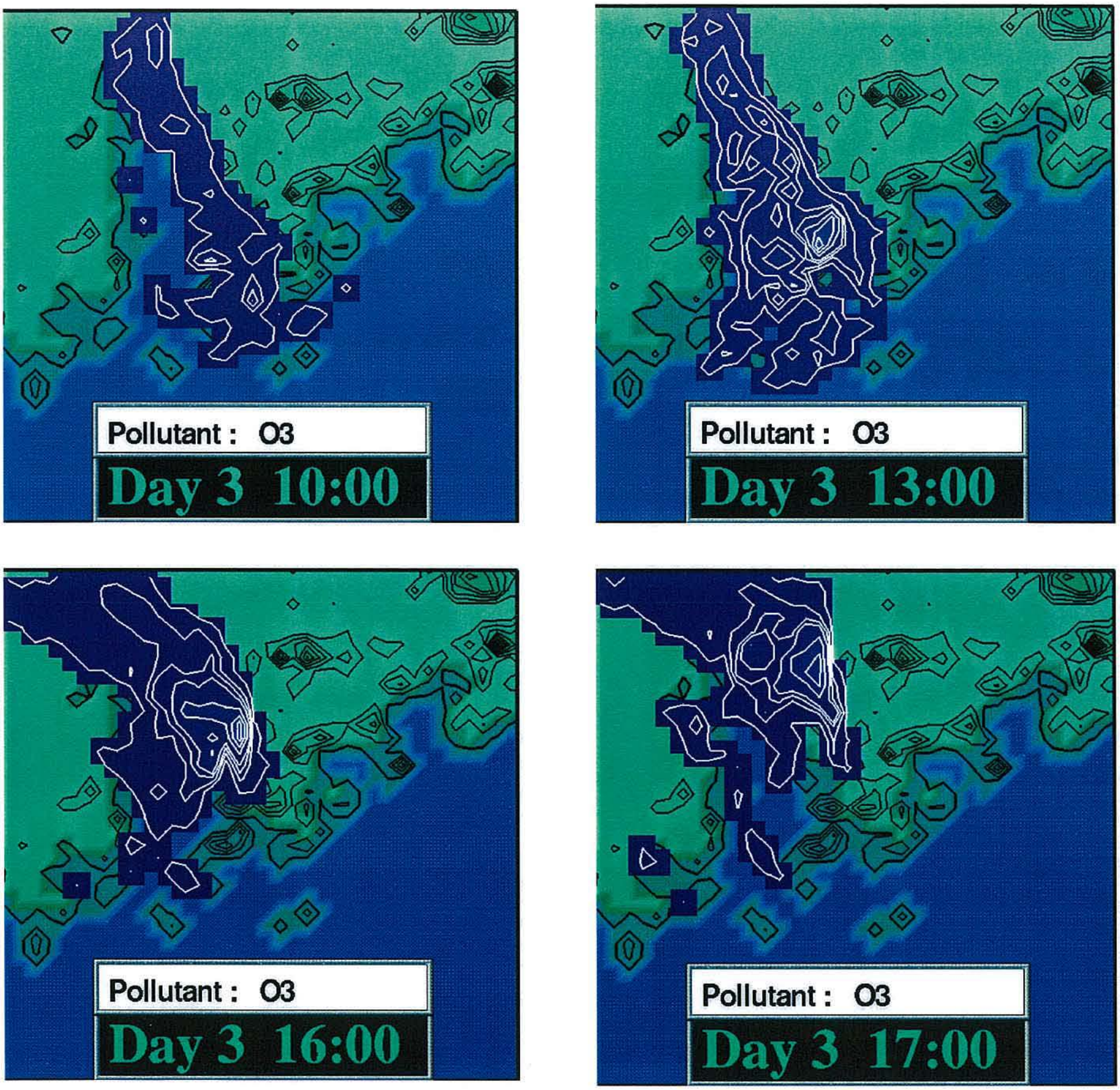


Figure 5.2d: Day 3. The distribution of O3 emissions in 2012 with a Coal-fired New Power Station at 1000, 1300, 1600 and 1700 LT under Scenario 1. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

Territories of the Hong Kong. By 1600 LT, the plume had consolidated with the peak having moved slightly northeast, but the rest of the plume having extended northwest into the inland. By 1700 LT, the remaining O_3 plume covered mostly the northern region of the PRD, with the maximum (situated over the northeast coast of the inland) having dropped to 200 ppb. There were some O_3 concentrations (approximately between 40 to 60 ppb) remaining near the west coast of the Pearl River Estuary.

5.2.2 *Photochemistry for 2002*

Figures 5.2e and *5.2f* show the concentrations of NO_x and O_3 respectively, at 1300, 1600, 1700 and 1800 LT for the simulations for 2002, before the commissioning of the New Power Station.

The very small degree of mixing between emissions from the Lamma Island sources and those from other sources was discussed in the previous section. There was no overlap with emissions from the *urban* source and only a small degree of interaction with those from the *airport* and perhaps *expressway* sources. When the simulation for the 2002 emission scenario (with only existing sources) was performed, there were no differences in the hourly regional maximum concentrations of the pollutants, except for very small differences in NO_x. This is not surprising considering that most maxima are associated with emissions from the *urban* source and that there is little interaction of *Lamma Island* emissions with those from other sources.

For each hour, the maximum and minimum glc differences (between the 2012 and 2002 simulations) across the region are shown in *Table 5.2c* for O_3 and NO_2. It is important to note that the values of the 'differences' tables shown in this section are calculated on a grid-point basis. The difference at each grid point between the two simulations of interest is calculated and the largest differences of the maxima and minima are then tabulated in the differences tables. Hence, the values in the differences tables do not necesarily correspond to a direct subtraction between the absolute maxima (*Tables 5.2a, 5.2b, 5.3a* and *5.3b*) or minima values, as the maxima and minima, at any particular time, for the various simulations are most likely located in different grid points. This would mean that the values in the differences tables will always be less than or equal to the differences between the absolute maxima and minima values.

From *Table 5.2c*, it can be seen that the differences between the 2002 and 2012 coal-fired simulations are small, especially when compared to typical maximum concentrations of 359 ppb and 285 ppb for O_3 and NO_2 respectively. Increased O_3 in 2012 occurs in areas where the total NO_x emissions from the *Lamma Power Station* plus the *New Power Station* are less than the NO_x emissions in 2002 from the *Lamma Power Station*. Bear in mind that the emissions from the two stations do not totally overlap, due to different effective stack heights. Before midday, the area of greatest positive O_3 difference occurs on Lantau Island, but in the afternoon it moves northward associated with a secondary O_3 maximum consisting of concentrations ranging between 200 to 250 ppb. Corresponding generally to these areas of positive O_3 are areas where the NO_2 glcs are less in 2012 than in 2002. Typical concentration values for NO_2 in these areas are 20 to 40 ppb.

Less O_3 is formed in 2012 than in 2002 (negative values in *Table 5.2c*) in those locations where emissions are found from the *New Power Station* but not from the existing *Lamma Power Station*. This is because the extra NO_x consumes some of the ozone and, hence the slight decrease seen at 1600 LT when compared to 1300 LT and 1700 LT. Correspondingly, higher NO_2 glcs occur in 2012 in those areas where emissions from the *New Power Station* are found, but not from the existing *Lamma Power Station.*

Table 5.2c ***Maxima and minima of differences between hourly-averaged ground-level concentrations in O_3 and NO_2 for the 2012 simulation with a coal-fired New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.***

Hour	Ozone (ppb)		Nitrogen Dioxide (ppb)	
	min	max	min	max
0900	0	0	0	0
1000	-2	6	-7	2
1100	-2	6	-8	3
1200	-5	30	-32	6
1300	-9	15	-19	10
1400	-4	20	-21	4
1500	-3	23	-25	3
1600	-6	13	-14	7
1700	-2	17	-18	3
1800	-3	6	-6	4

5.2.3 *Photochemistry for 2012 with Coal-Fired with De-NO_X New Power Station*

Figures 5.2g and *h* show the concentrations of NO_X and O_3 respectively, at 1300, 1600, 1700 and 1800 LT for the simulations for 2012 with a coal-fired with De-NO_X New Power Station.

Maximum and minimum differences in pollutant concentrations between 2002 and a 2012 scenario in which APC with De-NO_x technology is applied at the New Power Station are listed in *Table 5.2d*. *Table 5.2e* contains differences between the two 2012 scenarios, with and without the APC with De-NO_x technology at the New Power Station. Results in the latter Table indicates that application of the APC with De-NO_x technology in 2012 will decrease NO_2 glcs by a maximum of 27 ppb at 1300 LT. Conversely, O_3 glcs were increased by a maximum of 23 ppb also at 1300 LT.

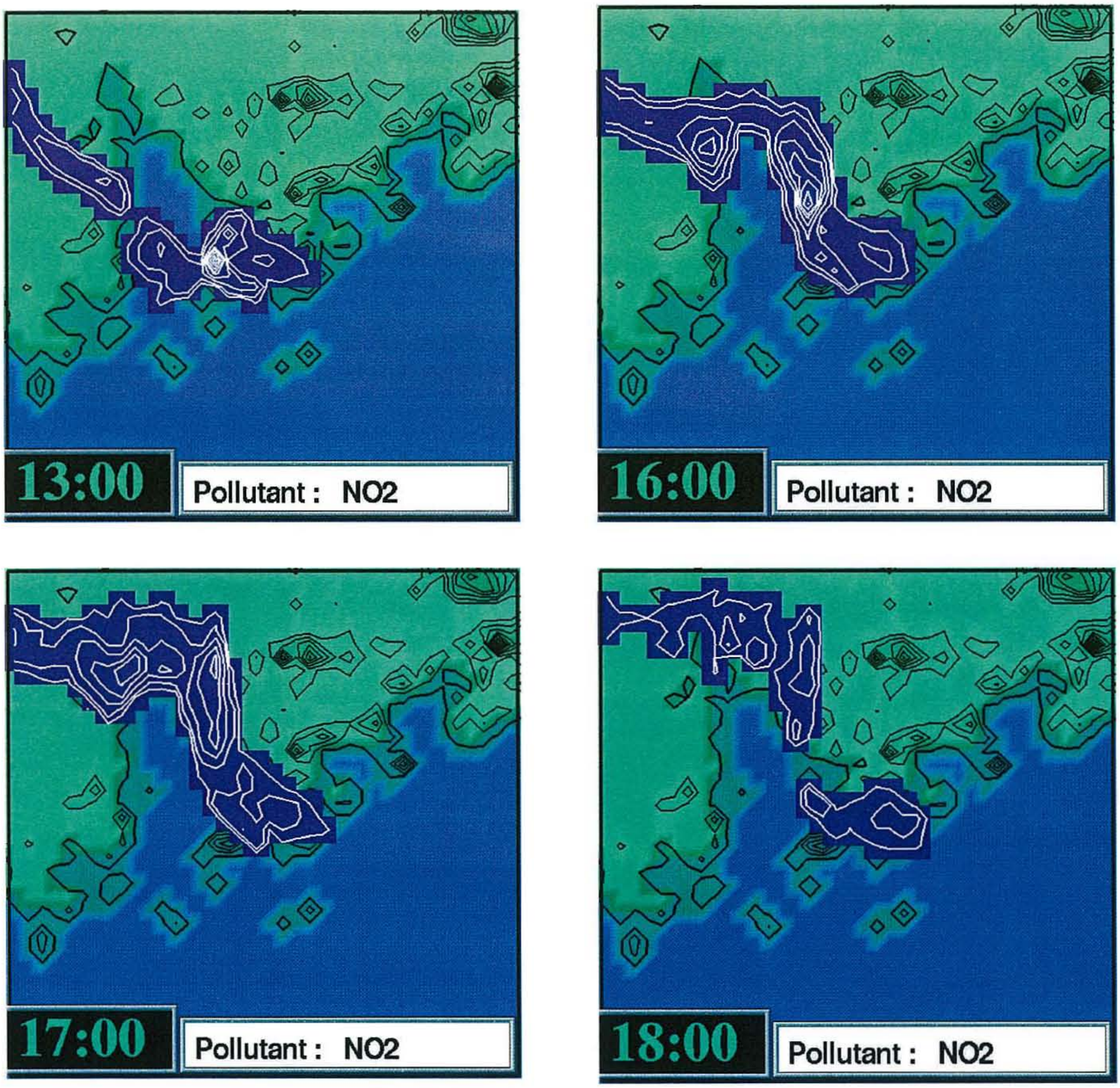


Figure 5.2e: The distribution of NO2 emissions in 2002 before the commissioning of a New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for NO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

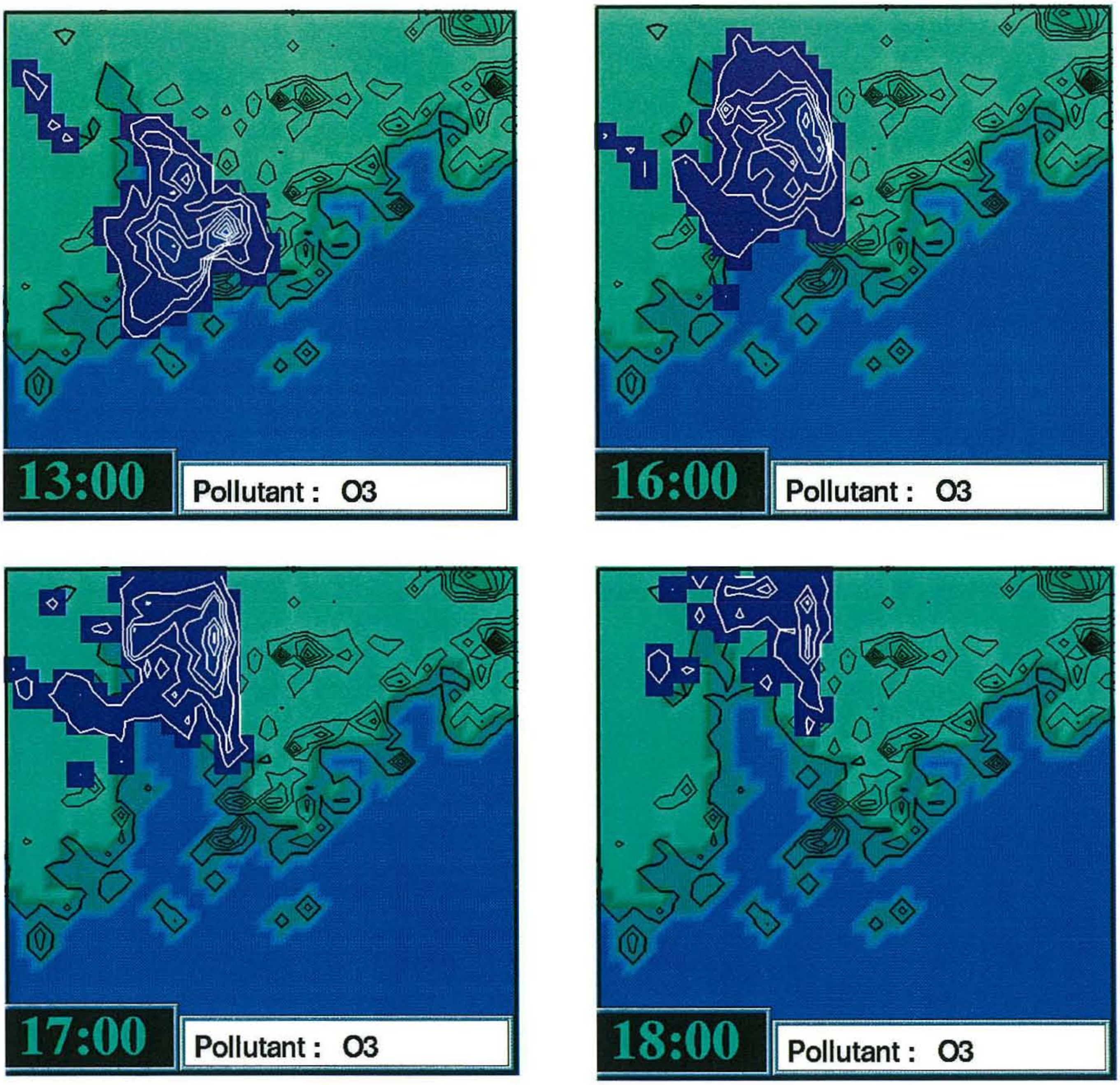


Figure 5.2f: The distribution of O3 emissions in 2002 before the commissioning of a New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

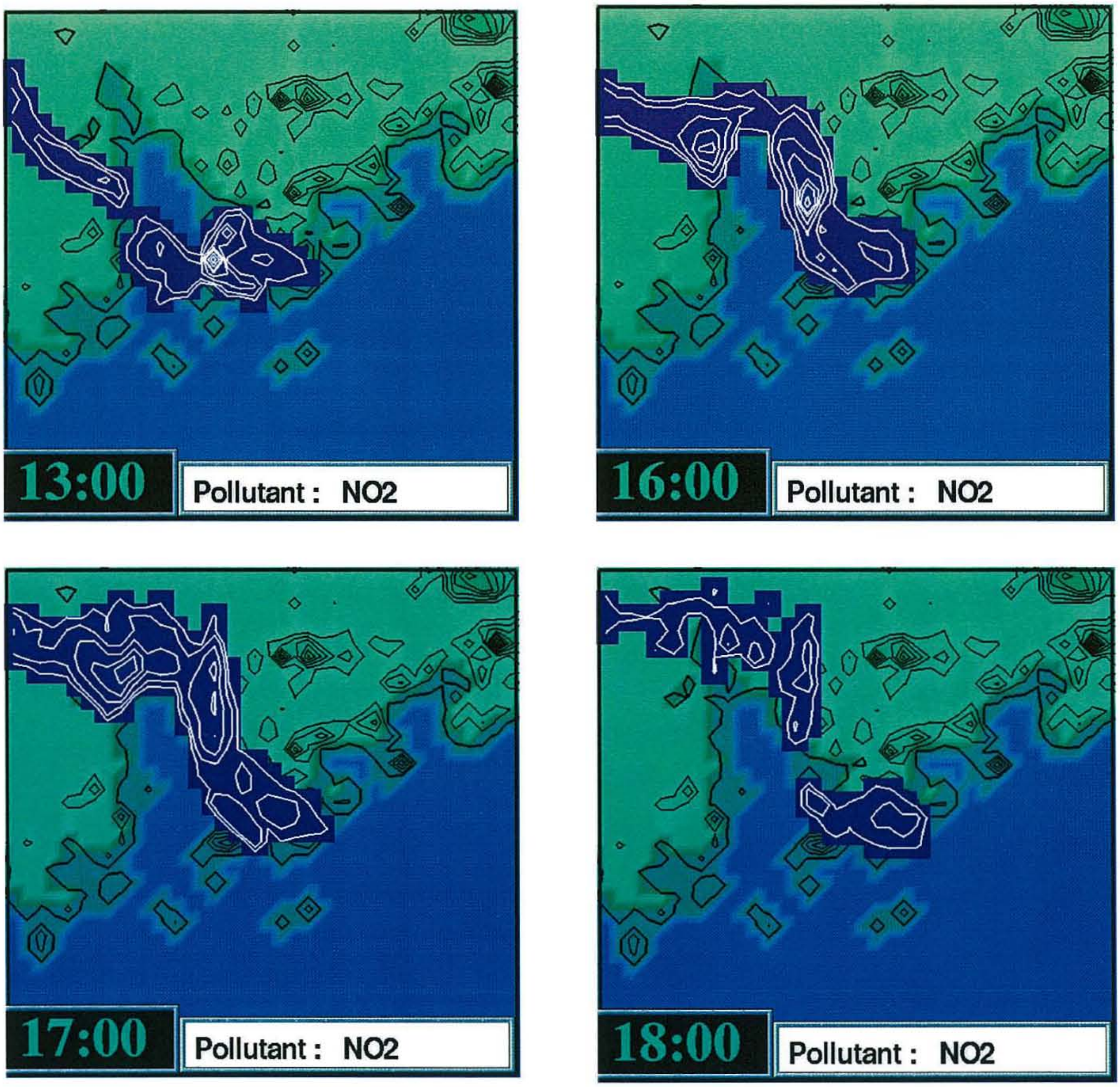


Figure 5.2g: The distribution of NO2 emissions in 2012 with a Coal-fired with de-NOX New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for NO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

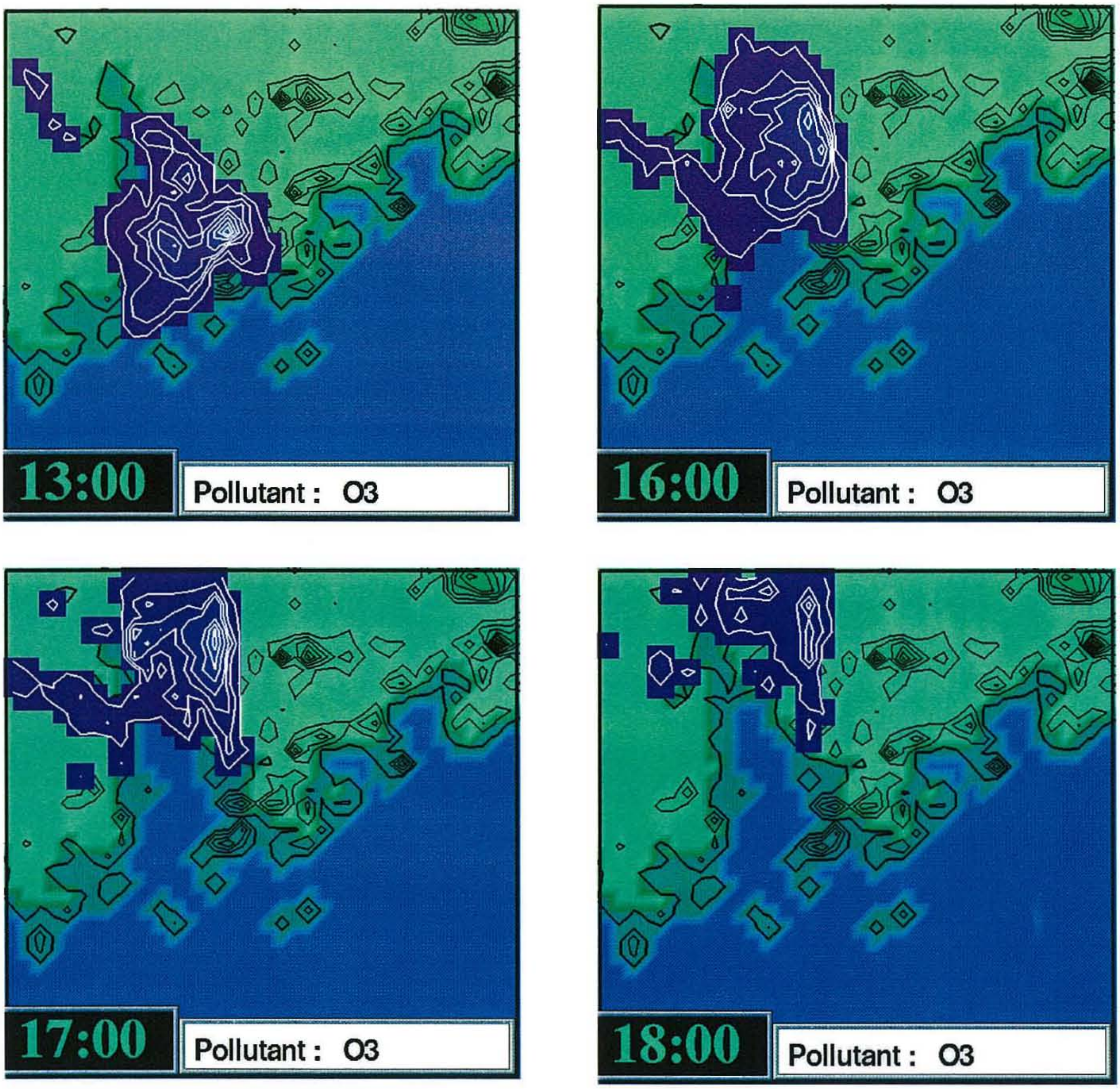


Figure 5.2h: The distribution of O3 emissions in 2012 with a Coal-fired with de-NOX New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

Table 5.2d *Maxima and minima of differences between hourly-averaged ground-level concentrations in O_3 and NO_2 for the 2012 simulation with a coal-fired with de-NO_x New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.*

Hour	Ozone (ppb)		Nitrogen Dioxide (ppb)	
	min	max	min	max
0900	0	0	0	0
1000	-1	8	-10	1
1100	0	10	-15	1
1200	-2	45	-49	2
1300	-2	38	-46	2
1400	-1	27	-29	0
1500	-1	38	-42	1
1600	-2	24	-25	1
1700	-1	26	-28	1
1800	-1	9	-9	1

Table 5.2e *Maxima and minima of differences between hourly-averaged ground-level concentrations in O_3 and NO_2 for the 2012 simulation with the a coal-fired with De-NO_x New Power Station and for the 2012 simulation with a coal-fired New Power Station without the new technology. Positive values indicate that concentrations are higher for the simulation with the new technology.*

Hour	Ozone (ppb)		Nitrogen Dioxide (ppb)	
	min	max	min	max
0900	0	0	0	0
1000	0	5	-6	0
1100	0	5	-9	0
1200	0	15	-17	0
1300	0	23	-27	0
1400	0	12	-13	0
1500	-1	20	-22	1
1600	-1	19	-21	0
1700	-1	14	-14	0
1800	-1	4	-5	0

5.2.4 *Photochemistry for 2012 with Gas-Fired New Power Station*

Figures 5.2i and *5.2j* show the concentrations of NO_X and O_3 respectively, at 1300, 1600, 1700 and 1800 LT for the simulations for 2012 with a gas-fired New Power Station.

The findings from this simulation were very similar to those of *Section 5.2.1* when the *New Power Station* was coal-fired. Typical plume heights were 420m at night and 350m during the day. Regional maximum glcs and concentration patterns are no different, due to the dominance of the *urban* source and limited mixing with emissions from other sources. Differences from the 2002 concentrations are shown in *Table 5.2f*, where the same general conclusions apply as for the coal-fired simulation. However comparison of this table with *Table 5.2c* shows that, from 2002 to 2012, a greater decrease in NO_2 and a greater increase in O_3 occur if the *New Power Station* is gas-fired than if it is coal-fired.

Table 5.2f ***Maxima and minima of differences between hourly-averaged ground-level concentrations in O_3 and NO_2 for the 2012 simulation with a gas-fired New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.***

Hour	Ozone (ppb)		Nitrogen Dioxide (ppb)	
	min	max	min	max
0900	-1	0	0	1
1000	-2	8	-9	2
1100	-1	14	-17	2
1200	-4	50	-56	5
1300	-5	46	-53	5
1400	-1	28	-32	1
1500	-2	55	-54	1
1600	-1	31	-34	1
1700	-3	26	-30	1
1800	-7	12	-13	2

5.3 *FSP AND SO_2 SIMULATIONS*

Tables 5.3 a and *5.3b* show the absolute maxima for FSP and SO_2 concentrations. It should be noted that most of these values occurred over the Hong Kong area, hence maximum values for the PRD region may not be reflected in these tables. The latter is illustrated more clearly in the relevant figures.

Table 5.3a ***Maximum concentrations of FSP ($\mu g/m^3$).***

Time	2002	2012 coal	2012 coal with De-NO_X	2012 gas	2012 existing sources (coal)[a]	2012 existing sources (gas)[b]
0900	103	103	103	103	103	103
1000	138	138	138	138	138	138
1100	177	177	177	177	177	177
1200	188	181	182	180	181	181
1300	223	223	223	223	223	223
1400	206	205	205	207	206	207
1500	125	125	125	148	126	148
1600	137	129	131	130	129	133
1700	151	149	151	164	151	167
1800	57	56	57	50	57	51
1900	25	25	25	28	25	28
2000	29	29	29	29	29	29
2100	30	30	30	30	30	30
2200	32	32	32	29	32	29

Note: a - this simulation was run for the purpose of calculating the contributions from a new coal-fired station and is not an option scenario.

b - this simulation was run for the purpose of calculating the contributions from a new gas-fired station and is not an option scenario.

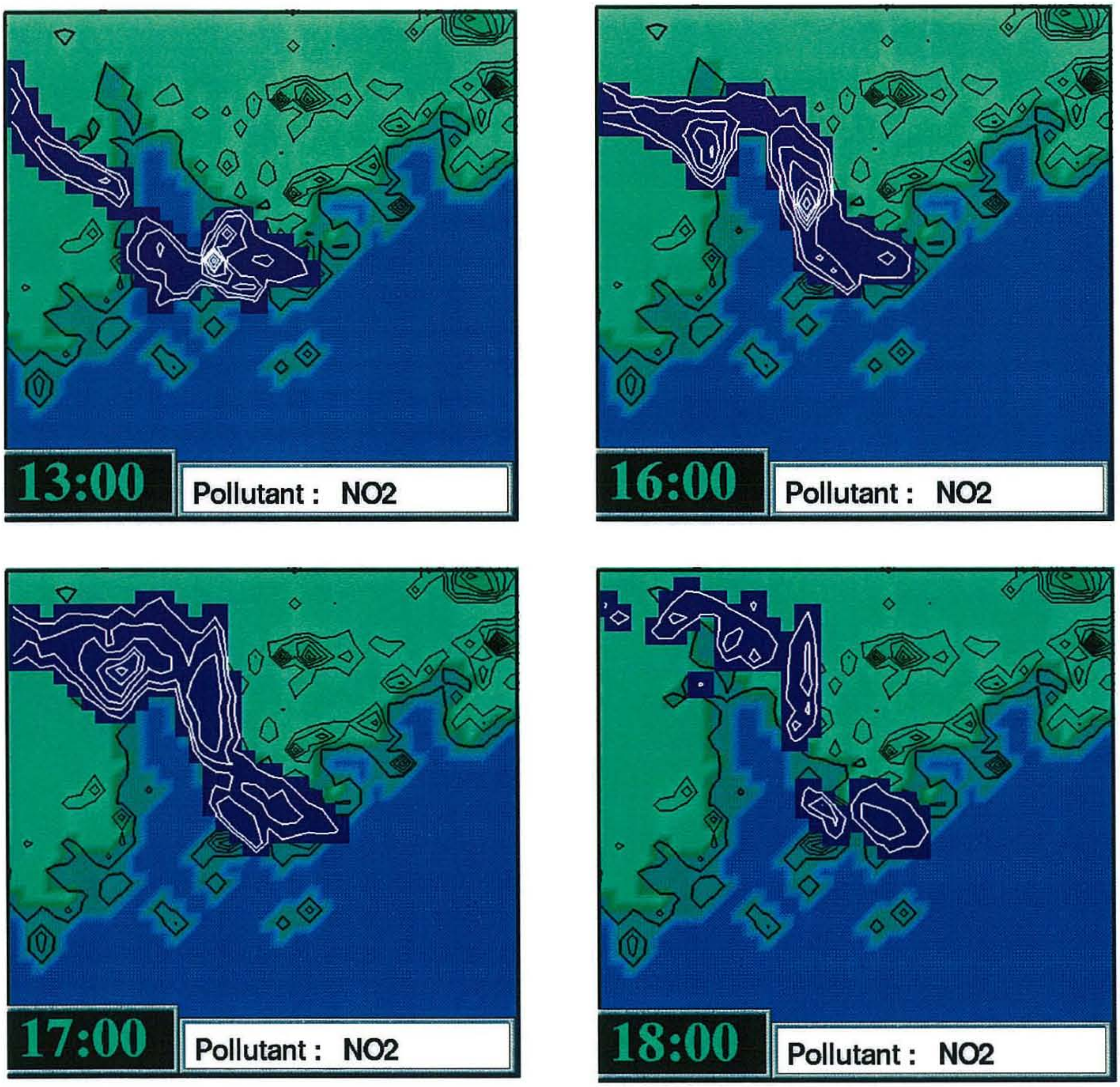


Figure 5.2i: The distribution of NO2 emissions in 2012 with a Gas-fired New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for NO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

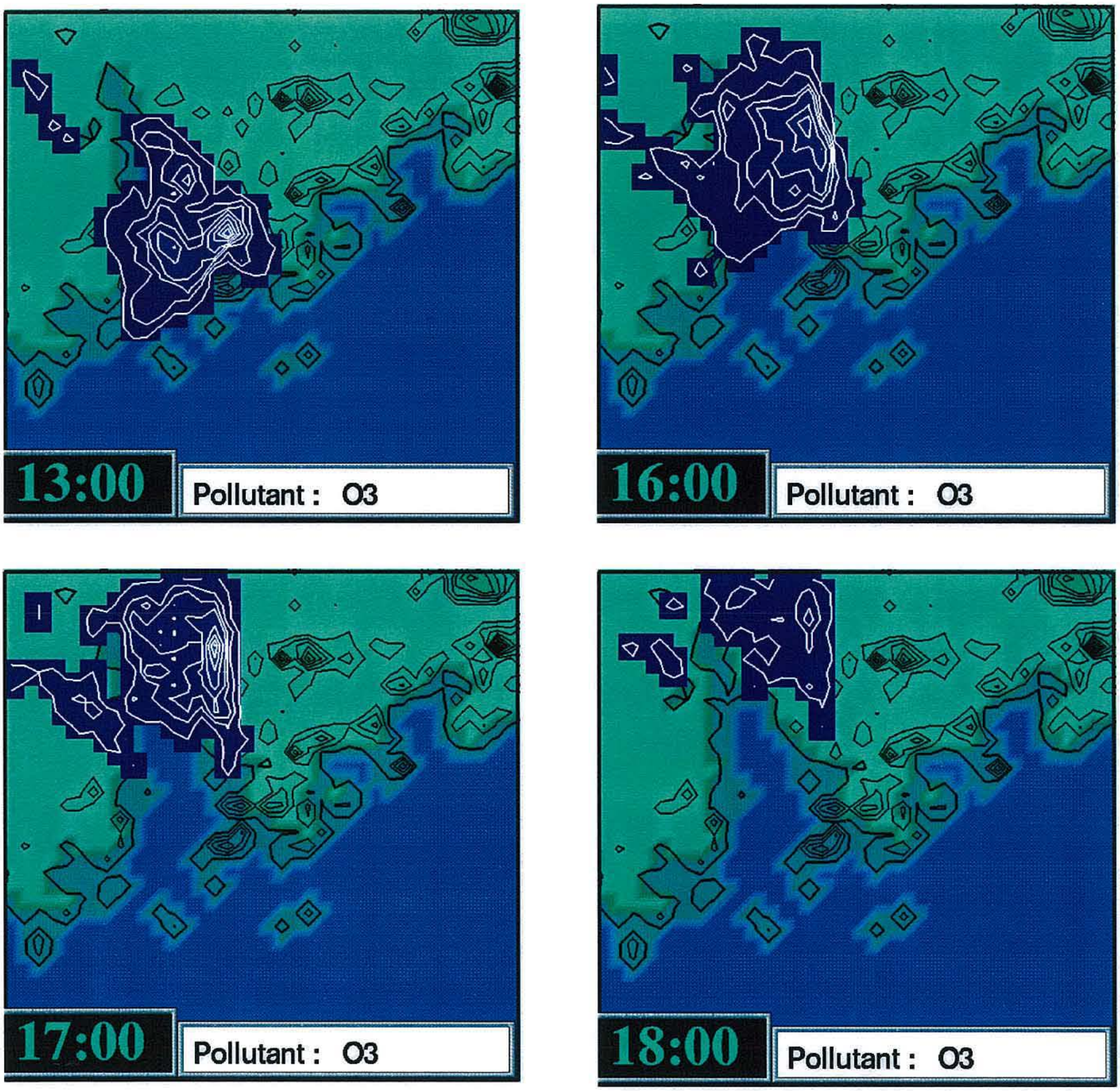


Figure 5.2j: The distribution of O3 emissions in 2012 with a Gas-fired New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

Table 5.3b *Maximum concentrations of SO_2 (ppb).*

Time	2002	2012 coal	2012 coal with De-NO_X	2012 gas	2012 existing sources (coal)[a]	2012 existing sources (gas)[b]
0900	77	77	77	77	77	77
1000	61	61	61	61	61	61
1100	191	80	80	77	77	77
1200	383	153	153	120	126	120
1300	318	184	184	135	165	135
1400	281	169	169	160	169	160
1500	198	183	183	192	182	192
1600	270	175	174	158	163	158
1700	174	162	162	157	161	157
1800	119	101	101	83	97	83
1900	19	19	19	23	19	23
2000	25	25	25	26	25	26
2100	27	27	27	26	27	26
2200	31	31	31	25	31	25

Note: a - this simulation was run for the purpose of calculating the contributions from a new coal-fired station and is not an option scenario.
b - this simulation was run for the purpose of calculating the contributions from a new gas-fired station and is not an option scenario.

High levels of particulates occurred between 1200 and 1400 LT for all four simulations, with the exception of the gas option which occurred slightly later at 1300 LT. At 1300 LT, all four simulations reached maximum concentrations. As the FSP concentrations reached a high levels only over a short period of time (for approximately 3 hours), AQO or NAQS are not expected to be breached.

The high levels of FSP occurring in the early afternoon were the same across each row in Table 5.3a, indicating that the impacts are due to existing sources (see *Section* 5.4.2).

For SO_2, the only exceedance of the AQO was by the 2002 simulation, which occurred for a short period between 1200 and 1300 LT (by a maximum of 78 ppb at 1200 LT). Similarly, the NAQS at level III was exceeded only by the 2002 simulation, but between 1200 and 1600 LT.

Again, the exceedances for SO_2 could not be accounted for by the New Power Station, suggesting that existing sources contribute to these exceedances (see *Section* 5.4.2).

5.3.1 *FSP and Visibility*

The FSP dispersion was generally similar for all four options: 2002; 2012 coal-fired; 2012 coal-fired with De-NO_X; and gas-fired (see *Figures 5.3a* to *5.3d*). *Tables 5.3c* to *5.3f* illustrate the differences in maxima and minima between the various options. In other words, different technologies or even the existence or non-existence of a new power station had no significant effect on FSP concentrations or dispersion.

Peak concentrations of approximately 223 $\mu g/m^3$ were detected at 1300 LT, with the plume covering most of the Hong Kong area as well as the whole of the Pearl

River Estuary and a narrow strip spanning inland, northwest from the estuary. By 1600 LT, the plume had travelled in a north-northwesterly direction covering the all coastal areas of the Pearl River Estuary with maximum concentrations dropping to about 130 μg/m³. By 1700 LT, the centre of the plume was located along the northern coast and had spread inland of the PRD and by 1800 LT, maximum concentrations had decreased to a little above 50 μg/m³. At this time, FSP levels were slightly lower for the gas-fired option than for the other three options.

These results imply that the different technologies have virtually no impacts on the distribution and maxima concentrations of FSP in the PRD, which in turn implies that visibility in the region will not be affected by the technology chosen for the operation of a new power station..

Table 5.3c *Maxima and minima of differences between hourly-averaged ground-level concentrations in FSP and SO_2 for the 2012 simulation with a coal-fired New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.*

Hour	FSP (μg/m³)		Sulphur Dioxide (ppb)	
	min	max	min	max
0900	0	0	0	0
1000	-5	0	-42	1
1100	-9	1	-111	1
1200	-14	1	-230	0
1300	-14	2	-167	3
1400	-7	1	-117	0
1500	-7	4	-74	10
1600	-8	2	-95	4
1700	-8	2	-80	5
1800	-12	2	-20	10

Table 5.3d *Maxima and minima of differences between hourly-averaged ground-level concentrations in FSP and SO_2 for the 2012 simulation with a coal-fired with De-NO_X New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.*

Hour	FSP (μg/m³)		Sulphur Dioxide (ppb)	
	min	max	min	max
0900	0	0.	0	0
1000	-4	0	-43	1
1100	-9	1	-111	1
1200	-14	1	-230	0
1300	-13	2	-167	2
1400	-7	1	-117	0
1500	-7	7	-74	9
1600	-7	2	-96	3
1700	-7	6	-81	5
1800	-9	3	-20	9

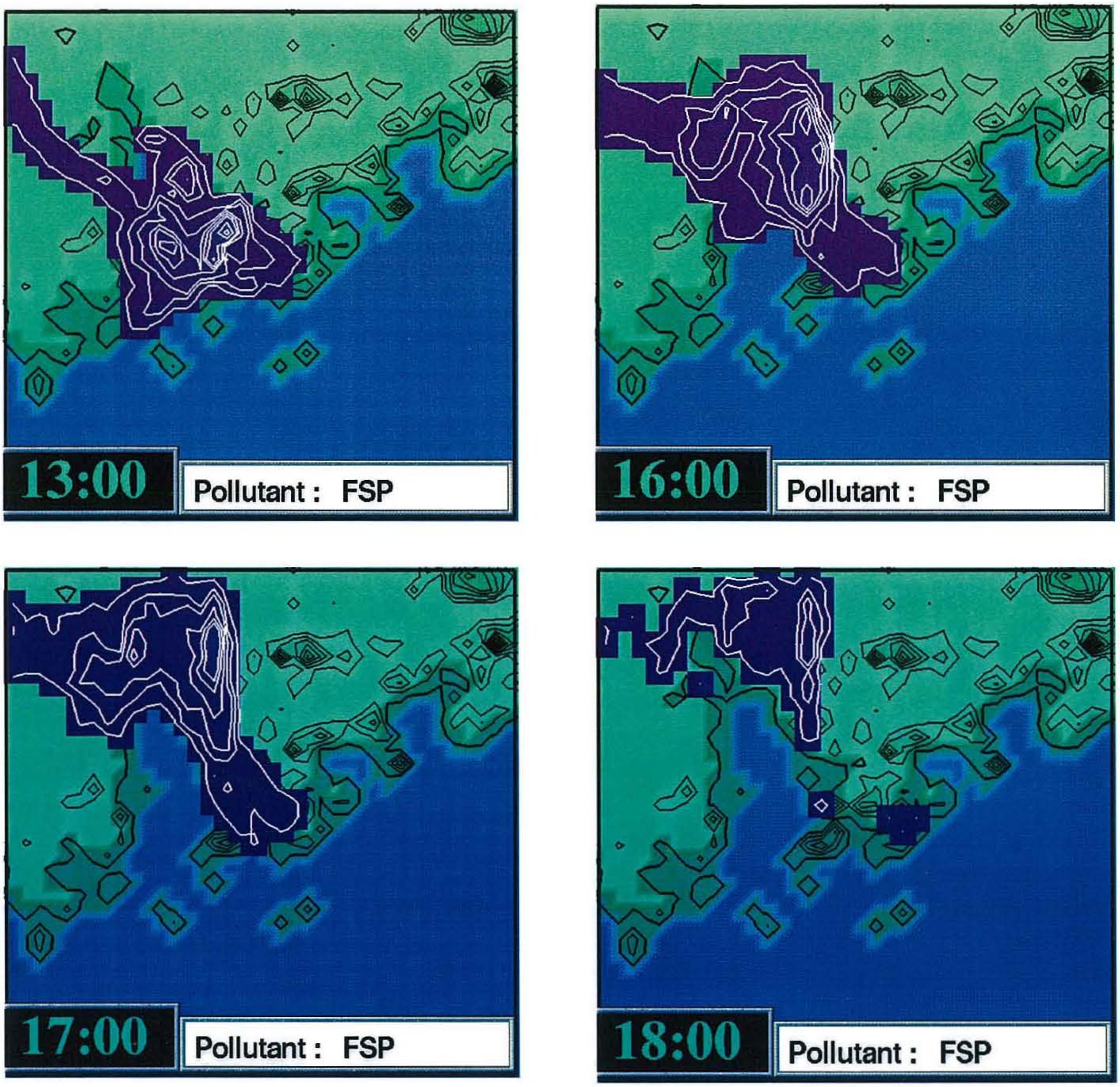


Figure 5.3a: The distribution of FSP emissions in 2012 with a Coal-fired New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for FSP are 20, 30, 40, 60, 80, 100, 150, 200 and 250 μg/m3.

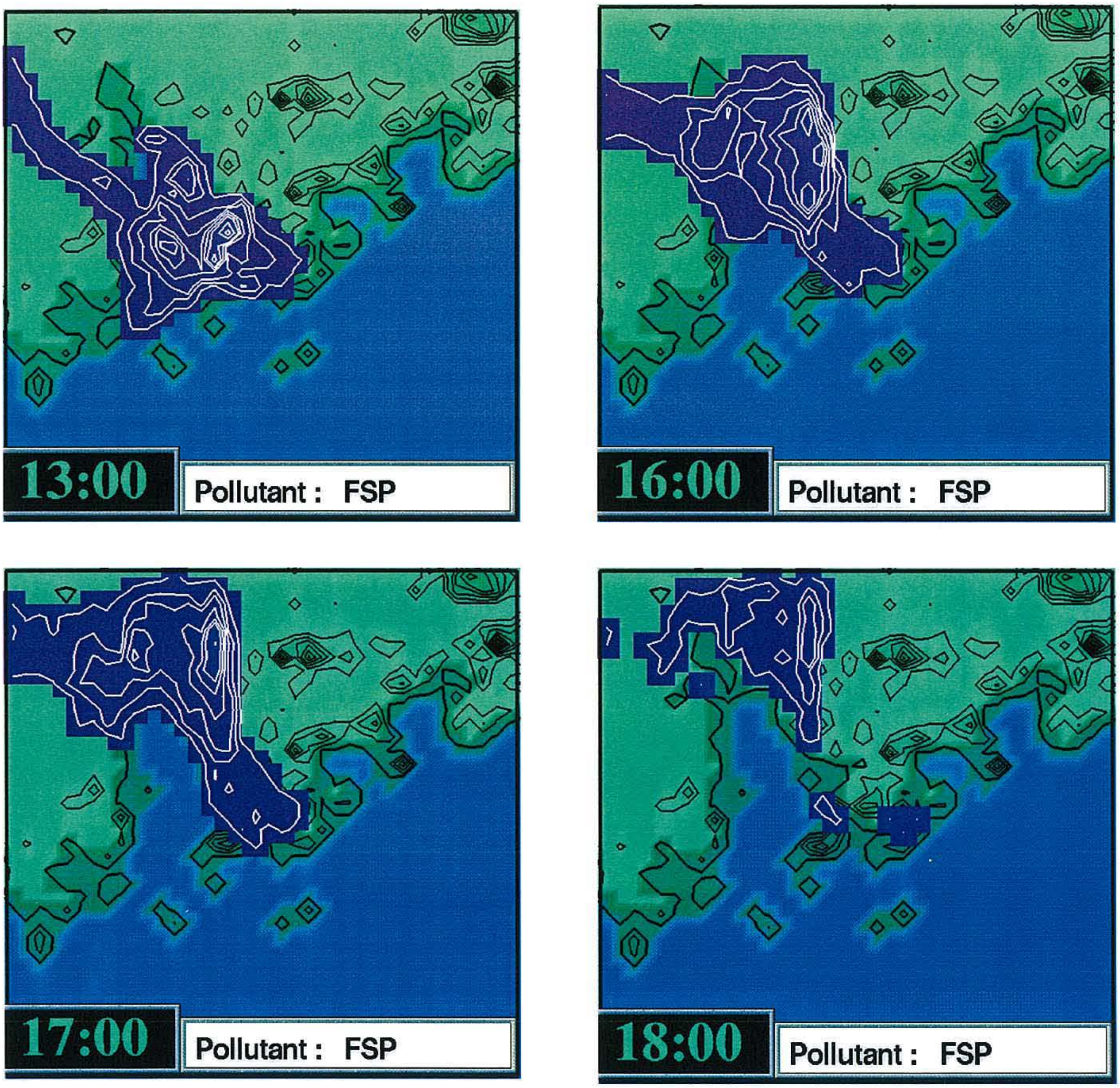


Figure 5.3b: The distribution of FSP emissions in 2002 before the commissioning of a New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for FSP are 20, 30, 40, 60, 80, 100, 150, 200 and 250 μg/m3.

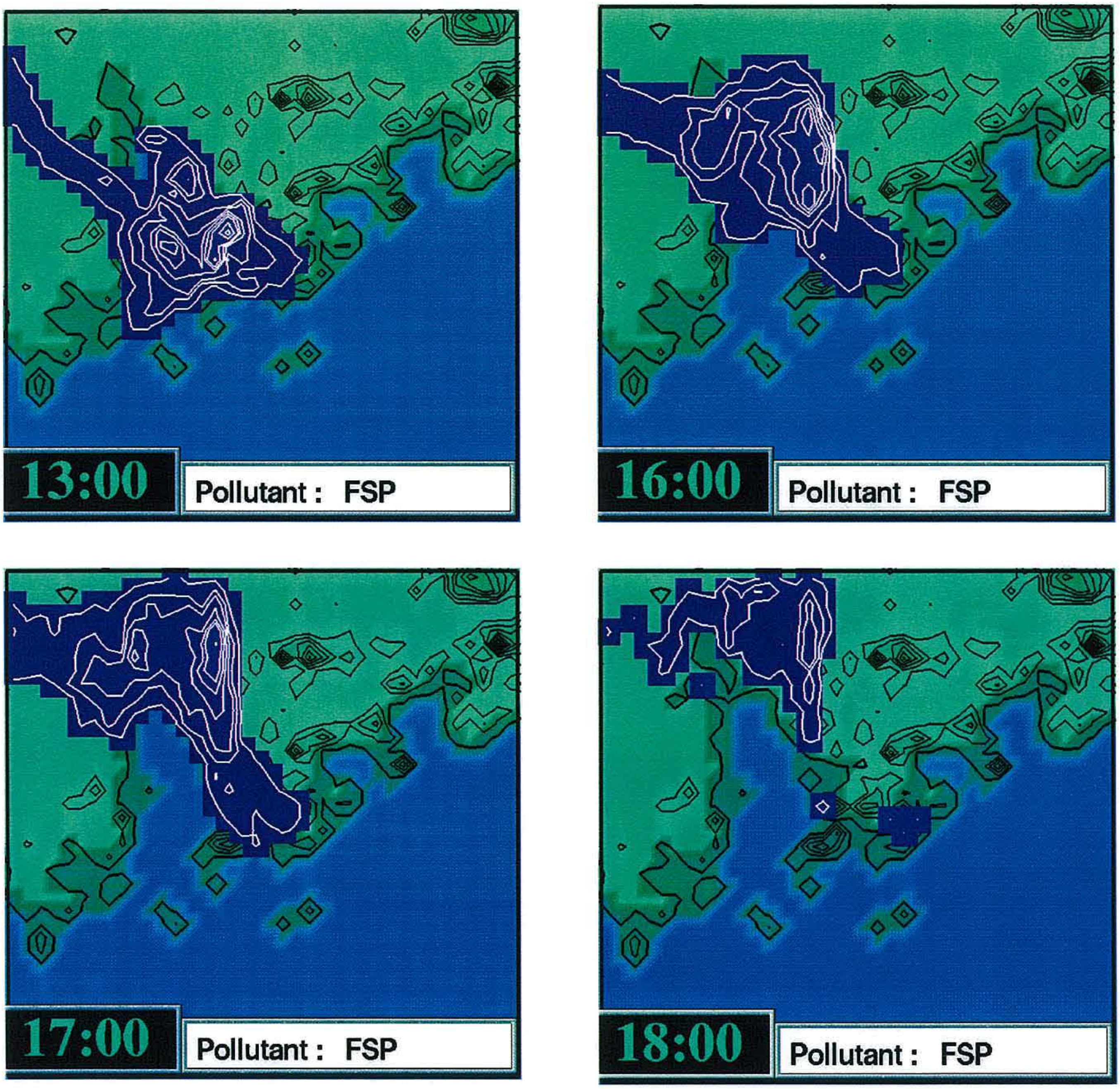


Figure 5.3c: The distribution of FSP emissions in 2012 with a Coal-fired with de-NOX New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for FSP are 20, 30, 40, 60, 80, 100, 150, 200 and 250 μg/m3.

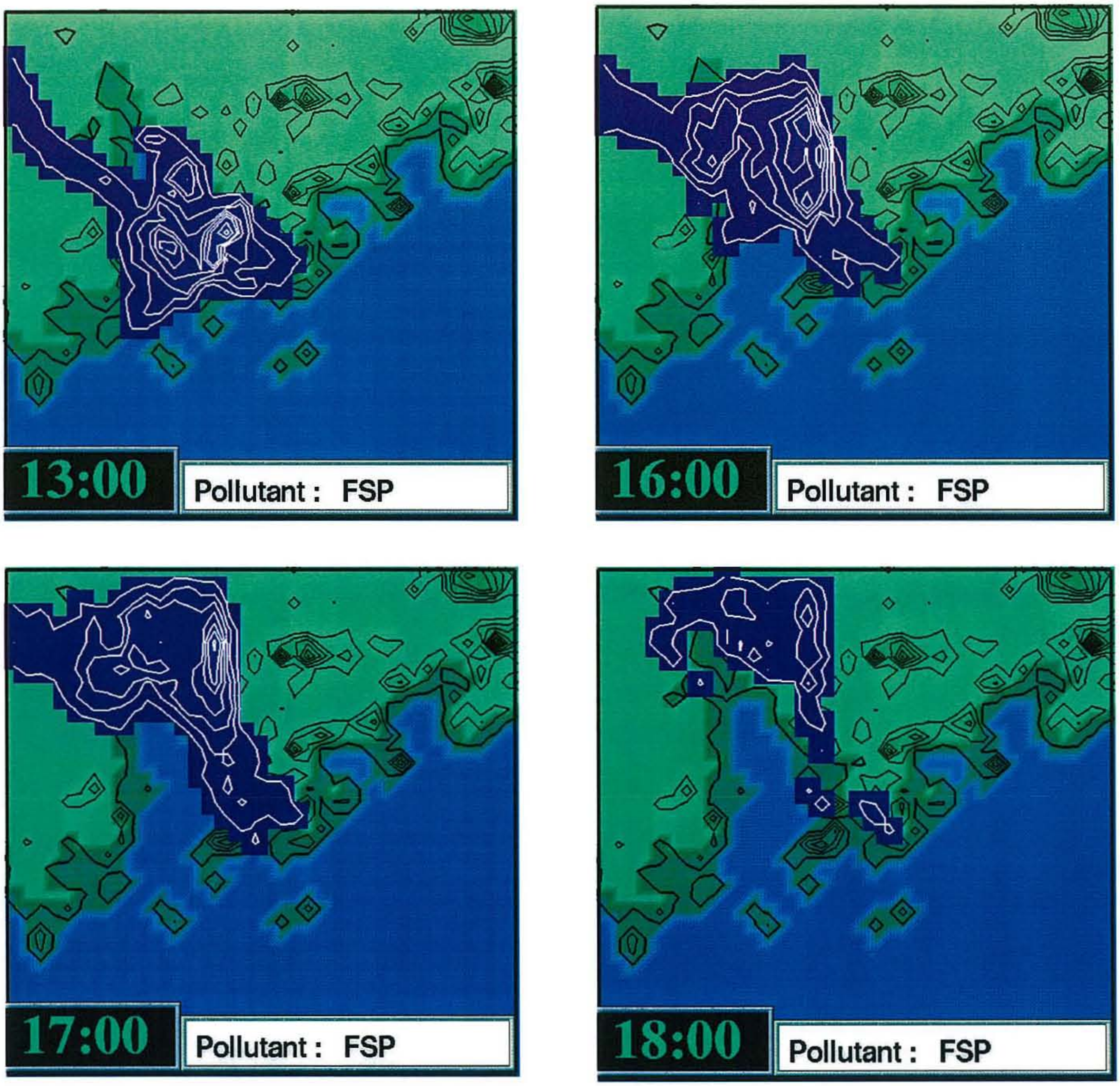


Figure 5.3d: The distribution of FSP emissions in 2012 with a Gas-fired New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for FSP are 20, 30, 40, 60, 80, 100, 150, 200 and 250 µg/m3.

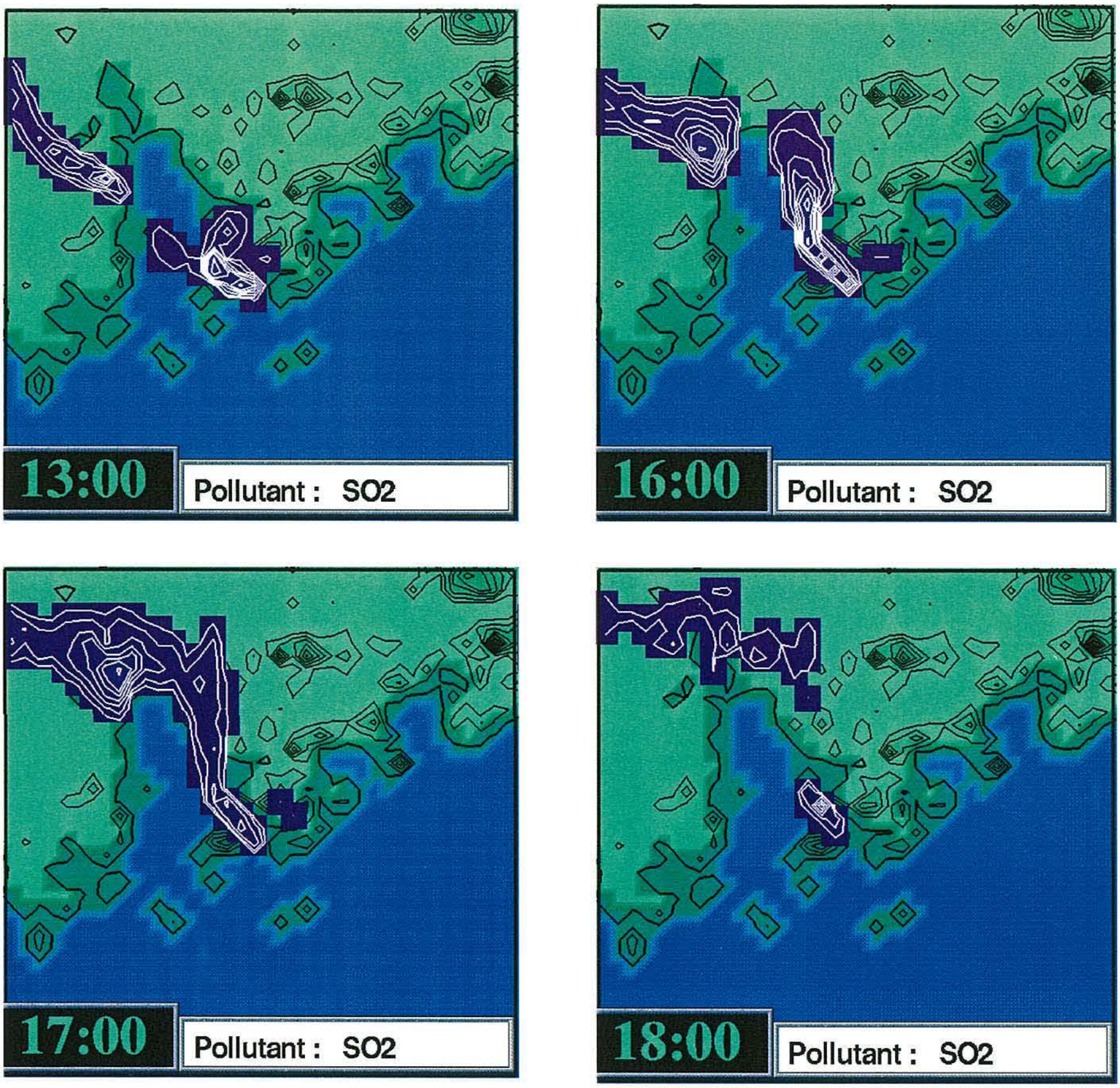


Figure 5.3e: The distribution of SO2 emissions in 2012 with a Coal-fired New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for SO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

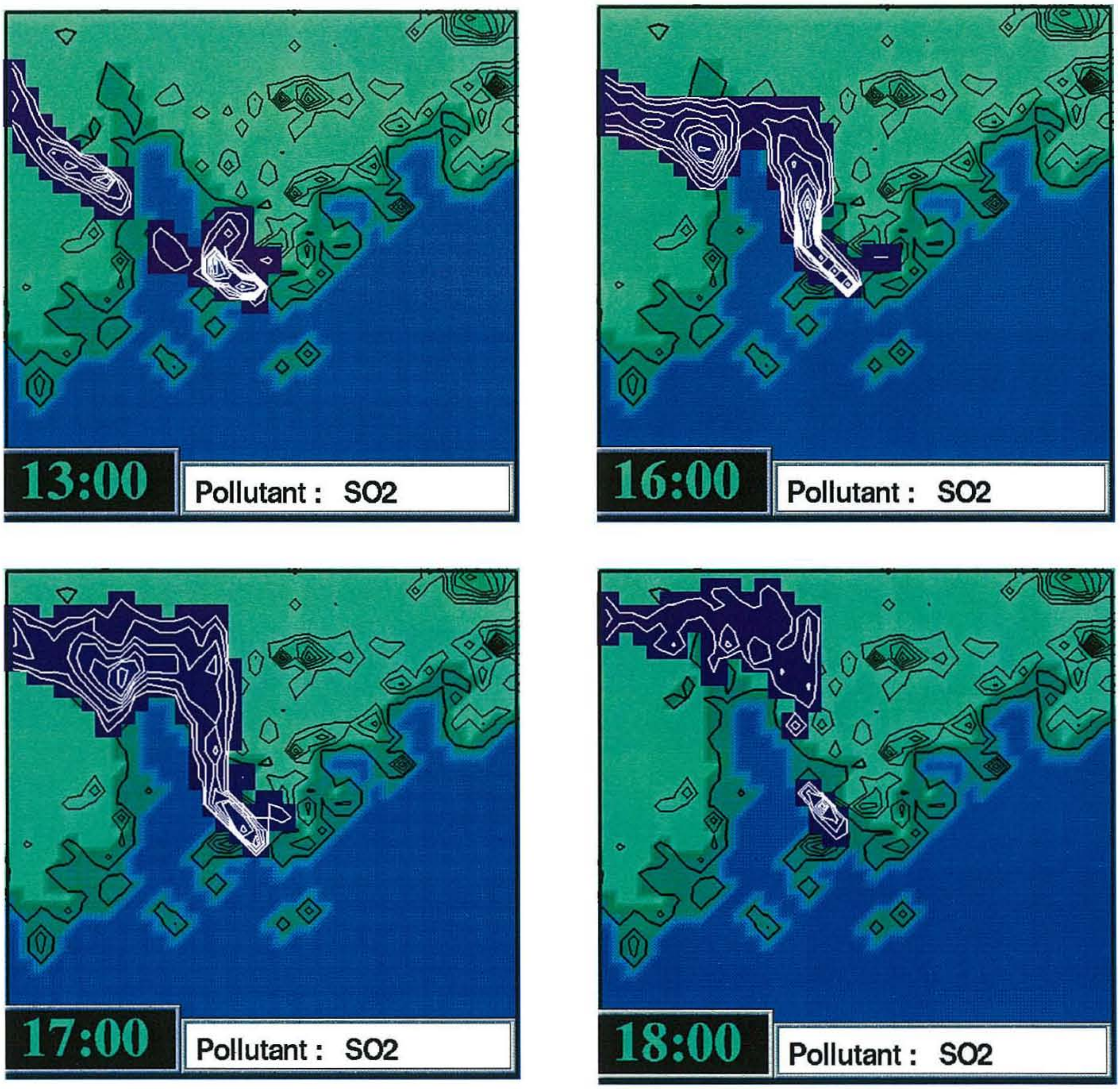


Figure 5.3f: The distribution of SO2 emissions in 2002 before the commissioning of a New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for SO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

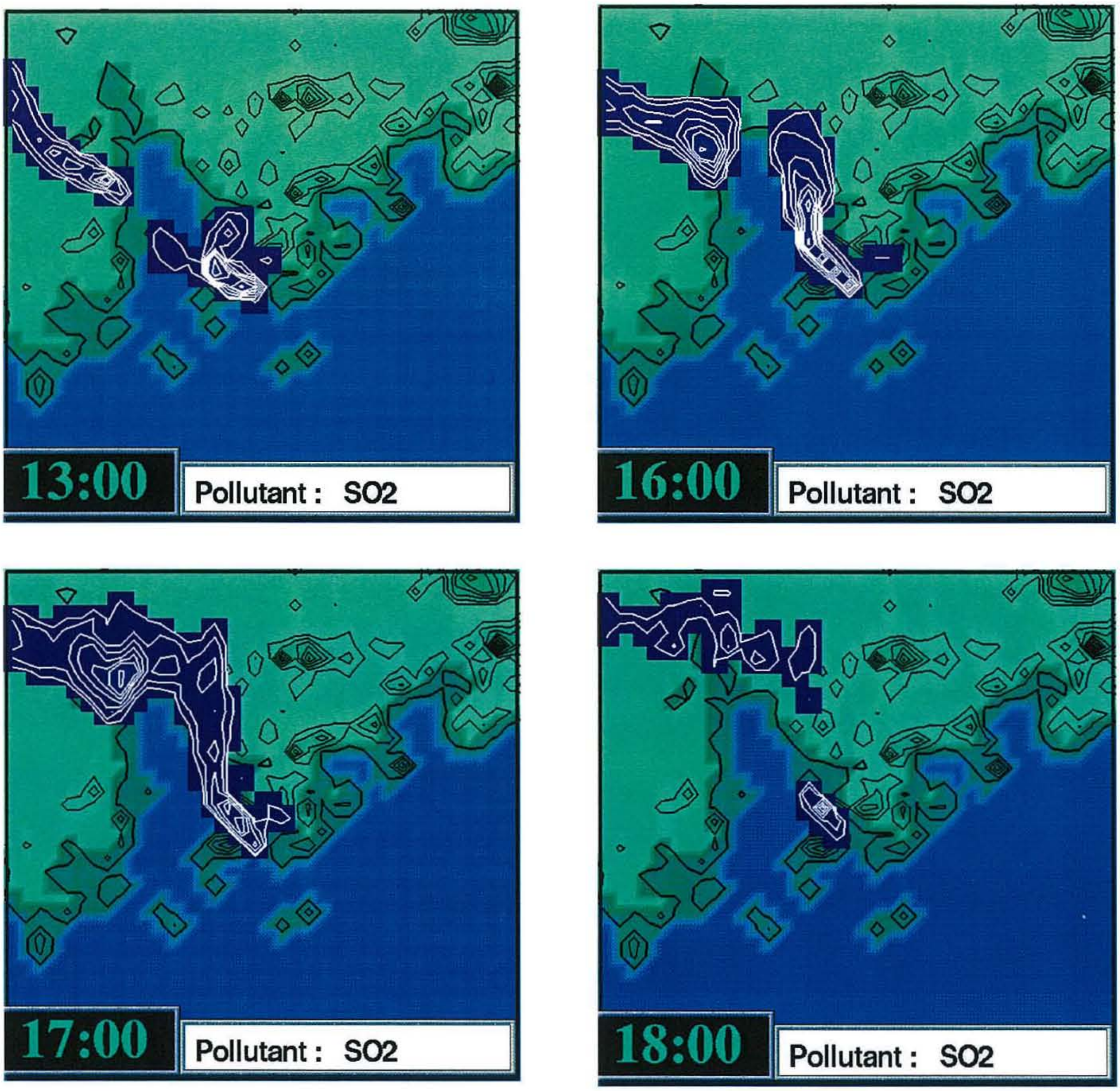


Figure 5.3g: The distribution of SO2 emissions in 2012 with a Coal-fired with de-NOX New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for SO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

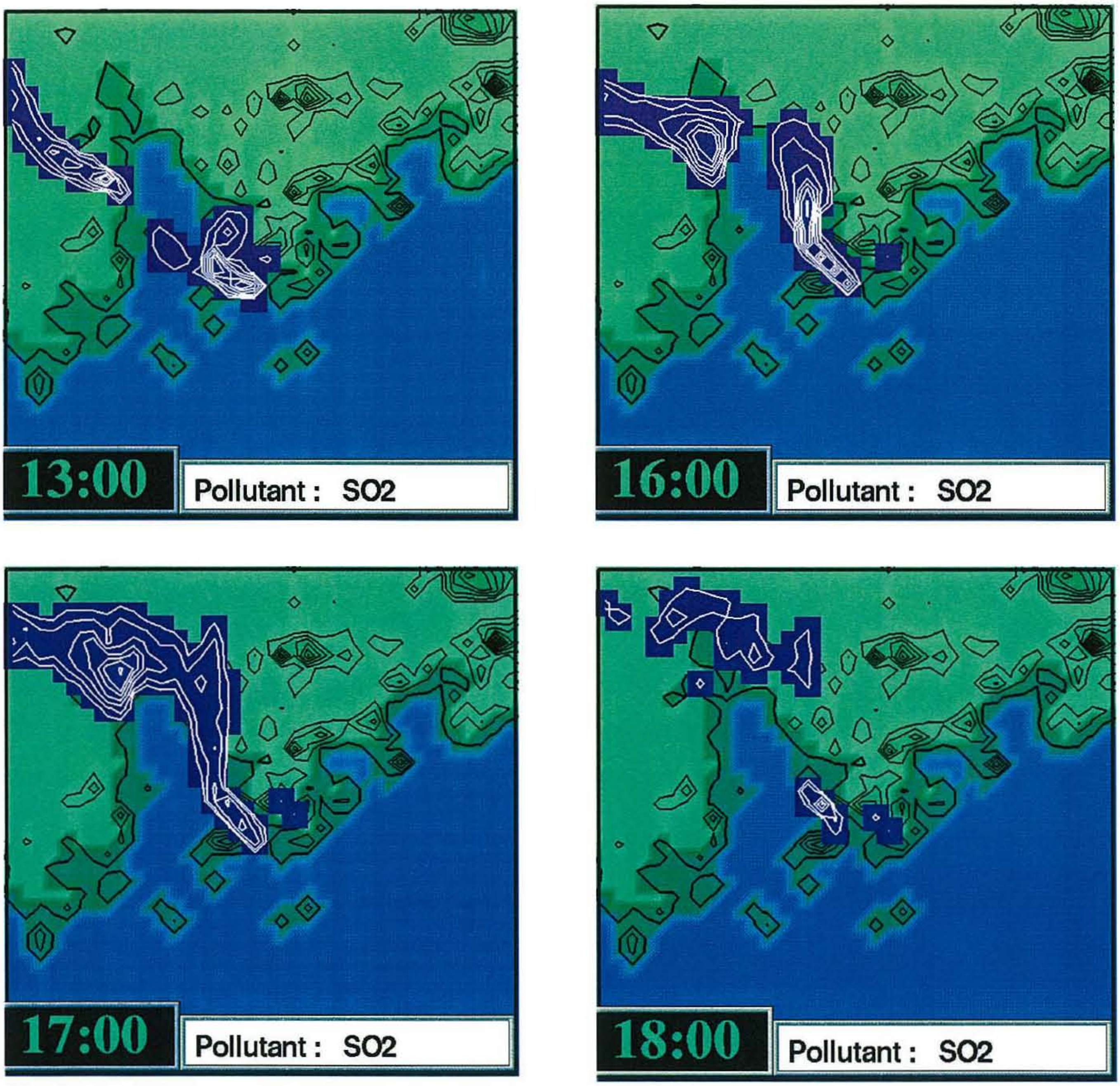


Figure 5.3h: The distribution of SO2 emissions in 2012 with a Gas-fired New Power Station at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for SO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

Table 5.3e *Maxima and minima of differences between hourly-averaged ground-level concentrations in FSP and SO_2 for the 2012 simulation with a coal-fired with De-NO_X New Power Station and the 2012 coal-fired New Power Station simulation. Positive values indicate that concentrations are higher for the 2012 simulation.*

Hour	FSP (μg/m³)		Sulphur Dioxide (ppb)	
	min	max	min	max
0900	0	0	0	0
1000	0	1	-1	0
1100	0	1	-1	0
1200	-1	1	-1	1
1300	-1	2	-1	0
1400	-1	1	-1	0
1500	-4	3	-1	1
1600	-2	4	-1	0
1700	-2	7	-2	0
1800	-4	3	-1	1

Table 5.3f *Maxima and minima of differences between hourly-averaged ground-level concentrations in FSP and SO_2 for the 2012 simulation with a gas-fired New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.*

Hour	FSP (μg/m³)		Sulphur Dioxide (ppb)	
	min	max	min	max
0900	0	0	0	0
1000	-5	0	-50	0
1100	-14	0	-152	0
1200	-22	0	-295	0
1300	-18	2	-205	0
1400	-12	3	-144	1
1500	-11	5	-83	2
1600	-14	4	-113	2
1700	-12	3	-101	3
1800	-9	5	-38	4

Local Visual Distances

Minimum values of local visual distance (LVD) at each hour over the region are listed in *Table 5.3g*. They are associated with the *urban* source, with negligible contribution from the *New Power Station*. The smallest values (of about 8 km), occured at 1300 and 1400 LT, due to urban emissions, and were located on the southern side of Deep Bay. Below 8 kilometres, visibility is not considered as good (*HMSO, 1982*). The differences in FSP values in *Table 5.3c* are too small to influence visibility to any extent, and certainly do not affect the values in *Table 5.3d*. The location of the FSP differences in *Table 5.3c* does not appear to be related to the emission footprints of the power stations on Lamma Island as is the case for O_3 and NO_2. This is because FSP consists of contributions from SO_2, NO_X and particulates.

Visibility on the part of Lantau Island where emissions from the HEC and WEIF sources on Lamma come to ground in the morning and early afternoon, varies between 30 and 40 km for the 2002 simulatins. *Table 5.3c* shows that there are both positive and negative differences in FSP concentrations between 2012 and 2002, located in the vicinity of the HEC plume footprints for most of the day. However, the overall effect of the new and existing coal-fired power stations in 2012 is a decrease in FSP values on Lantau Island in the morning, hence increasing visibility. Substitution of a difference of 15 $\mu g/m^3$ from *Table 5.3c* in the visibility formula (*Section 2.2.1*, using a typical glc for 2002 in that area of 50$\mu g/m^3$) for example, results in an improvement in visibility of about 15 km. From 1500 LT onwards, when emissions from the Lamma Island sources (and other sources) are in the Castle Peak and Deep Bay area, FSP concentrations are less in 2012, leading to an increase in visibility.

In summary, visibility minima are mainly associated with the *urban* source and not to the New Power Station.

Table 5.3g ***Minimum local visual distance (LVD) in kilometres for 2012***

Hour	06	07	08	09	10	11	12	13	14	15	16	17	18
LVD (km)	43	43	28	16	12	10	9	8	8	13	13	11	28

5.3.2 *SO_2 Concentrations*

The dispersion patterns for SO_2 were generally similar for all four options (see *Figures 5.3e* to *5.3h*), except that the 2002 simulation (before the commissioning of the new power station) showed a slightly greater area of distribution of SO_2 concentrations over the PRD region as well as greater concentrations than the other three options. At 1300 LT (see *Table 5.3b*), SO_2 concentrations for 2002 were about 73% more than the maximum concentrations for the coal options and 136% more than the gas option). The gas-fired option produced an area of distribution similar to the coal options but with lower concentrations. *Tables 5.3c* to *f* illustrate the differences in maxima and minima between the various options.

At 1300 LT, SO_2 concentrations for all four simulations were focused in two plumes, one centred over the west side of the Hong Kong and the other on the northwest inland of the PRD. Maximum concentrations at this time were approximately 318 ppb for the 2002 simulation, 184 ppb for the two coal-fired sceanrios, and 135 ppb for the gas simulation. A maximum conentration of about 383 ppb was reached earlier on at 1200 LT for the 2002 simulation, as compared to 153 ppb for the two coal simulations, and 120 ppb for the gas one.

By 1600 LT, the SO_2 plume over the Hong Kong for all four simulations had begun to disperse northwards along the east coast of the Pearl River Estuary, while the plume on the PRD inland had expanded and was advancing in an easterly direction towards the northern coast of the Estuary. SO_2 maxima of approximately 270 ppb for the 2002 simulation, about 175 ppb for the coal simulations, and 158 ppb for the gas one, occurred mainly in the Hong Kong area.

By 1700 LT, the SO_2 distribution patterns as well as peak concentrations, for all four options over the PRD region, were similar. For the PRD region, this was the time with the largest distribution of peak SO_2 concentrations with maxima of about 174 ppb for 2002, 162 ppb for both coal-fired options and 157 ppb for the gas simulation. By 1800 LT, only small amounts of SO_2 remained in the northwest region of the PRD inland, with similar distribution patterns for all four simulations. Maximum concentrations in the PRD were greatest for the 2002 simulation (maximum of about 40 ppb) and least for the gas option (maximum of about 20 ppb). Local maxima ranged between 83 -119 ppb.

These results imply that the different technologies have little impact on the distribution and maxima concentrations of SO_2 in the PRD region. In addition, the results suggest that not having a new power station may increase SO_2 emissions, due to the operation of all existing (ageing) stations at their maximum capacity (instead of using newer equipment and technology, and decreasing the load on the older stations) and hence a changed diurnal cycle of SO_2 emissions.

5.4 *CONTRIBUTIONS OF A NEW POWER STATION*

The contributions of a new power station were calculated as described in *Section 5.2* and the results described in the following sections.

5.4.1 *NO_2 and O_3*

The peak contributions of NO_2 from a new power station to the maxima occurred at 1300 LT for both coal options and the gas option (see *Table 5.2a*) and were located generally within the local domain. The estimated contributions were approximately 47 ppb for the coal-fired option (about 18% of the maximum concentration), 20 ppb for the coal-fired with De-NO_X option (about 8% of the maximum concentration), and 24 ppb for the gas-fired option (about 10% of the maximum concentration). Hence, it can be deduced that the De-NO_X and gas options can reduce NO_2 emissions by 8-10%. The relatively small percentage contributions suggest that the majority of the NO_2 is from existing sources.

From the regional perspective, maximum NO_2 concentrations in the Pearl River Delta did not occur until 1700LT, at which time the maximum contributions projected were about 1ppb, or 1% of the maximum concentrations, for all New Power Station options, regardless of the technology or fuel used (see *Table 5.2a*).

Findings for O_3 (see *Table 5.2b*) indicated that the new power station would actually reduce O_3 concentrations, although the magnitude of the reductions is small. The greatest reductions occurred at 1700 LT in the Pearl River Delta region for both coal-fired options: 12ppb for the coal-fired option (5% of the maximum concentration); and 4 ppb for the coal-fired with De-NO_X option (1% of the maximum concentration). The maximum reduction of 5 ppb (about 2% of the maximum concentration) for the gas option occurred at 1500 LT.

The decrease in total O_3 concentrations suggests that regardless of which technology or fuel is utilised for the proposed new power station, improvement in O_3 levels are expected. The minor effects of the new power station suggest that most of the O_3 originates from other existing sources.

5.4.2 *FSP and SO_2*

The similarity of the values across each row of *Table 5.3a*, suggest that contributions from a new power station would generally be negligible. It can generally be concluded that both the use of different technologies or fuels has no significant effects on FSP concentrations and hence, visibility.

From the regional perspective, there were no significant contributions of FSP for any of the options (differences of only 1-3 ppb, less than 2% of the maxima, were detected).

The peak contributions of SO_2 (see *Table 5.3b*) from a new power station occurred at 1200 LT for both coal options. The estimated contributions were approximately 27 ppb (about 18% of the maximum concentrations) for both the coal-fired option and the coal-fired with De-NO_x option. The gas option showed no contributions to SO_2 emissions. These results suggest that for SO_2 emissions, there is no difference in the technology used for the coal-fired options, but that there is a significant difference for the fuel used, with gas being the better option.

From a regional perspective, SO_2 contributions of about 12 ppb (7% of maximum concentrations) occurred in the PRD at 1600LT for the two coal options, while no contribution was registered for the gas option.

5.5 SUMMARY

A three-dimensional meteorological and air quality model has been used to examine the regional impact of a new 1800 MW power station on photochemically-produced pollutants in the Territory of Hong Kong. The model was run for the year 2002 (without the New Power Station) and for 2012 (with the new power station). Simulations for both years included the following sources: Chek Lap Kok Airport and the North Lantau Expressway, the Hong Kong urban source centred in Kowloon, a Waste-to-Energy Incinerator situated on Lamma Island, the existing Lamma power station, and the Castle Peak and Black Point power stations. All these sources were assigned the same emissions in 2002 and 2012, in order to isolate any changes arising from the new power station, except for the HEC power station on Lamma Island, for which its emissions differed in both years (to mirror the shifts in loading due to the addition of the New Power Station). In the 2012 simulations, the new power station was situated on Lamma Island. Simulations for 2012 were carried out with the new power station either coal-fired or gas-fired. For the coal-fired scenario, another simulation was done with reduced NO_x emissions due to APC with De-NO_x technology at the new power station.

The meteorological scenario chosen consisted of upper-level southeasterly winds with easterly or east-northeasterly winds nearer the ground. It was considered the worst-case because it optimised the probability of emissions from the New Power Station mixing with photochemically reactive emissions from other known sources, primarily the *urban* source. It was also necessary to ensure that the meteorology was realistic in the Hong Kong context and was conducive to photochemistry. While it could be argued that the null result of this Study implied that the worst-case scenario may not be the worst-case, the scenario was chosen after much careful analysis involving background knowledge of the dynamics of Hong Kong's meteorology and photochemistry. It was the one *most likely* to yield a worst-case, given the general area of the New Power Station. It is highly probable that the general photochemistry conclusions of this Study would not change if any of the other possible sites in the southern region of Hong Kong were chosen for the new station.

It is crucial to acknowledge that the simplicity of the model renders it suitable only for general comparisons of different scenarios and not for an accurate assessment of the scenarios themselves.

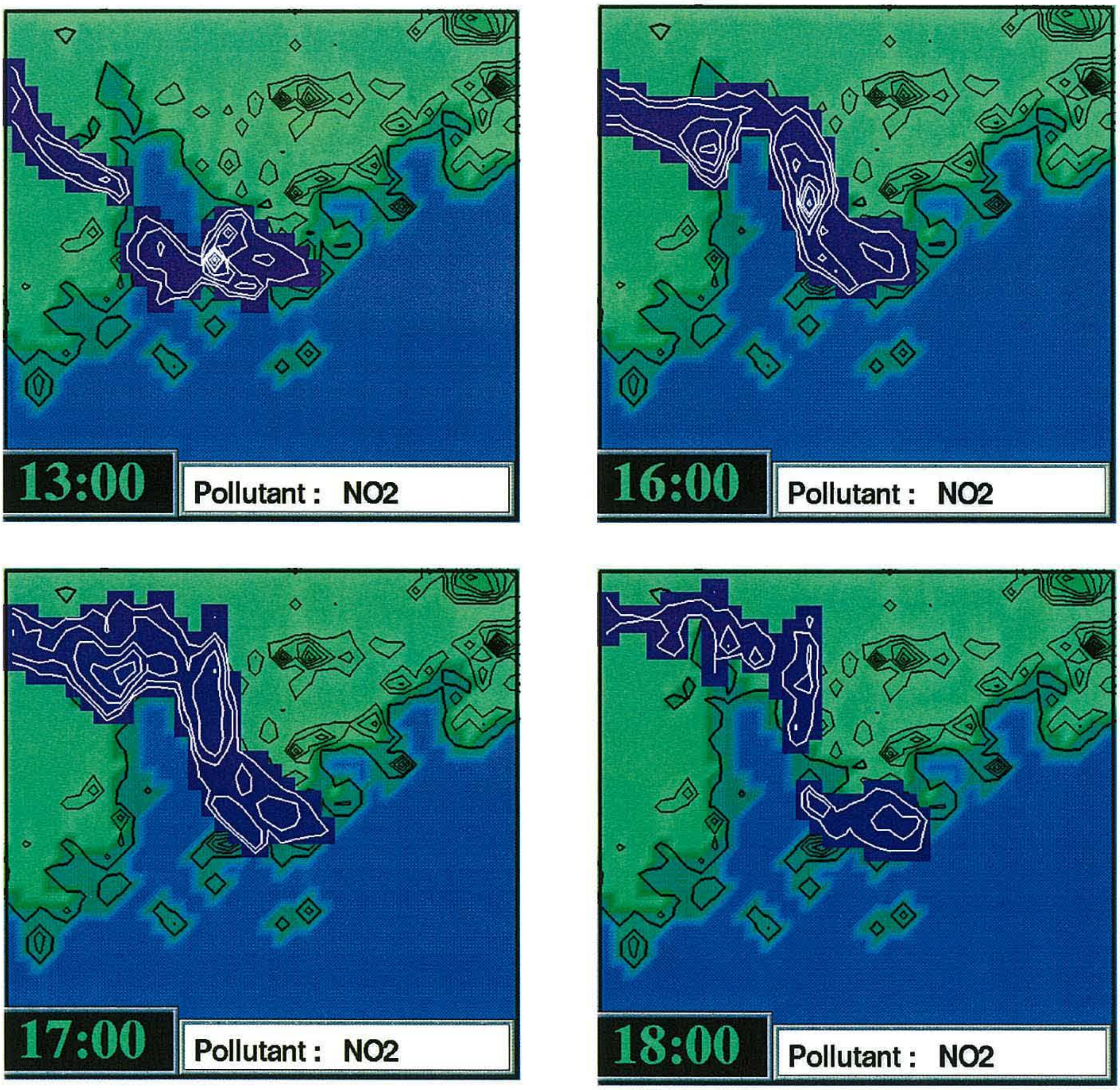


Figure 5.4a: The distribution of NO2 emissions in 2012 from existing sources at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for NO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

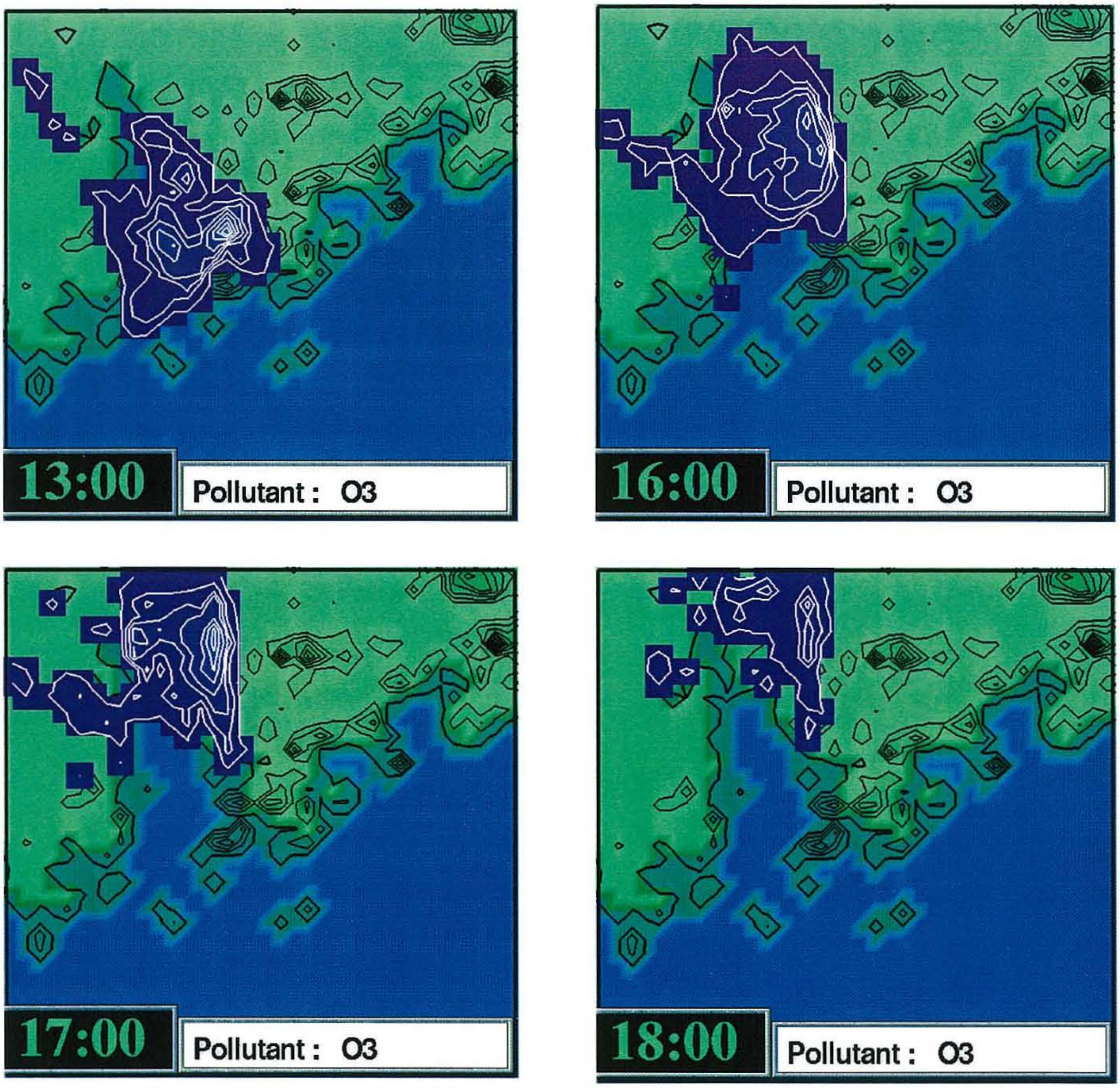


Figure 5.4b: The distribution of O3 emissions in 2012 from existing sources at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

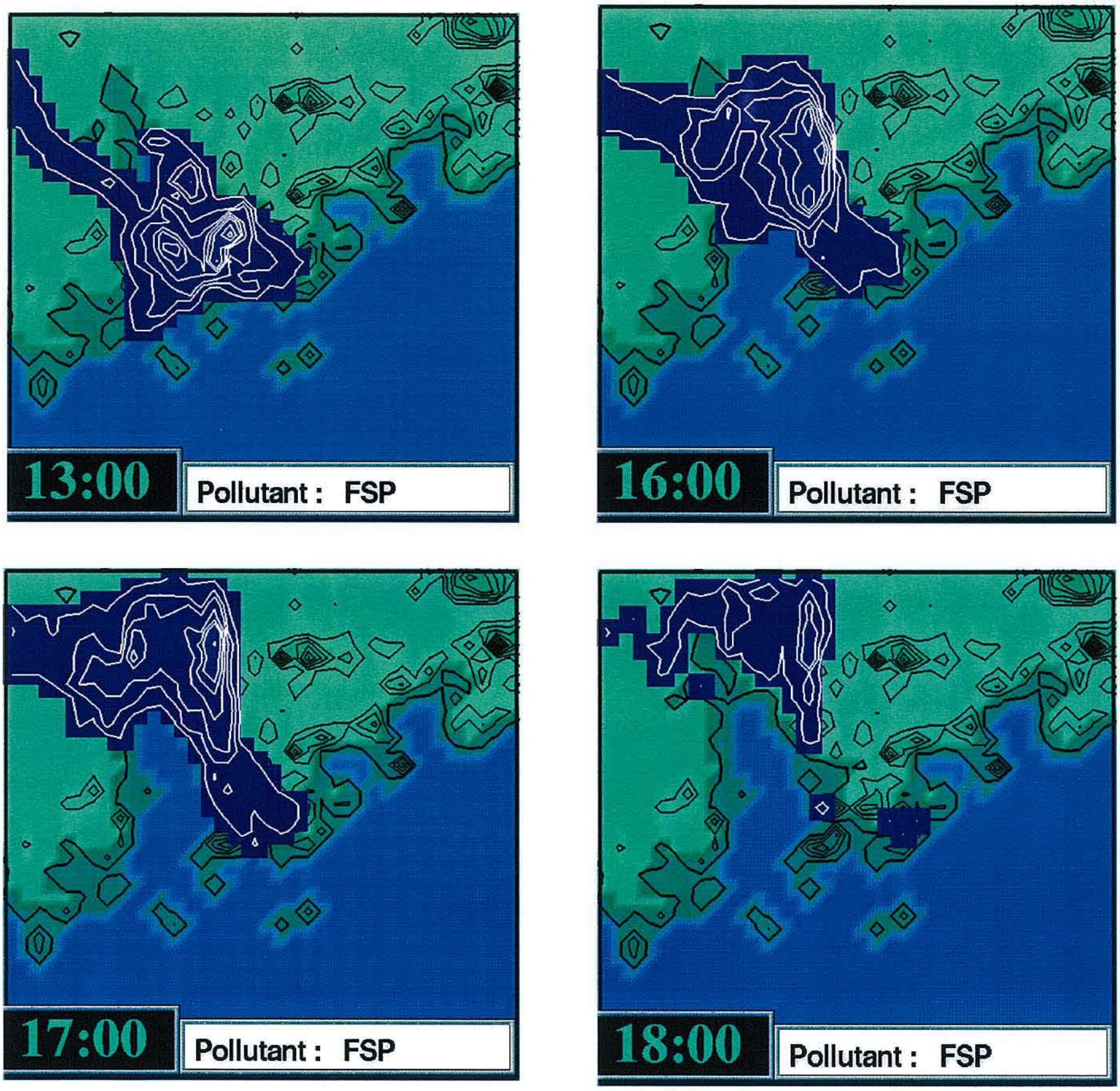


Figure 5.4c: The distribution of FSP emissions in 2012 from existing sources at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for FSP are 20, 30, 40, 60, 80, 100, 150, 200 and 250 μg/m3.

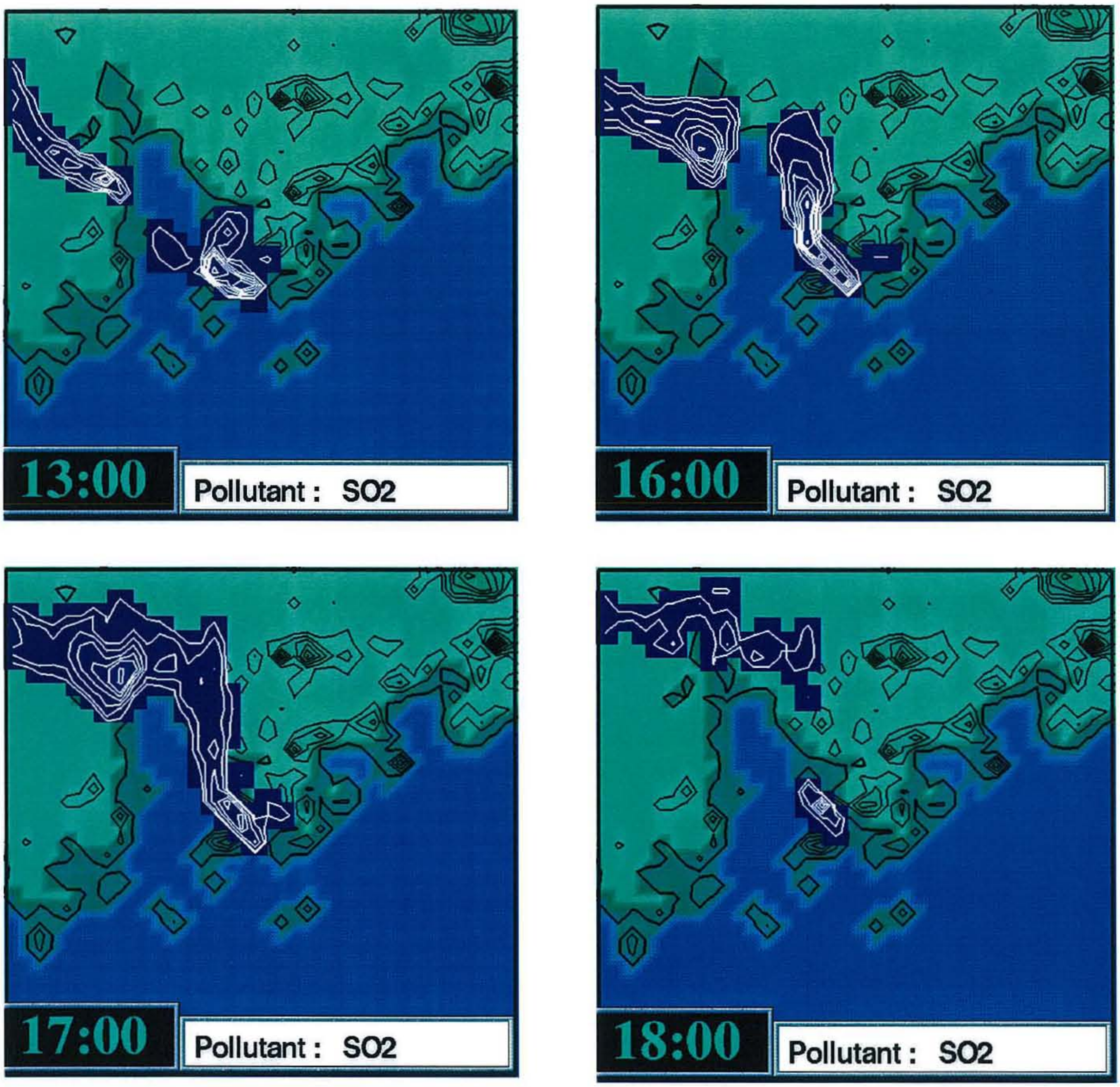


Figure 5.4d: The distribution of SO2 emissions in 2012 from existing sources at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for SO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

The photochemistry on the next day was also simulated for 2012 with the coal-fired option, to address the effect of an extended photochemistry run (48 hours), even though the review of the meteorological conditions had not identified recirculation of pollutants within the PRD region. *Figures 5.2c* and *d* show the predicted NO_2 and O_3 concentrations on the third day. The concentrations observed at 1000 LT, were remnants of the previous day's photochemistry involving sources in the Hong Kong area.

A comparison of the four different simulations (*Figures 5.5a* and *5.5b*), showed that the predicted NO_2 and O_3 concentrations in 2012 generally differed very little from those in 2002 (by less than 10% of their maximum concentrations). This is because these maxima were due almost entirely to the large existing *urban* source and there was little mixing between emissions from the *urban* source and the New Power Station. The difference in concentrations from the use of different fuels or technologies was also small.

In general, O_3 concentrations reached a peak at around 1300 hrs and by 1600 hrs, the plumes were outside the Hong Kong SAR boundary and were concentrated in the PRD region. At 1700 hrs, the plumes from the various sources seemed to have combined over the PRD region but by 1800 hrs, the O_3 plumes had progressed inland and had declined to maximum concentrations of less than 40 ppb.

For the coal-fired 2012 scenario, there were areas where O_3 concentrations were smaller (by less than 10 ppb) in 2012 than in 2002, but the actual concentrations in these areas were less than 40 ppb. There were also regions where O_3 glcs were greater (by about 30 ppb) in 2012.

Some NO_2 consistently remained in the Hong Kong area and it seemed that the major contributor in the region was the *urban* source of emissions. As with the O_3 plumes, the NO_2 plumes had migrated to the PRD region by 1600 hrs but concentrations of about 20-40 ppb remained present in the Hong Kong. At 1700 hrs, the NO_2 concentrations have moved and expanded inland from the PRD and by 1800 hrs, the NO_2 plumes have dispersed to maximum concentrations of 20 ppb and there was complete isolation of the plumes in the Hong Kong and the PRD.

Apart from a minor decrease of about 20 ppb in maximum NO_2 concentrations detected at 1700 hrs in the eastern PRD region, the application of APC with De-NO_X technology in 2012 had no effect as compared to both the 2012 with new coal-fired (without De-NO_X) power station and 2002 simulations. The same general conclusions applied for a gas-fired new power station as for a coal-fired station. However, from 2002 to 2012, a greater decrease in NO_2 and a greater increase in O_3 occurred if the new power station was gas-fired.

Assessments for FSP and SO_2 were also performed although they are considered less relevant in the regional context. Results for FSP show that the maximum concentration for the PRD region occurs at 1700 hrs (see *Figure 5.5c*). Visibility in the PRD region was generally unaffected by the use of the different power generation technologies. Local visibility of about 40-50 km in the Deep Bay region, in the vicinity of the HEC plumes in 2002, was improved in 2012 by about 15 km in the afternoon. This was mainly due to a reduction in SO_2 and particulate emissions in 2012, with a contribution due to a changed diurnal cycle of SO_2 emissions.

For SO_2, maximum concentrations at 1700 hrs for the four options are shown in *Figure 5.5d*. It was indicated that the presence of a New Power Station would decrease SO_2 concentrations in the PRD region as compared to 2002.

Contributions of a new power station to NO_2, O_3 (see *Section 5.4.1*) and FSP (see *Section 5.4.2*) concentrations are generally insignificant. However, the proposed power station does contribute to SO_2 concentrations, but more so in the vicinity of the New Power Station (see *Section 5.4.2*). For NO_2, the greatest contribution to regional maximum concentrations was 1ppb or approximately 1% of maximum concentrations. For O_3, maximum regional contributions ranged between 4 to 12ppb or 1 to 5% of maximum concentrations, with the contribution being the greatest for the coal option. There were no significant regional contributions of FSP for any of the options (differences of only 1-3 $\mu g/m^3$, less than 2% of the maxima, were detected). For SO_2, a regional contribution of up to 12 ppb (7% of the maximum concentration) was projected. No SO_2 contributions were projected for the gas option.

In summary, it can be concluded that additional emissions of nitrogen oxides, from a new power station in the southern area of Hong Kong, would contribute insignificantly to *regional* surface O_3 and NO_2 concentrations under the worst-case scenario modelled. This is irrespective of whether the new station is fired by coal or gas. APC with De-NO_x technology decreases NO_2 concentrations, but increases O_3 concentrations, compared to emissions with no De-NO_x technology, but both are of a very small magnitude. The insignificant differences between the four simulations also apply to FSP and visibility as well. For both FSP and SO_2, there is a very slight decrease in concentrations if the gas-fired option were to be chosen over the coal-fired ones, and for SO_2 predicted concentrations are highest for 2002, before the commissioning of a New Power Station. The contributions of the proposed power station to existing pollutant concentrations are minor because the emissions from an additional power station, when compared to the vast amount of existing emissions in Hong Kong, are small.

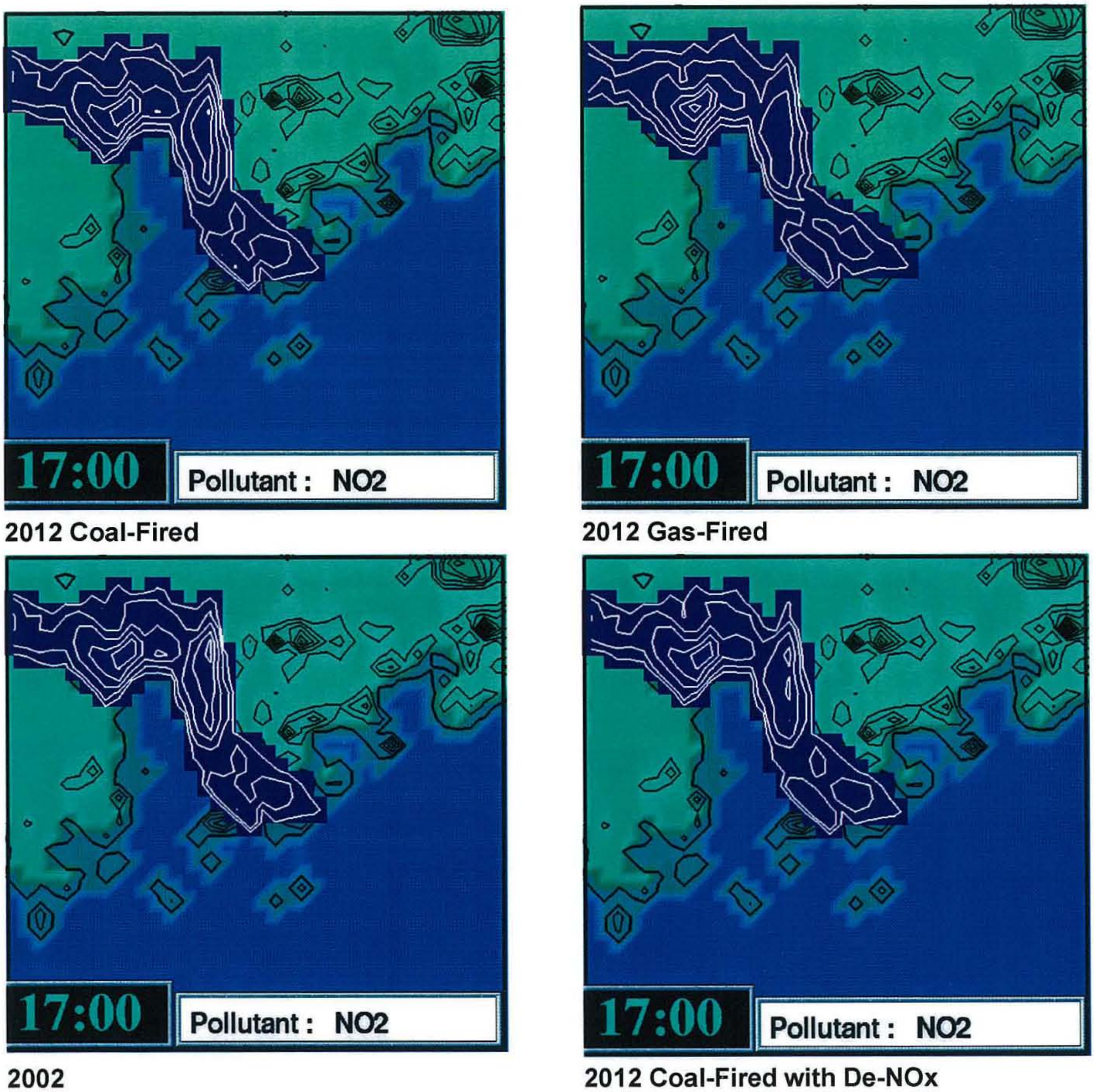


Figure 5.5a: The distribution of NO2 concentrations for all 4 simulations at 1700 LT. Contour values for NO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

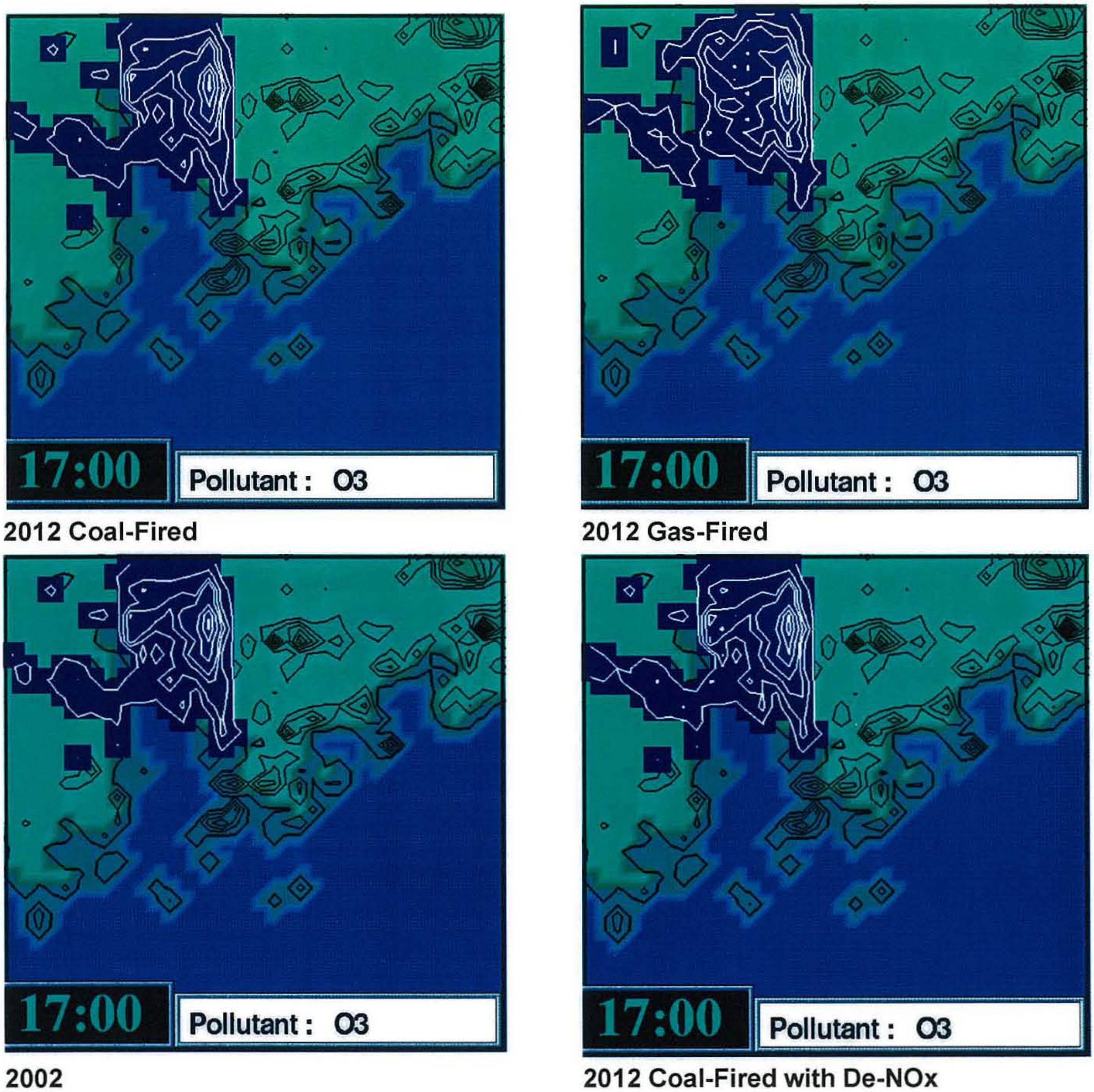
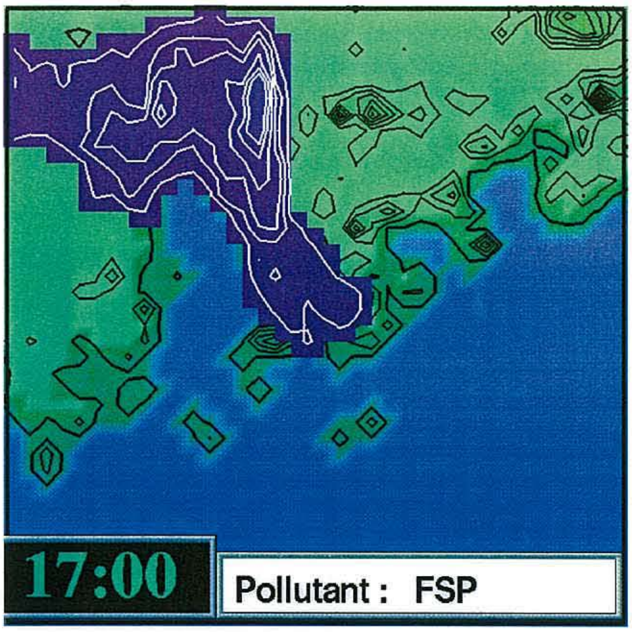
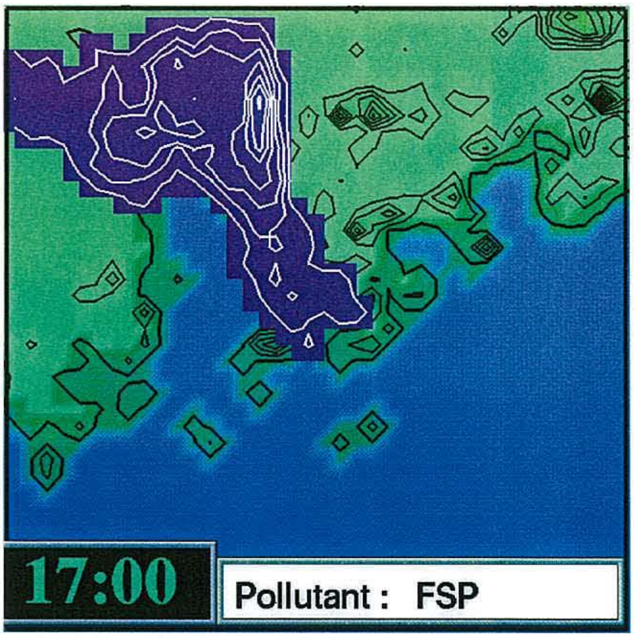


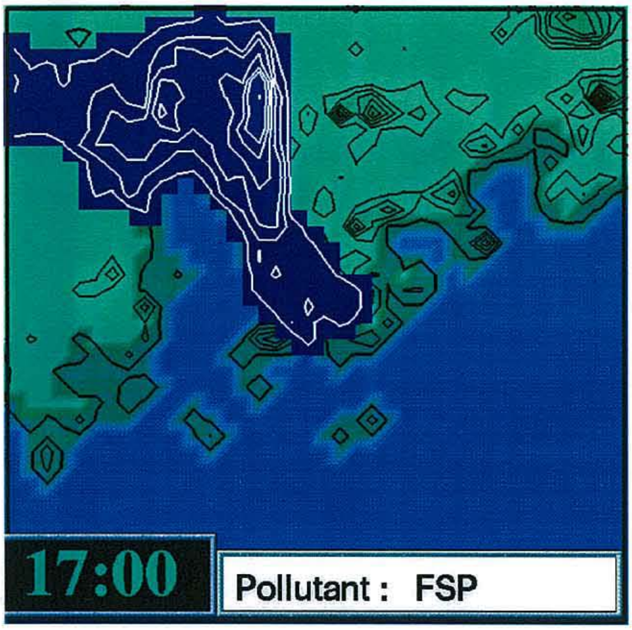
Figure 5.5b: The distribution of O3 concentrations for all 4 simulations at 1700 LT. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.



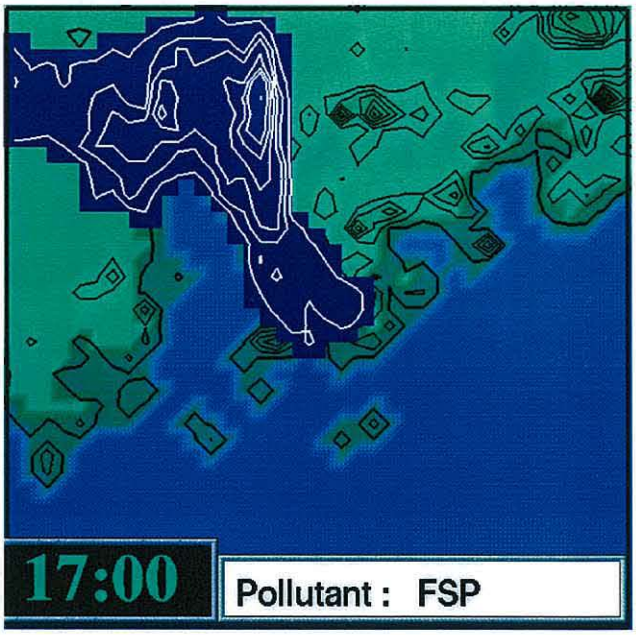
2012 Coal-Fired



2012 Gas-Fired



2002



2012 Coal-Fired with De-NOx

Figure 5.5c: The distribution of FSP concentrations for all 4 simulations at 1700 LT. Contour values for FSP are 20, 30, 40, 60, 80, 100, 150, 200 and 250 µg/m3.

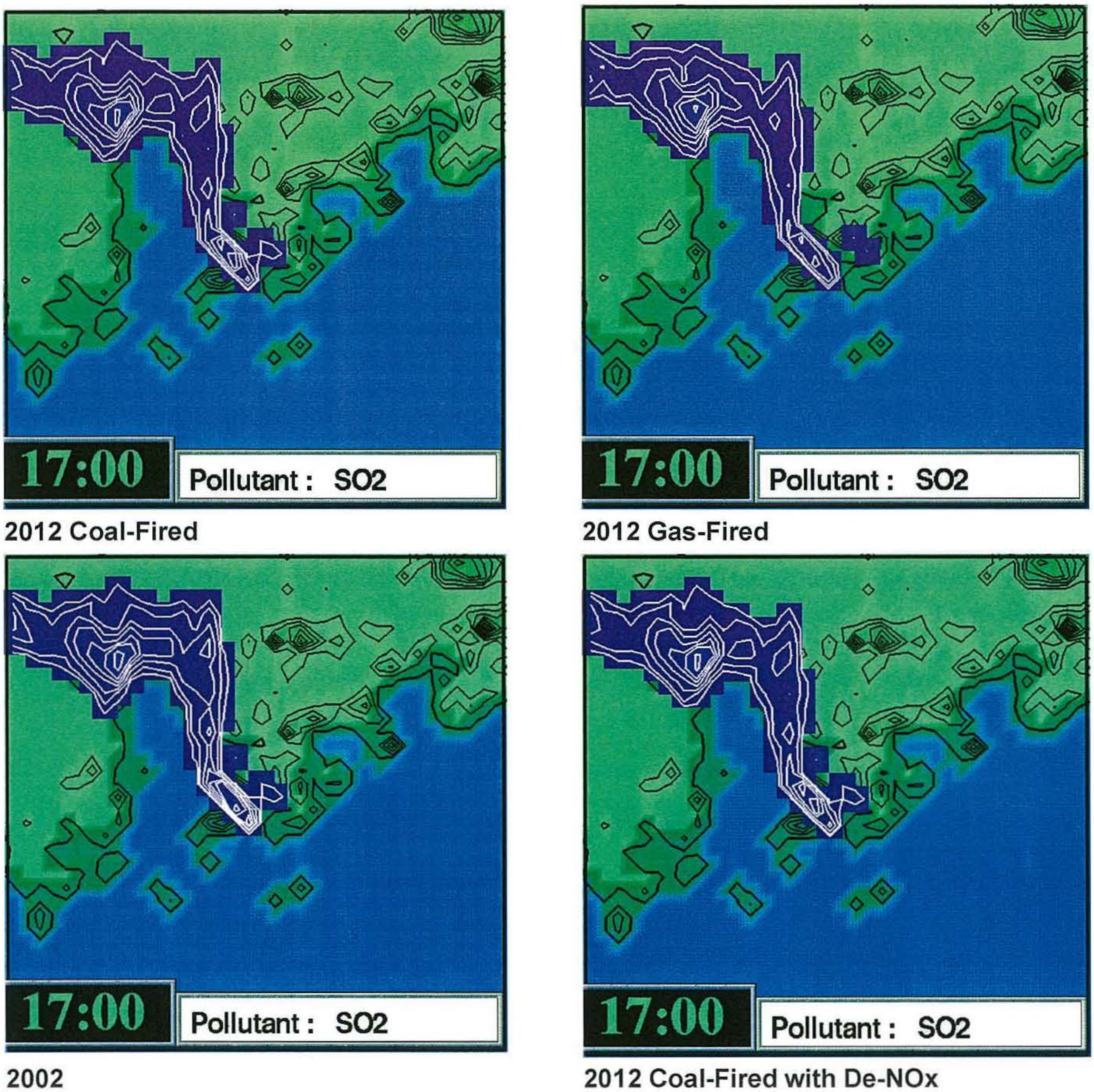


Figure 5.5d: The distribution of SO2 concentrations for all 4 simulations at 1700 LT. Contour values for SO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

6 ANNUAL WET AND DRY DEPOSITION FLUXES

6.1 INTRODUCTION

Gases and particulate matter emitted into the atmosphere by activities such as power generation and transport are reintroduced to terrestrial ecosystems during wet and dry deposition processes. Wet deposition removes pollutants during rain events whereas dry deposition occurs without the intervention of precipitation. Although dry deposition is considered to be less efficient at scavenging gases and particles from the atmosphere, wet deposition is sporadic, and in Hong Kong and the Pearl River Delta, largely confined to the summer period of May to September.

Monitoring by the EPD over the past ten years has established that wet deposition is widespread and relatively uniform across the Hong Kong area (*EPD 1991, Figure 24*). Estimates of dry deposition by *Ayers and Yeung (1996)* point to the dominance of deposition by dry processes in the central regions of Hong Kong due to urban activity. *Ayers and Yeung (1996)* infer a background total acid deposition flux of order 160 $meq/m^2/yr$ with higher values in central regions of Hong Kong.

To assess whether a level of the order of 160 $meq/m^2/yr$ is important, international experience is consulted. The most comprehensive analyses of acid deposition phenomena worldwide are provided by the European (*Hettelingh et al., 1991*), US (*NAPAP, 1991*) and Canadian (*RMCC, 1992*) acid deposition assessment programs. These sources provide a wealth of information too broad to be reviewed here and should be consulted directly if details of the conclusions reached by each of these programs are of interest (see *Appendix A*).

The essential core of the acid deposition issue is not in dispute (*Hettelingh et al., 1991; NAPAP, 1991; RMCC 1992*): anthropogenic emissions of SO_2 and NO_X on a global basis have so perturbed the natural atmospheric sulfur and reactive nitrogen cycles that at some locations the natural inputs/outputs of S and N have been elevated by 1 - 2 orders of magnitude. Since removal of S and N from the atmosphere by wet and dry deposition result in transfer of strong mineral acidity (sulfuric and nitric acids) to the earth's surface, acidification and adverse environmental consequences will follow where the anthropogenically-enhanced acid deposition fluxes exceed the capacity of the surface soils, surface waters and ecosystems to buffer (neutralise) the incoming acidity.

One framework widely adopted for assessing possible consequences of acid deposition is that of comparing measured acid deposition inputs (wet plus dry) with regional 'critical loads', which are in essence the maximum levels of incoming acidity that the surface receptors can buffer in the long term.

Table 6.1a presents the results of critical loads analyses carried out in the European program, whereby five classes of environmental susceptibility to acidification have been defined in terms of critical loads assigned to each environment. These critical loads are evaluated and defined after consideration of locale-specific relevant factors such as parent bedrock material, land-use, soil type and rainfall.

Adverse environmental consequences may then be predicted to occur in the long term (decadal time scales) in any situation where the measured acid deposition for a given location exceeds the assigned critical load for that location. It is important to note that in principle a comprehensive acid deposition assessment should include all input pathways, not only atmospheric acid deposition, but also additional pathways such as fertiliser addition, or production of leguminous crops that fix nitrogen and add mineral/acid nitrate to the soil.

Table 6.1a ***Target deposition levels for European ecosystems according to evaluations by the Stockholm Environment Institute (SEI) and the Coordinating Centre for Effects (CCE), (Chadwick, 1990; see also Hettelingh et al. 1991).***

Relative Sensitivity	Critical Loads ($meq/m^2/yr$ of H^+)	
	SEI	CCE
1	>160	>200
2	160	200
3	80	100
4	40	50
5	20	20

Clearly the properties of European systems cannot be extrapolated to Asian countries; however, it is striking that the total background deposition value of $160meq/m^2/yr$ found by *Ayers and Cheung (1996)* equals or exceeds the critical loads for four of the five sensitivity classes assessed for European ecosystems.

The critical load for a given soil/surface water system can be defined as "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effect on specified elements of the environment do not occur according to our current knowledge" (*Nilsson and Grennfelt, 1988*).

Recently the RAINS-Asia study (*IIASA, 1996*), a major program funded over five years by the World Bank and Asian Development Bank, reported a broad assessment of critical loads for Asia. While based on the methodology adopted in Europe, it is not as thorough as the assessments done there. Nevertheless the study does give a good indication of the state of the science on ecosystem sensitivity for the Asian region. One result is reproduced in *Figure 6.1a* (at the P20 level, up to 20% of each assessed sub-region is as sensitive as indicated in the legend) which claims that the Pearl River Delta is far less sensitive to acid deposition than its surroundings, with a total acid deposition load of over $200meq/m^2/yr$ required before long-term ecosystem change occurs. In contrast, as shown in detail in *Figure 6.1b*, Hong Kong is judged as being particularly sensitive to total acid deposition, with a critical load of approximately 10 $meq/m^2/yr$ at the P20 level. Both the levels and the gradient between grid squares derived in the RAINS-Asia for the region of Pearl River Delta and Hong Kong appear to be highly suspect. These results illustrate the current uncertainty that exists in acid deposition research in the Asian region.

In *Section 6.2*, the acid deposition for Hong Kong is estimated and in *Section 6.3*, attention turns to the Pearl River Delta. *Section 6.4* is a summary of the findings.

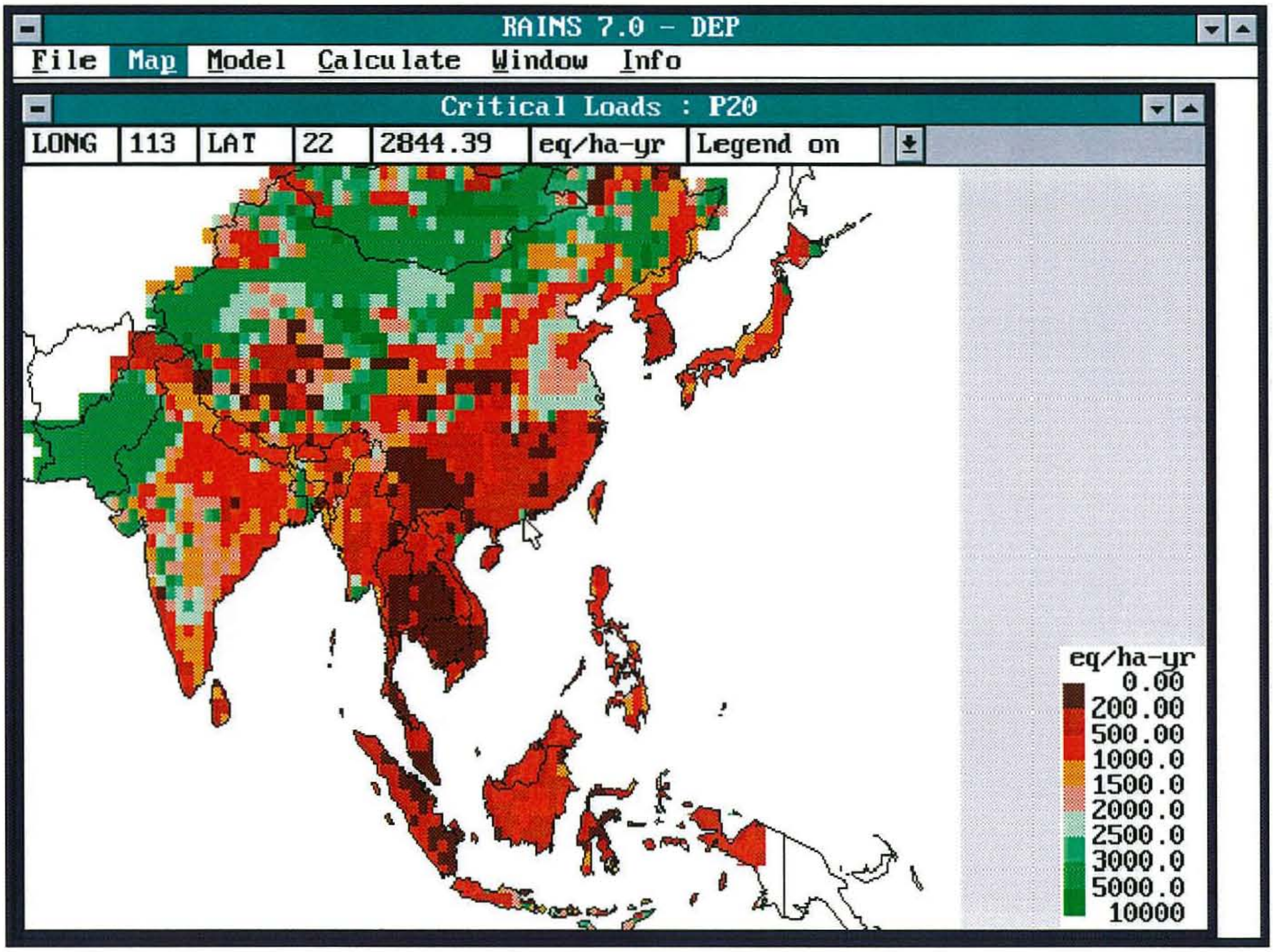


Figure 6.1a Critical Load estimates for the Asian Region (IIASA, 1996). The arrow points to the Pearl River Delta: there the determination is for a critical load of 2,044 eq ha-1 yr-1 200 meq m-2 yr-1 at the P20 level.

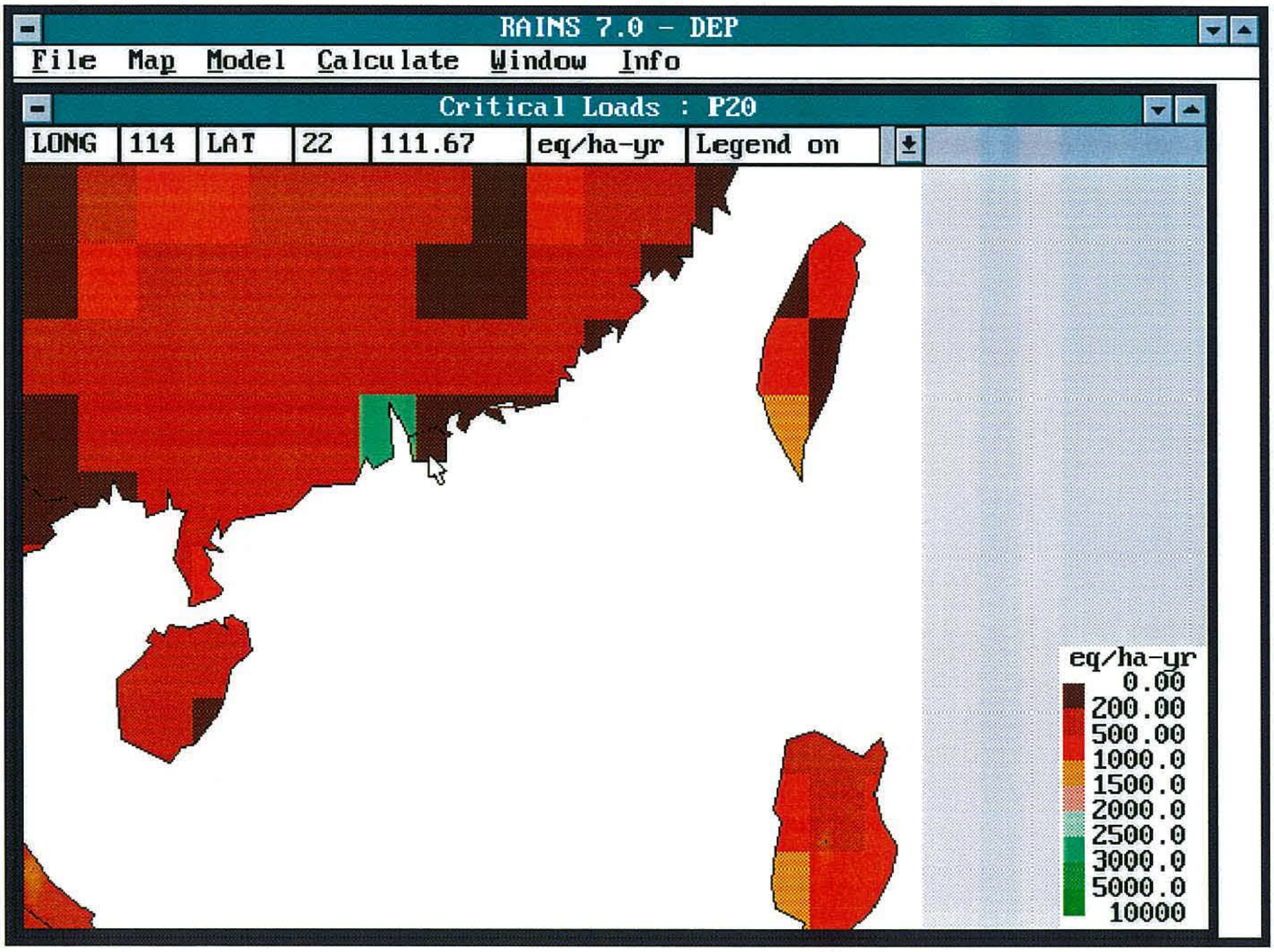


Figure 6.1b Detailed diagram showing critical load estimates for the Hong Kong Region (IIASA, 1996). The arrow points to Hong Kong: there the determination is for a critical load of 112 eq ha-1 yr-1 10 meq m-2 yr-1 at the P20 level.

In conclusion, it is estimated that by 2012, HEC operations under the coal-fired option would contribute no more than 25% of the total acid deposition in Hong Kong and less than 2% in the Pearl River Delta. For the de-NO_X option, the figures are 22% and 1%, and for the gas-fired option 19% and 1% respectively.

6.2 *HONG KONG*

6.2.1 *Approach*

As has been illustrated by the problems with the RAINS-Asia (*IIASA, 1996*) determinations of critical loads for the region, it is a very difficult undertaking to estimate acid deposition impact, let alone the current contribution of the HEC pollutant emissions to it. Estimating how these impacts are expected to change with the introduction of a new plant over 15 years is even more difficult. The approach adopted here is to concentrate on the acid deposition fluxes. Since there is so much uncertainty about how to interpret the results, there is no point in undertaking a comprehensive modelling exercise which in any event would need to cover all conditions over a whole year, not just seeking 'worst case conditions' as is done in the rest of this Report. Not enough is known about the regional emissions of acid gases, surface conditions, nor tropical atmospheric chemistry to do a valid assessment of the total acid deposition. The simplified approach adopted here should only be taken as a guide to the expected deposition, even though it is very powerful in its application of conservation of mass and apportionment principles. The approach is comprised of a number of stages:

1. Determine for a recent year (1995, the only year for which detailed data are available) the total emissions of NO_X and SO_2 for Hong Kong and the fraction that is due to HEC operations.

2. Project these emissions to the years 2002 and 2012.

3. Evaluate total anthropogenic wet deposition from Environmental Protection Department (EPD) measurements. The latest year available with full year measurements is 1993 and the station used is Kwun Tong, since its data have been shown by EPD to be representative of most of Hong Kong: wet deposition is usually well spread and spatially uniform in a region.

4. Estimate dry deposition using data for the same year as wet deposition, viz 1993. Concentrations averaged across the Hong Kong (EPD) monitoring network were used to estimate dry deposition, as there were no other representative data for this purpose. The result is expected to be an overestimate of dry deposition from HEC operations, due to the contributions from other sources. Deposition velocities are taken from Ayers and Yeung (1996).

5. Evaluate the total acid deposition for the year of measurements.

6. Assign to HEC a fraction of the total acid deposition in proportion to its emissions of the relevant gases.

7. Project total acid deposition to 2002 and 2012 in proportion to the changes in emission.

8. Estimate the fraction of the total acid deposition due to HEC emissions in 2002 and 2012 in proportion to its emissions of the relevant gases.

This is a conservative (upper bound) approach with respect to estimating the expected future fraction of acid deposition in Hong Kong due to changes in HEC operations. While increases in emissions due to urban activity in Hong Kong are assumed to be balanced by more stringent vehicle and industrial emission controls, the method does not take into account the much larger emissions that are occurring upwind for much of the year in the Pearl River Delta and the rest of Guangdong Province. These emissions are currently more than twice those from Hong Kong for SO_2 and for NO_X and are likely to increase very significantly by 2012. While possibly less important for dry deposition, they are likely to be a significant contributor to wet deposition in Hong Kong.

6.2.2 *Emissions*

Emissions data are available for 1995 (*Tilly, 1997*) and are summarised in *Table 6.2a*. *Table 6.2a* also summarises emissions data for the year 2002: the new airport is operating (data from EPD) and while urban fuel consumption has grown from 1995, application of existing and proposed controls on emissions were assumed to maintain them at the 1995 level. Emissions data for HEC and CLP are derived from projected coal and gas consumption. Data on a proposed waste-to-energy incineration facility has also been included for this assessment. The increase in HEC emissions reflects a strong growth in projected electricity supply from HEC.

Emissions data for 2012 for three HEC scenarios: with NPS coal-fired, NPS coal-fired with De-NOx, and NPS gas-fired respectively is also summarised in *Table 6.2a*. CLP is taken to operate on a high coal consumption scenario.

Table 6.2a Estimated NO_X and SO_2 Emissions in Hong Kong and the Pearl River Delta (with the New Power Station Operating in 2012)

Source	1995		2002		2012 Coal-fired		2012 Coal-fired with De-NO_X		2012 Gas-fired	
	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr
HK International Airport	3,037	1	-	-	-	-	-	-	-	-
New International Airport Lantau	-	-	7,204	465	7,204	465	7,204	465	7,204	465
Vehicle + Domestic + Industrial Surface	46,106	16,745	46,106	16,745	46,106	16,745	46,106	16,745	46,106	16,745
Town Gas Production Plant	1,366	1,638	1,366	1,638	1,366	1,638	1,366	1,638	1,366	1,638
Waste-to-Energy Incinerator Facility	-	-	4,503	2,810	4,503	2,810	4,503	2,810	4,503	2,810
HEC Total	30,000	25,100	60,234	76,065	49,543	41,217	37,080	41,217	33,807	31,347
CLP Coal	58,676	92,967	33,483	57,379	66,654	125,337	66,654	125,337	66,654	125,337
Total Hong Kong Emissions	139,185	136,451	152,896	155,102	175,375	188,212	162,913	188,212	159,640	178,342
PRC Emissions in the PRD Region[d]	232,500[a]	336,300[a]	1,040,000[b]	1,840,000[b]	1,450,000[c]	2,550,000[c]				

Notes: a - figures are for the year 1993
b - figures are for the year 2000
c - figures are for the year 2010
d - *Researches on Perspective Plan for the Pearl River Delta Economic Region*, Guangdong Province Planning Committee (1995)

6.2.3 *Present Wet Deposition*

Data for 1994 are the most recent data available but do not include wet deposition sampling for the first half of the year (*EPD 1994*). As *eg*, EPD (1991) shows, there can be substantial rain in the April-May period. Therefore, data from the EPD (1993) for the Kwun Tong station was used instead, since it is the latest data available for a full year and data from Kwun Tong are representative of most other stations (*EPD, 1991*).

EPD (1991) also shows that the lowest weighted mean pHs occur either side of the summer period. Only in the summer period are the winds consistently from the south (ie from Lamma Island towards Hong Kong and the mainland). At other times the winds generally have a northerly component, eliminating HEC as a source and strongly implicating sources hours to days upwind, that is sources in Guangdong Province as well as from the New Territories of Hong Kong. The spatial uniformity of the pH readings suggests sources a long way upwind so that the smearing of individual sources has occurred. As shown in *Table 6.2b*, the total wet deposition of acid-base species for 1993 was 140 $meq/m^2/yr$.

Table 6.2b ***Wet deposition monitoring data for Kwun Tong corrected for sea salt (nss-) and summed in total equivalents over the year 1993.***

Species	kg/ha/yr	$meq/m^2/yr$
NH_4^+	5.42	30.1
NO_3^-	10.63	17.1
SO_4^{2-}	39.13	
nss-SO_4^{2-}	33.5	69.9
Cl^-	39.69	
Na^+	22.22	
Ca^{2+}	5.55	
nss-Ca^{2+}	4.7	23.5
Total		*140.6*

6.2.4 *Present Dry Deposition*

Dry deposition occurs via uptake by vegetation, natural surfaces and materials of the acid gases sulfur dioxide, nitrogen dioxide and nitric acid vapour. It is measured as the product of a deposition velocity and the local gas concentration. Thus dry deposition is coincident with the footprint of annual average ground level concentrations of these gases. EPD has measured 'dry deposition' along with wet deposition at several sites. However, the EPD data do not characterise what is currently understood to be the relevant process - their measurement technique captures a vast range of wind-blown materials to an uncharacterised surface that does not act like any actual surface. Hence, the EPD data was not used.

Dry deposition is not uniform across Hong Kong. It is expected to be highest in areas of high gas concentrations such as in urban districts near industrial areas like Tsuen Wan, Kwun Tong and Kwai Chung, and lower in areas of less development such as Junk Bay, Hong Kong South and Tai Po. An average of the gas concentrations for all the stations in the Hong Kong monitoring network was used to estimate dry deposition impacts from HEC operations, as it was assumed to be representative of the entire Hong Kong situation.

The deposition velocity varies strongly with time of day, surface properties and weather conditions. A wide range of values have been reported. Most earlier estimates are highly inaccurate due to a variety of experimental problems, including failure to recognise the diurnal variation. An indication of the diversity of results can be seen in *Figure 6.2a*. No data were reported for tropical Asian conditions.

Ayers and Yeung (1996), in a study of acid deposition in Hong Kong, took as a representative deposition velocity, the average of those inferred from the high quality data of Meyers *et al.* (1991) for US spring, summer and fall conditions. Data from nine sites were used, ranging from grassy meadows to maple, beech and pine forests, to agricultural sites. Ayers and Yeung took the average deposition velocity, 0.36 cm/sec, to be representative of the conditions across the range of land-use conditions in Hong Kong for dry deposition of both SO_2 and NO_2.

The only direct determinations of dry deposition velocity in tropical conditions following current practice that are available for this Report are from an investigation in Petaling Jaya, a mixed commercial, industrial and agricultural region on the outskirts of Kuala Lumpur, Malaysia. Drawing on monitoring data from Malaysian Meteorological Service and Ministry of Environment, evaluated dry deposition velocities as reported by *Manins (1993)* are shown in *Figure 6.2b* for each hour of 1992. The large spread of results reflects the range of meteorological conditions, particularly rain events. Nevertheless, the diurnal cycle is pronounced. An annual average deposition velocity of 0.31 cm/sec for SO_2 was evaluated.

While recognising that the Malaysia value may be correct, the higher dry deposition velocity estimates of *Ayers and Yeung (1996)* are used in this Report. With average SO_2 and NO_2 concentrations for 1993 from EPD data, the sum of total acid dry deposition is 220 meq/m^2/yr as shown in *Table 6.2c*. An addition due to deposition of nitric acid vapour formed in the air from the emissions of NO_X could be included if data were available. The derived value of total acid deposition is likely to be an overestimate, due to use of average ground level concentrations across Hong Kong, most of which are due to local transport, commercial and industrial emissions.

Table 6.2c ***Average acid gas concentration data for Hong Kong (EPD 1993) and estimated acid dry deposition flux for 1993.***

Species	**μg/m^3**	**meq/m^2/yr**
NO_2	50	123.4
SO_2	26	92.2
Total		*215.6*

6.2.5 *Present Acid Deposition and Estimated HEC Contribution*

The present acid deposition sums to approximately 360 meq/m^2/yr, of which approximately 330 meq/m^2/yr is attributable to strong acid flux from combustion products (see *Table 6.2d*). This is a very high level, indicating that mitigation of regional acid gas emissions should be a high priority. Based on their fractional contribution to emissions of acid gases in 1993-5, HEC may have contributed up to approximately 20% of the combustion-related acid deposition in Hong Kong.

Table 6.2d ***Strong acid deposition fluxes and estimated fractional contributions in 1993-95 in Hong Kong due to HEC power generation.***

	Totals ($meq/m^2/yr$)	HEC Fraction ($meq/m^2/yr$)	HEC (%)
Nitrogen species	170.7	36.8	22%
Sulfur species	162.1	29.8	18%
Total	332.8	66.6	20%

6.2.6 *Estimated Acid Deposition in 2002*

Table 6.2e shows that by 2002, HEC operation may be contributing no more than approximately 44% of the combustion-related acid deposition in Hong Kong. Although the contribution to wet deposition from the tail stacks of HEC is expected to be well-spread across Hong Kong, in those parts of the region where direct plume impacts from HEC operations are rare, the total HEC contribution would include only a small dry deposition component. The predictions in are likely very conservative.

Table 6.2e ***Estimated acid deposition in 2002 in Hong Kong and the fraction attributable to HEC.***

	Totals ($meq/m^2/yr$)	HEC Fraction ($meq/m^2/yr$)	HEC (%)
Nitrogen species	187.5	73.9	39%
Sulfur species	184.3	90.4	49%
Total	371.8	164.3	44%

6.2.7 *Estimated Acid Deposition in 2012*

Coal-fired Option

The coal-fired option shows that the combustion-related total acid deposition in Hong Kong is expected to increase by 18% to 440 $meq/m^2/yr$ relative to 2002 for this option. Changes in HEC operations alone are expected to reduce their fractional contribution in 2012 to no more than 25% of the combustion-related total acid deposition in Hong Kong (down from 44% in 2002).

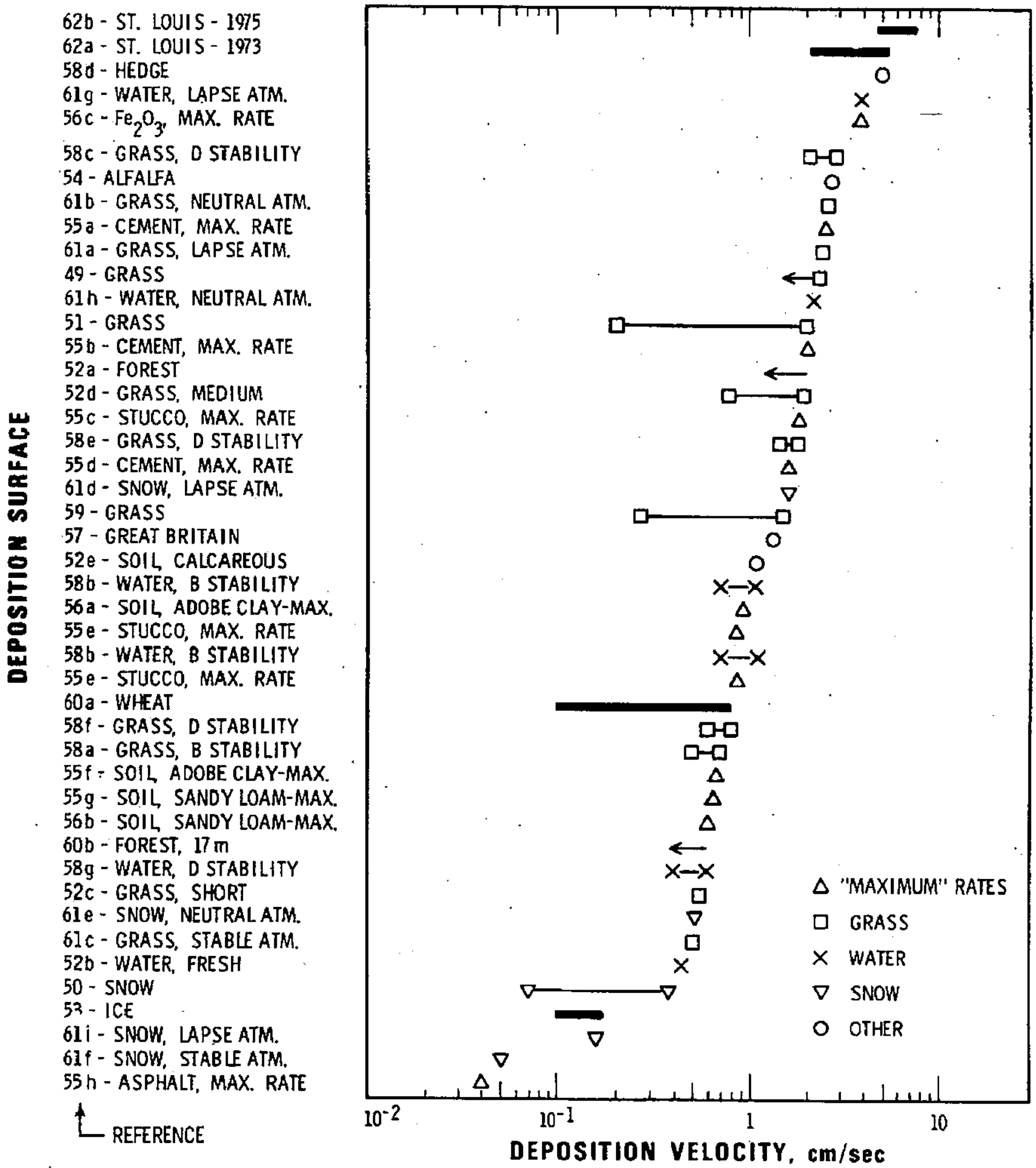


Figure 6.2a Range of deposition velocities for SO2 reported by Sehmel (1980).

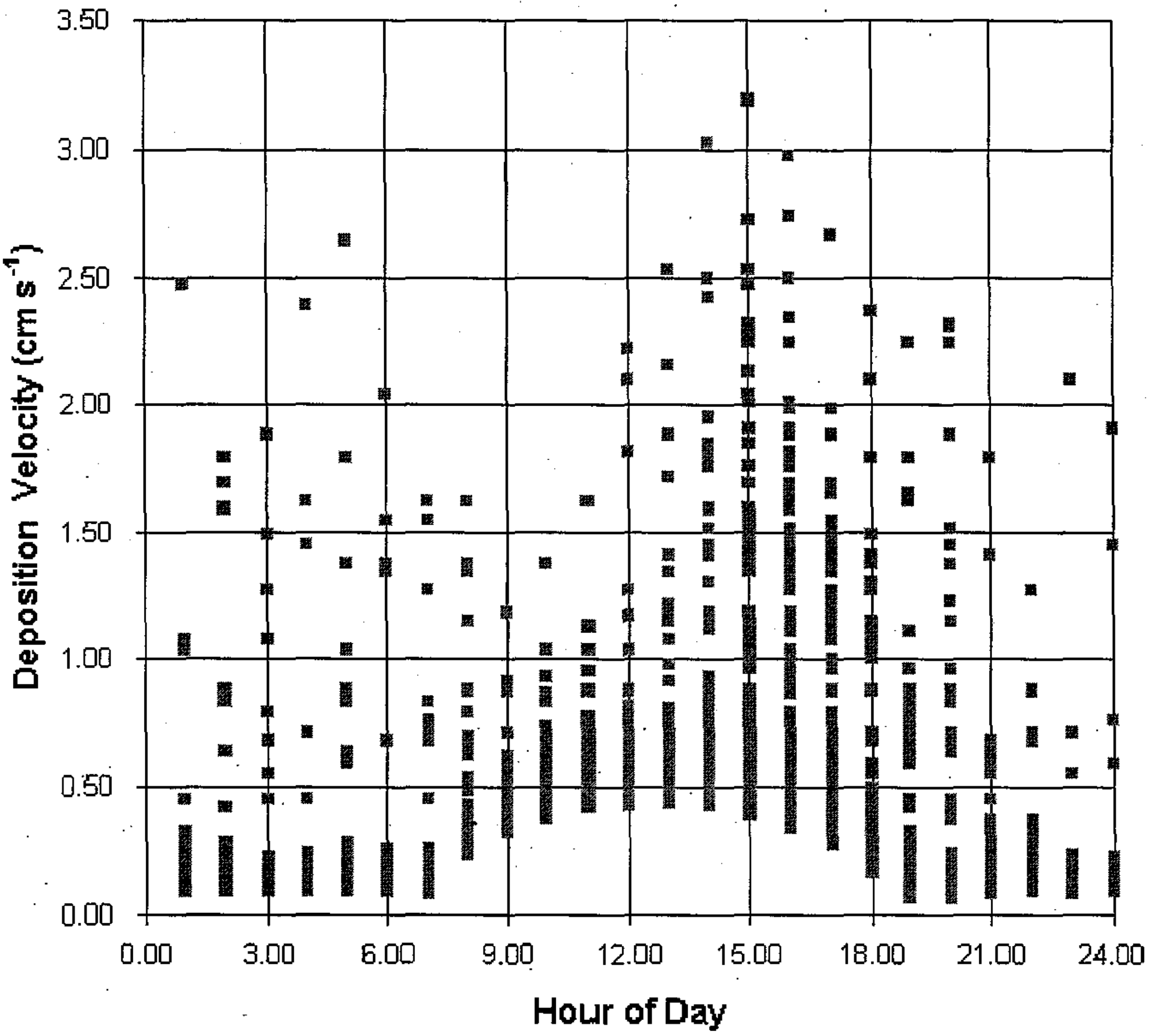


Figure 6.2b 1992 of determined hourly average deposition velocities for SO2 at Petaling Jaya.

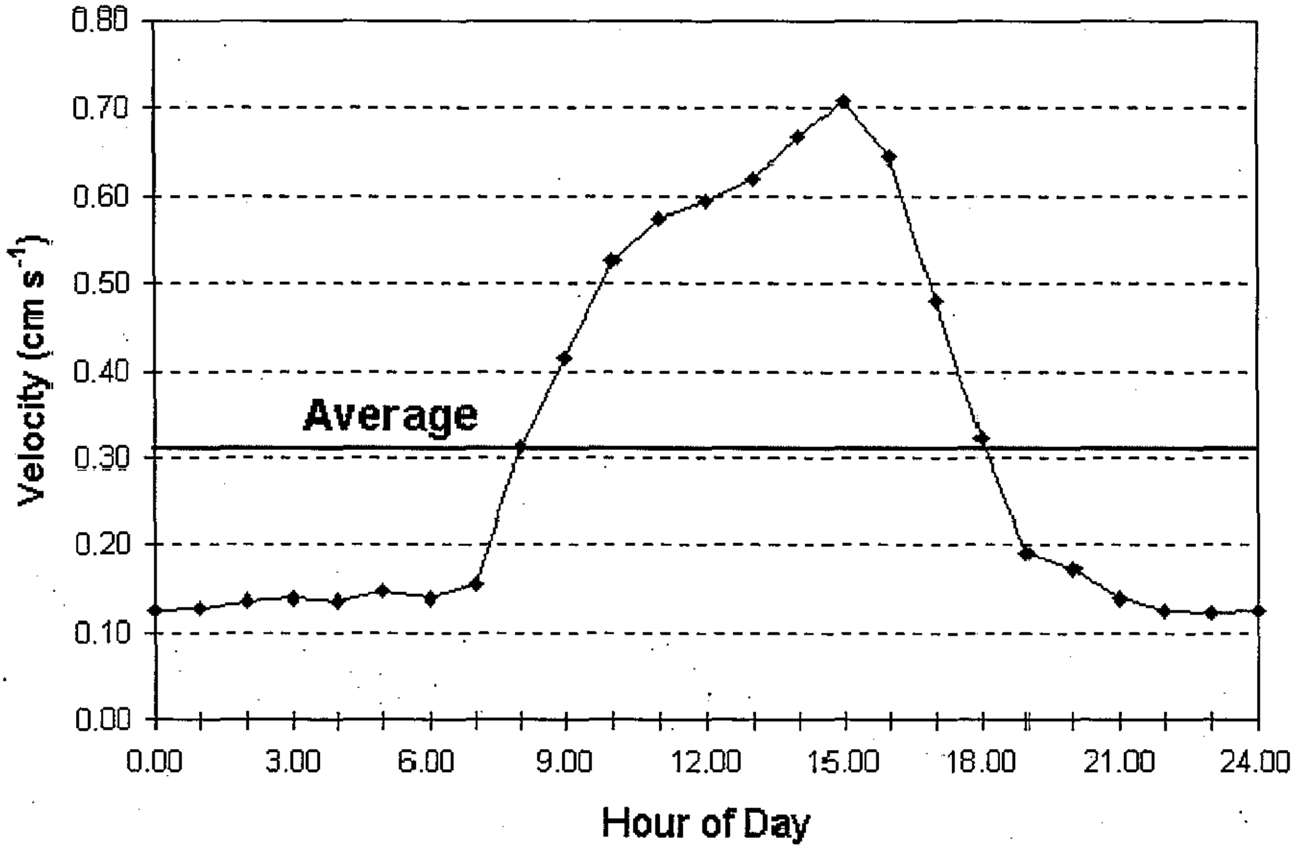


Figure 6.2c Annual average deposition velocity for 1992 for SO2 vs time of day at Petaling Jaya. The diurnal average is 0.31 cm s^{-1}.

Table 6.2f ***Comparison of the estimated acid deposition in 2012 in Hong Kong and the fraction attributable to HEC - coal option with that estimated for 2002.***

	2012 Totals (meq/ m^2/yr)	2012 HEC Fraction (meq/m^2/yr)	2012 HEC (%)	2002 HEC (%)
Nitrogen species	215.0	60.7	28%	39%
Sulfur species	223.6	49.0	22%	49%
Total	438.6	109.7	25%	44%

Coal-fired Option with De-NO_X

Coal-Fired Option with De-NO_X shows that the combustion-related total acid deposition in Hong Kong is expected to increase by 14% to 420 meq/m^2/yr relative to 2002 for this option. Changes in HEC operations alone are expected to reduce their fractional contribution in 2012 to no more than 22% of the combustion-related total acid deposition there (down from 44% in 2002).

Table 6.2g ***Comparison of the estimated acid deposition in 2012 in Hong Kong and the fraction attributable to HEC - coal option with De-NO_X with that estimated for 2002.***

	2012 Totals (meq/m^2/yr)	2012 HEC Fraction (meq/m^2/yr)	2012 HEC (%)	2002 HEC (%)
Nitrogen species	199.8	45.5	23%	39%
Sulfur species	223.6	49.0	22%	49%
Total	423.4	94.5	22%	44%

Gas-fired Option

Relative to 2002, *Table 6.2h* shows that the combustion-related total acid deposition in Hong Kong is expected to increase by 10% to 410 meq/m^2/yr. Changes in HEC operations alone are expected to reduce their fractional contribution in 2012 to no more than 20% of the combustion-related total acid deposition there (down from 44% in 2002).

Table 6.2h ***Comparison of the estimated acid deposition in 2012 in Hong Kong and the fraction attributable to HEC - gas option with that estimated for 2002.***

	2012 Totals (meq/m^2/yr)	2012 HEC Fraction (meq/m^2/yr)	2012 HEC (%)	2002 HEC (%)
Nitrogen species	195.7	41.5	21%	39%
Sulfur species	211.9	37.2	18%	49%
Total	407.6	79.7	20%	44%

A summary of the total acid deposition under the various options for the new power station as compared to 2002, is shown in *Table 6.2i*. *Table 6.2j* summarises HEC impacts on acid deposition in Hong Kong and gives the maximum expected contributions for Hong Kong due to HEC operations and the new HEC power station alone.

Table 6.2i ***Comparison of the total estimated acid deposition for the various power station options with 2002.***

	2002 (meq/m²/yr)	2012 Coal (meq/m²/yr)	2012 Coal with De-NO_x (meq/m²/yr)	2012 Gas (meq/m²/yr)
Nitrogen species	187.5	215.0	199.8	195.7
Sulfur species	184.3	223.6	223.6	211.9
Total	371.8	438.6	423.4	407.6

Table 6.2j ***Estimated maximum percentage contribution by HEC operations to total combustion-related acid deposition in Hong Kong.***

	2002 (meq/m²/yr)	2012 Coal (meq/m²/yr)	2012 Coal with De-NO_x (meq/m²/yr)	2012 Gas (meq/m²/yr)
HEC Operations	44%	25%	22%	20%
HEC New Station	-	8%	4%	2%

6.3 *PEARL RIVER DELTA*

6.3.1 *PRD Policy on Power Station Development*

As one of the fastest growing provinces in China, Guangdong's energy demand has risen sharply in the past decade. The majority of this demand is met by large capacity thermal power stations using coal or oil as a primary fuel. Many of these power plants are located in the PRD region, including:

Shajiao A	Coal	3x200MW + 2x300MW	1987-1993
Shajiao B	Coal	2x350MW	1987
Shajiao C	Coal	3x660MW	1995-1996
Zhujiang I&II	Coal	2x300MW + 2x300MW	1992-1997
Huangpu III	Coal	2x300MW	1989-1990
Huangpu Riming	Coal	1x125MW	1995
Mawan	Coal	2x300MW	1996-1997
Zhuhai I	Coal	2x700MW	1999-2000
Huangpu	Oil	1x125MW	1995
Nanhai I	Oil	2x200MW	1997
Zhongshan	Oil	2x125MW	1997-1998

The power stations listed above represent the major fossil-fuelled power plants either recently built or still under construction. There are additional power stations commissioned in parts of Guangdong Province outside of the PRD, such as at Zhangjiang and Shantou. The total capacity added to the Guangdong grid over the past decade is more than 10,000MW with more stations to be constructed within the next decade, eg Zhuhai Phase II (4x600MW coal) and Taishan (8x660MW coal); the plans for these new power stations have already been approved by the State Planning Committee but the construction schedules have yet to be fixed, dependant as they are upon system demand and the availability of funds.

It should be noted that none of the existing power plants in the province have flue gas desulphurisation (FGD) or NOx control facilities; these factors influence the high level of concern expressed regarding the development of coal-fired power station in the province, particularly in the PRD region where the majority of the power plants are located. The total acid deposition in Guangzhou in the early 1990's was more than five times that of Hong Kong. Retrofitting FGD to the existing power plants is considered to be too capital intensive to be implemented on a large scale, although one or two power plants may be retrofitted with FGD in the near future.

In general, there are no plans to modify existing power plants in the region due to a lack of funding for retrofitting emission control facilities to existing power plants. The interim measure adopted by the Guangdong Power Bureau and the Environmental Protection Bureau is, therefore, to limit the future development of coal or heavy oil fired power plants unless suitable emission control facilities are specified. According to the Guangdong Environmental Protection Bureau[2] "*In principle, no coal-fired power plants shall be built in the PRD region. Starting from this year no thermal power plants of unit capacity 125MW or less shall be built. New power plants of capacity 200MW or above shall be equipped with FGD... Emphasis shall be placed on developing hydro power and nuclear power; some development on oil firing; and to create conditions for development of gas firing.*" The Guangdong Power Bureau is also implementing similar planning guidelines for future power development. Since they presently have surplus capacity in the grid, and there are substantial coal-firing capacities already approved for development within the next decade, the Guangdong Power Bureau is now shifting to gas-firing as well as nuclear technology for future developments.

6.3.2 *Approach*

The only reasonably complete data for wet deposition available were for the city of Guangzhou. From what little data that was available from other cities in the PRD region, it could be deduced that Guangzhou is the major contributor to acid deposition (see *Table 6.3a*). Hence, conditions there were taken to be representative of the whole of the Pearl River Delta.

For dry deposition, acid gas concentrations are summarised in a report by the Guangdong Province Planning Committee (1995) entitled "Researches on Perspective Plan for the Pearl River Delta Economic Region". Similar to the determinations regarding HEC impacts in Hong Kong, which represent upper bounds on the possible impacts on the PRD region, an approach that gives upper bound estimates for PRD is also adopted here.

1. Use reported estimates for the change in emissions in the Pearl River Delta.

2. Evaluate total combustion-related wet deposition from reported measurements in Guangzhou. The latest year available is 1993.

3. Estimate dry deposition using data for the same year as wet deposition for Guangzhou and other cities of the Pearl River Delta.

[2] The 7th Guangdong Provincial Environmental Protection Conference (November 1996)

4. Evaluate the total combustion-related acid deposition for the year of measurements.

5. An upper bound estimate of the percentage contribution by HEC to combustion-related acid deposition in PRD is then the ratio of the contribution in Hong Kong to the determined total deposition in PRD.

6. Project total acid deposition to 2012 in proportion to the changes in emissions from step 1 for the three HEC scenarios.

7. An upper bound estimate of the fraction of the total combustion-related acid deposition due to HEC emissions in 2012 in PRD is then the ratio of the contributions in Hong Kong for the three scenarios to the determined total deposition in PRD.

Table 6.3a ***SO_2 and NO_X emissions in various PRD cities for 1993.***

City	SO_2 (10,000 tonnes)	NO_X (10,000 tonnes)
Guangzhou	15.15	9.58
Shenzhen	0.51	0.99
Zhuhai	0.63	0.39
Dongguan	6.40	5.62
Zhongshan	0.30	0.78
Foshan	6.12	3.46
Jiangmen	2.86	1.74
Huizhou	0.52	0.31
Zhaoqin	1.14	0.38
PRD Total	*33.63*	*23.25*

6.3.3 *Emissions*

Estimates for the Pearl River Delta for the years 1995, 2000 and 2010 are given in Guangdong Province Planning Committee (1995) and are summarised here in *Table 6.3b*. Very large increases are forecasted.

Table 6.3b ***Emissions in Guangdong Province in 1995 and as predicted for 2000 and 2010 (Guangdong Province Planning Committee, 1995).***

Year	SO_2 (tonnes/yr)	Change with ref to 1995 (tonnes/yr)	NO_X (tonnes/yr)	Change with ref to 1995 (tonnes/yr)
1993	336,300		232,500	
2000	1,840.000	447%	1,040,000	347%
2010	2,550,000	658%	1,450,000	524%

6.3.4 *Present Acid Deposition*

Rainfall composition data are available for Guangzhou from Wang *et al.* (1993). Taking the annual rainfall as 1,675 mm for that city, shows that the combustion-related wet deposition of sulfate was approximately 430 meq/m^2/yr and for nitrogen species approximately 290 meq/m^2/yr. Zhu Jiang (1995) reports annual average concentrations of NO_X and SO_2 in Guangzhou. These and the same deposition velocities used for Hong Kong are used here to determine the dry deposition in Guangzhou, as also shown in *Table 6.3c*. Then the total combustion-related acid deposition in the early 1990s in Guangzhou is estimated to have been 990 meq/m^2/yr, a remarkably high result approximately three times as big as for Hong Kong.

Table 6.3c ***Wet and dry deposition determinations for Guangzhou for 1993 using data from Wang et al (1993) and Guangdong Province Planning Committee (1995) and an annual rainfall of 1,675mm.***

Deposition		
Wet Deposition	*meq/l*	*meq/m^2/y*
NH_4	141.1	236
NO_3^-	33.3	56
SO_4^{2-}	254.9	427
Dry Deposition	*µg/m^3*	*meq/m^2/yr*
NO_2	41	102
SO_2	47	167
Total Acid Deposition		*meq/m^2/yr*
Nitrogen species		394
Sulfur species		594
TOTAL		988

As a first approximation and in recognition of the expected widespread distribution of acid rain, the wet deposition results for other cities in the Pearl River Delta are taken to be the same as for Guangzhou. Dry deposition estimates follow from the reported acid gas concentrations. The estimates for total acid deposition for 1993 are summarised in *Table 6.3d*.

Since the HEC contribution to combustion-related acid deposition in the Pearl River Delta can be no more than its contribution to Hong Kong, we take its contribution (estimated in *Table 6.2d*) as 67 meq/m^2/yr, as an upper bound. From *Table 6.3d*, the fractional contribution to acid deposition in 1993-5 in Guangzhou, Shenzhen, Dongguan, Zhonggshan, Jiangmen and Foshan from HEC operations would have been no more than 7%.

Table 6.3d ***Estimated total wet and dry acid deposition for cities in the Pearl River Delta in 1993. Wet deposition is taken to be the same for all cities (720 meq/m²/yr) based on data for Guangzhou, and dry deposition varies according to measured pollutant gas concentrations.***

City	$meq/m^2/yr$
Guangzhou	988
Shenzhen	889
Dongguan	897
Zhongshan	923
Jiangmen	926
Foshan	997

6.3.5 *Predicted Acid Deposition in 2002 and 2012*

The predictions are summarised in *Table 6.3e*. By 2002, emissions of acid gases in PRD are estimated to increase by 450% for SO_2 and by 350% for NO_X so under current development policies, combustion-related total acid deposition is expected to increase to a staggering 4,500 to 5,000 $meq/m^2/yr$ there. By 2012, assuming present plans are fulfilled, the levels in PRD may be as high as 6,200 to 6,900 $meq/m^2/yr$.

For 2002, HEC operations were estimated to contribute an upper bound of 164$meq/m^2/yr$ to Hong Kong and therefore also to the Pearl River Delta. The resulting fractional contribution to acid deposition in 2002 from HEC operations is expected to be no more than 3%.

By 2012, the HEC coal-fired option contributes an upper bound of 110$meq/m^2/yr$ to Hong Kong and therefore also to the Pearl River Delta. The resulting fractional contribution to acid deposition in 2012 from HEC operations if the coal-fired option is utilised, is expected to be no more than 2%.

The HEC coal-fired option with De-NO_X would contribute an upper bound of 94$meq/m^2/yr$ to Hong Kong and therefore also to the Pearl River Delta. The resulting fractional contribution to acid deposition in 2012 from HEC operations if the coal option with De-NO_X is utilised, is expected to be no more than 1%.

For the HEC gas-fired option, an upper bound of 79 $meq/m^2/yr$ would be contributed to Hong Kong and therefore also to the Pearl River Delta. The fractional contribution to acid deposition in 2012 from HEC operations if the gas-fired option is utilised, is expected to be no more than 1%.

Table 6.3e ***Estimated maximum contribution by HEC operations to total combustion-related acid deposition in the Pearl River Delta (using the Mass-ratio Method).***

	2002	2012 Coal	2012 Coal with De-NO_X	2012 Gas
Total Acid Deposition ($meq\ m^{-2}yr^{-1}$)	164	110	94	79
Percentage Contribution (%)	3%	2%	1%	1%

6.3.6 *Acid Deposition for Pearl River Delta Based on Worst-Case Modelling*

We can use the predictions of earlier prognostic modelling sections to make alternative estimates of the contribution to changed HEC operations in 2002 and 2012 to acid deposition in the Pearl River Delta. The results, summarised in *Table 6.3f*, are about half those presented in *Tables 6.2e-h*, consistent with the very conservative approach for the latter of using areawide estimates of dry deposition in Hong Kong. The approach generally followed here for estimating maximum likely contributions by HEC operations to combustion-related acid deposition in PRD and Hong Kong may overestimate the HEC contributions by this same factor of two.

Take for example the 2012 coal-fired option. The maximum wet deposition in PRD due to HEC operations will be no more than that in Hong Kong, viz 38meq/m^2/yr. To estimate the HEC contribution to dry deposition, proceed as follows.

The prognostic modelling shows that ground level concentrations of NO_2 in the PRD at distances of Guangzhou due to HEC emissions reach 70 ppb for no more than two hours of the modelled day. The concentrations there are zero for the rest of the day. Analysis of three years of Hong Kong Observatory meteorological data shows that winds with an easterly to southerly direction (viz, those winds capable of carrying HEC emissions to the PRD) occur on only 33% of days. So the annual average ground level concentrations in 2012 in PRD due to HEC emissions are expected to be 70 x 2 x (0.33/24) = 1.9 ppb. Then the dry deposition of NO_2 is expected to be 9 meq/m^2/yr. Similarly for SO_2 the estimated dry deposition is expected to be 15 meq/m^2/yr. So the acid dry deposition in PRD due to HEC operations with NPS coal-fired in 2012 is expected to be no more than 24 meq/m^2/yr. The total acid deposition is then no more than 62 meq/m^2/yr with a fractional contribution of 1% to the projected acid deposition in Guangzhou.

Table 6.3f ***Derivation of maximum percentage contribution by HEC operations to total combustion-related acid deposition in Pearl River Delta (using the Worst-case Modelling Method).***

	2002	2012 Coal	2012 Coal with De-NO_X	2012 Gas
Maximum Wet Deposition (meq/m^2 yr)	59	38	34	28
Max Annual Average NO2 (ppb)	2.5	1.9	1.4	1.1
Max Annual Average SO2 (ppb)	3.1	1.6	1.5	1.0
Max Dry Deposition (meq m^{-2} yr^{-1})	40	24	20	14
Total Acid Deposition (meq m^{-2} yr^{-1})	99	62	54	42
Max HEC Contribution to Acid Deposition	2%	1%	1%	1%

6.4 SUMMARY

Future acid deposition in the region was estimated based on the projected emissions for the assessment years and the likely contribution from HEC's power stations under two different assumptions. The results indicated that the large emissions within the whole PRD have a high potential to cause acid deposition problems. However, it should be noted that the contribution from HEC is relatively minor under different emission scenarios in the year 2012. The proposed new power station will help to reduce the overall acid deposition to the region by about 1% and the contribution of the new power station is negligible in the context of the marked increases in emissions from the whole PRD region.

Annex A

Results For 2 km Simulations

ANNEX A

RESULTS FOR 2 KM SIMULATIONS

More accurate results were obtained for local photochemistry in the 2 km grid simulations. *Tables 1* to *4* show maximum concentrations of NO_2, O_3, FSP and SO_2 respectively, for the 2 km simulations.

Table 1: Maximum concentrations of NO_2 (ppb) for 2 km simulations.

Time	2002	2012 Coal	2012 Coal with de-NO_X	2012 Gas
0300	38	38	38	38
0400	41	41	41	41
0500	44	44	44	44
0600	45	45	45	45
0700	61	61	61	61
0800	99	99	99	96
0900	160	160	160	170
1000	384	384	384	326
1100	293	293	293	315
1200	123	128	116	116
1300	137	131	126	114
1400	130	129	123	120
1500	54	54	51	68
1600	66	66	63	68
1700	83	75	72	67
1800	44	43	41	37
1900	39	39	39	41
2000	39	39	39	40
2100	39	39	39	39
2200	39	39	39	39

Table 2: Maximum concentrations of O_3 (ppb) for 2 km simulations.

Time	2002	2012 Coal	2012 Coal with de-NO_X	2012 Gas
0300	33	33	33	33
0400	33	33	33	33
0500	33	33	33	33
0600	33	33	33	33
0700	33	33	33	33
0800	35	35	35	35
0900	43	43	43	42
1000	84	84	84	97
1100	155	155	155	384
1200	227	227	227	230
1300	230	230	230	198
1400	181	181	181	181
1500	145	145	145	139
1600	127	132	133	113
1700	84	84	85	69
1800	37	37	37	45
1900	33	33	33	33
2000	33	33	33	33
2100	33	33	33	33
2200	33	33	33	33

Table 3: Maximum concentrations of FSP ($\mu g/m^3$) for 2 km simulations.

Time	2002	2012 Coal	2012 Coal with de-NO_X	2012 Gas
0300	29	29	29	29
0400	37	37	37	37
0500	46	46	46	46
0600	53	53	53	53
0700	63	63	63	63
0800	86	86	86	84
0900	133	133	133	131
1000	274	274	274	239
1100	224	224	224	283
1200	153	153	153	158
1300	140	140	140	125
1400	101	101	101	103
1500	82	82	82	79
1600	104	107	108	79
1700	62	58	58	55
1800	32	29	29	30
1900	29	29	29	36
2000	30	30	30	33
2100	31	31	31	31
2200	30	30	30	31

Table 4: Maximum concentrations of SO_2 (ppb) for 2 km simulations.

Time	2002	2012 Coal	2012 Coal with de-NO_X	2012 Gas
0300	24	24	24	24
0400	39	39	39	39
0500	53	53	53	53
0600	64	64	64	64
0700	68	68	68	68
0800	78	78	78	77
0900	123	115	115	101
1000	348	181	181	169
1100	332	156	155	130
1200	355	297	297	201
1300	289	250	249	191
1400	258	235	235	228
1500	363	251	251	188
1600	443	284	284	214
1700	439	288	288	233
1800	203	104	103	82
1900	24	24	24	35
2000	26	26	26	32
2100	29	29	29	28
2200	27	27	27	28

Tables 5 to 8 maxima and minima differences between various simulations.

Table 5: For meteorological scenario 1, maxima and minima of differences between hourly-averaged ground-level concentrations for the 2012 simulation with a coal-fired New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.

Hour	O_3 (ppb)		NO_2 (ppb)		FSP (μg m^{-3})		SO_2 (ppb)	
	min	max	min	max	min	max	min	max
0600	0	0	0	0	0	0	0	0
0700	0	0	0	0	0	0	0	0
0800	0	0	0	0	0	0	0	0
0900	-9	7	-11	10	-7	1	-81	4
1000	-7	14	-18	8	-19	1	-248	1
1100	-2	8	-11	2	-16	1	-207	1
1200	-4	4	-6	5	-8	1	-112	0
1300	-3	6	-6	4	-9	1	-81	15
1400	-5	5	-6	6	-7	5	-60	20
1500	-4	4	-4	5	-13	6	-134	13
1600	-3	7	-8	3	-20	7	-197	14
1700	-2	7	-10	3	-11	2	-151	13
1800	-3	4	-3	4	-16	2	-50	20

Table 6: For meteorological scenario 1, maxima and minima of differences between hourly-averaged ground-level concentrations for the 2012 simulation with APC with De-NO_x technology at the New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.

Hour	O_3 (ppb)		NO_2 (ppb)		FSP (μg m^{-3})		SO_2 (ppb)	
	min	max	min	max	min	max	min	max
0600	0	0	0	0	0	0	0	0
0700	0	0	0	0	0	0	0	0
0800	0	0	0	0	0	0	0	0
0900	-3	10	-16	3	-6	1	-82	3
1000	-1	16	-20	1	-19	2	-248	1
1100	-1	9	-15	1	-16	1	-208	0
1200	-1	6	-10	1	-7	1	-113	0
1300	-1	11	-11	0	-8	2	-82	14
1400	-1	7	-8	1	-7	3	-61	20
1500	-2	5	-5	1	-13	6	-134	13
1600	-1	9	-9	1	-20	8	-197	14
1700	-1	9	-11	1	-8	7	-151	13
1800	-1	6	-5	1	-8	3	-50	20

Table 7: For meteorological scenario 1, maxima and minima of differences between hourly-averaged ground-level concentrations for the 2012 simulation with the APC with De-NO_x technology at the New Power Station and for the 2012 simulation without the new technology. Positive values indicate that concentrations are higher for the simulation with the new technology.

Hour	O_3 (ppb)		NO_2 (ppb)		FSP (µg m^{-3})		SO_2 (ppb)	
	min	max	min	max	min	max	min	max
0600	0	0	0	0	0	0	0	0
0700	0	0	0	0	0	0	0	0
0800	0	0	0	0	0	0	0	0
0900	0	8	-11	0	0	1	-1	0
1000	0	8	-11	0	0	1	-1	0
1100	0	6	-8	0	0	1	-1	0
1200	0	10	-12	0	0	2	-1	0
1300	0	6	-7	0	0	2	-1	0
1400	0	6	-6	0	-4	2	-1	1
1500	0	3	-4	0	-6	1	-1	1
1600	-1	4	-4	0	-1	1	-2	0
1700	0	6	-5	0	-3	4	-1	1
1800	0	3	-3	0	-6	2	-1	1

Table 8: For meteorological scenario 1, maxima and minima of differences between hourly-averaged ground-level concentrations for the 2012 simulation with a gas-fired New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.

Hour	O_3 (ppb)		NO_2 (ppb)		FSP (µg m^{-3})		SO_2 (ppb)	
	min	max	min	max	min	max	min	max
0600	0	0	0	0	0	0	0	0
0700	0	0	0	0	0	0	0	0
0800	0	0	0	0	0	0	0	0
0900	-9	9	-13	10	-12	0	-110	0
1000	-2	17	-22	2	-27	1	-305	0
1100	-1	11	-18	2	-21	0	-252	1
1200	-4	6	-11	5	-17	0	-164	0
1300	-5	18	-19	6	-25	1	-107	2
1400	-5	14	-15	6	-9	1	-87	5
1500	-5	6	-6	6	-17	3	-175	18
1600	-2	4	-5	3	-25	16	-252	7
1700	-4	9	-11	3	-15	2	-228	16
1800	-8	4	-5	2	-11	0	-84	18

Annex B

References

ANNEX B

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Annex C

Responses to Comments

Response to Comments
Stage 1 EIA for a New Power Station:
Draft Technical Paper on Pearl River Delta Air Quality Assessment

No.	Department	Reference	Comments	Consultants' Response
1	Environmental Protection Department dated 6 August 1997	EP1/G/160 VI	General Comments The technical paper on Pearl River Delta Air Quality Assessment is not acceptable. The study brief requirements [see section 2.2, 5.3, 7(g), 8.3(k) of the study brief] are to address environmental impacts on a regional scale (i.e. the whole of Pearl River Delta). But the technical paper has focused primarily on the impact within the Hong Kong Territory with only very limited coverage on air quality impact in the rest of the PRD region (discussing only in very broad and simple terms with very little references on PRC's information) which is far from enough to satisfy the study requirements.	It is possible to re-run the photochemical simulations on the 5-km spacing grid under one meterological scenario for comparison, which contains the whole Pearl River Delta. However, these supplementary model runs will not be as accurate as for the 2 km grid. Results of this coarse grid modelling will be presented in a supplementary report. See also Consultants' response to Comment 3a.
2			In particular, what we have repeatedly been asking HEC/ERM to address [in our meeting with HEC (13.1.97), comments on draft inception report (21.2.97), comments on ERM's proposed modelling approach (4.4.97), 1st SMG meeting (26.2.97) and 2nd SMG (28.4.97)] on policy moratorium on power station in the PRD region which are essential for the administration to consider is still not covered.	Please refer to the attached summary of the power station development in the PRD region.

No.	Department	Reference	Comments	Consultants' Response
3			The modelling assessment in the technical paper is also not acceptable:	
			a. Though the CLP's (at Black Point and Castle Peak) and HEC's plumes do not merge within the spatial domain (basically Hong Kong Territory) shown in the paper for the scenarios considered (section 5.1, page 71), they may do so further downwind and can potentially create a photochemical problem further north into within the PRD. Hence the consultants should include all these plumes (i.e. including the Black Point and Castle Peak sources) to simulate these effects. The duration of the run (section 2.1.1, page 4) should be extended to simulate photochemistry on the next day or such time as appropriate to ensure that the effects of the sources are simulated. This is necessary to assess the impact on the photochemistry within the PRD.	CLP's Black Point and Castle Peak sources will be added to simulate the photochemical effects of these sources, as suggested by EPD. However, this will be done for one meteorological scenario only as the modelling results under the two worst-case meterological scenarios are very similar. An extensive analysis of 3 years of Hong Kong Observatory wind data has not found any synoptic situation whereby Hong Kong elevated emissions can be recirculated within the Pearl River Delta. The prognostic model utilised is not designed to run for more than 48 hours, as the solution on the third day begins to be affected by errors propagating from the boundary conditions. Winds on a third day should be treated with caution. However, we will be pleased to review the potential photochemical oxidation that may occur on the morning of the third day. It should also be noted that for the type of day we have simulated, there is no recirculation of emissions within the Pearl River Delta from one day to the next.
			b. The "pragmatic" approach (section 6.2, page 105) to estimating HEC's contribution to the overall acid loading in the PRD is inadequate in that the relative spatial distribution (which can be readily determined using simple modelling tools) cannot be estimated.	We have provided a revised Section 6 during the working group meeting on 8 August 1997 to address HEC's contribution to the acid loading in the PRD region.
4			In presenting the modelling results as pollution contour, the consultants should present the complete picture including, but not limited to, pollution contour covering the domain including the PRD under the various scenarios (e.g. including year 2002 modelled. Based on the modelling results, the consultants should assess the contribution of HEC's emission, using different technologies, on the air quality in PRD. From the best available information, and based on their professional judgement, the consultants should appraise the implications of HEC's proposed new power station in the context of the existing and future air quality problems over PRD.	Noted.

No.	Department	Reference	Comments	Consultants' Response
5			Notwithstanding our comments in item 3, the modelling assessment indicated cases of AQO exceedance (O_3) within the Hong Kong's Territory which warrant more detailed discussions and attention in the paper and in the final report. The consultants should highlight those cases in the paper (both in the sections on photochemistry and in the summary) with detailed information (e.g. the actual predicted concentration figures, % above the AQO limits, the locations where such exceedances occurred, etc.)	Noted. For this Study, the only concern should be the impact on air quality of emissions from HEC's proposed power station.
6			Furthermore, the effect of HEC's emissions on Hong Kong's photochemistry should not be confined to the immediate effect due to direct plume impingement. Pollutants can be advected away from Hong Kong only to be brought back due to the shifting wind directions. When assessing HEC's impact on Hong Kong, all pollution sources from Hong Kong must be included and allowed time to merge and subsequently brought back to Hong Kong.	The Consultants are aware of this and it is the reason that an extensive data analysis and many preliminary model simulations were carried out. These were reported in the Working Paper, concluding that the chosen scenarios were the worst-case and that recirculation of HEC emissions is extremely unlikely to occur under any conditions.
7			<u>Specified Comments</u> Section 2.2.1, page 7, 3rd para: The consultants should specify the unit of the value of 0.0067 used to represent reactivity.	The unit for the value of 0.0067 is moles smog per mole of ROC carbon per unit cumulative-light flux.
8			Section 2.2.1, page 8, last line: The consultants should correct the typo error and explain what they refer.	The last sentence of this paragraph should read as "The smaller domain is used for that part of the Study which is concerned with dispersion of non-reactive gas."
9			Section 4.1, page 45: Actual emission figures should be included for omitted sources for review.	Noted.
10			Figure 4.1a: Legends should be included to show the emission sources.	Noted.

No.	Department	Reference	Comments	Consultants' Response
11			Table 4.2a, page 49: NO_x emission rates for both with and without De-NO_x option should be shown.	We will include the NOx emission rates for APC with de-NOx option which is 215 g/s in Table 4.2a.
12			Section 4.2.1, page 49 and 50: The proposed emission rates used were only about 60% of that operating at full capacity. The consultants should explain in detail (e.g. like that presented for HEC) what were assumed under the CLP High Coal Consumption scenario for our review of the validity of the proposed emission rates used.	The emission rates quoted in Table 4.2a are based on the emission rates contained in CLP's Specified Licence which are the theoretical maximum when all the units are running at maximum capacity. It should be noted that Castle Peak Power Station is not the only source of electricity supply for CLP as a significant portion of the projected demand will be met by the supply from the Daya Bay Nuclear Power Station and Back Point Power Station. The emission rates we used for the model runs are based on the average daily projected fuel consumption under the high coal consumption scenario which has the same annual coal assumption used in the *Greenhouse Gas Technical Paper*. The estimated emission rates are considered reasonable for the selected worst-case scenarios which are more likely to occur in autumn when the demand is less.
13			Section 5.1, page 71: The consultants should explain whether, besides among the three plumes (namely CLP's Castle Peak , Black Point source and HEC's), there will be interaction of the other sources with the three plumes discussed. See also comments in item 3 (a) above.	As explained in comment 3 above, we will include CLP's Castle Peak and Back Point sources in the photochemistry runs to show the interaction of the individual plumes on the 5-km grid.
14			Section 5.2.2, page 74, 1st para, last line and figure 5.2g, page 87: The consultants should explain why "the total HEC NO_x emissions happens to be very similar for 2002 and 2012".	The NOx emission from the new power station is much lower than the existing Lamma Power Station (see Table 4.2a) due to the adoption of low-NOx technology in the burner design. The load shifting to the new power station in 2012 would reduce the emissions from the older units (i.e. Unit 1-3) and the gas turbine units which would be utilised to a much higher level in 2002.

No.	Department	Reference	Comments	Consultants' Response
15			Figures 5.2a, 5.2b and 5.3a: The values of the contour should be shown.	These figures are not intended to show contour values as the contours are only there to indicate where the emissions are reaching the ground.
16			Tables 5.2a, 5.2c, 5.2d, 5.2e, 5.3a, 5.3c, 5.3d and 5.3e: The consultants should show the absolute numbers (the maximum concentration) along side the values in the tables.	The predicted maximum values of the pollutants are primarily associated with the urban source and thus not included.
17			Section 5.2.4, page 89 and section 5.3.4, page 93: Findings on Local Visual Distance (LVD) should also be discussed.	This will be discussed in the Final Technical Paper.
18			Section 5.4, page 103 and section 6.8, page 109: For ease of interpretation of the reader, the consultants should consolidate and tabulate the findings (in quantitative terms whenever possible) with regard to the various scenarios and pollutants for the various technology options.	Noted.
19			Section 6.3, page 106, last para: The consultants should explain how they projected the emissions from the cities in the region.	The projected emissions from the cities in the region are from the reference "Researches on Perspective Plan for the Pearl River Delta Economic Region".
20	PELB		The content of the paper appears to be very technical and I am unable to comment on the specifics. However, I noted that a number of figures were up-side-down and the table 4.2a did not clarify whether the emissions stated for the "Proposed New Power Station" is for APC with De-NO_x or without De-NO_x (as agreed both should be presented). Furthermore, the paper did not advise whether the predicted levels under various conditions are acceptable, in particular, the effect on western part of Shenzhen.	The figure in Table 4.2a is for standard APC technology and we will include emission from APC with De-NOx in the table. We will make reference to the predicted pollution levels with established criteria.

No.	Department	Reference	Comments	Consultants' Response
21			It appears that the coverage shown in the paper just include Shenzhen and it did not even address/indicate where significant polluters outside HKSAR are located and whether the cumulative effect would be acceptable.	Please refer to responses to item 1 and 3. Unfortunately, it is not possible to add further sources in Guangdong Province as the model cannot handle more than six sources when doing photochemistry. This is because the number of tracer particles needed to properly represent sources become too large and the model takes far too long to run (more than a week on CSIRO's CRAY). However, it should be noted that the main objective of the modelling is to predict the add-on effect of HEC's new power station in PRD region against the background as explained in Item 19.
22			I would suspect that the wind condition would be different for different seasons of the year rather than always going from east to west as show in the figures.	Yes, the wind condition varies for different season. As we are assessing the impact of the new power station on the Pearl River Delta, winds from the east and the south-east are considered appropriate. See also our response to item 6.
23			I find the report did not go far enough to address our concern on the environmental effects of HEC's proposal have on the regional perspective.	Please refer to our response to item 1 and 3.
24			I have no comment on the technical details of the technical report but would like to point out that according to section 5.2.1 of the Stage 1 EIA Study Brief, the report should identify the preferred site(s) in terms of air quality impacts for each of the two fuel options (coal and pipeline natural gas). In reviewing the report, however, I do not think this requirement is fulfilled. The consultants have made their assessment assuming that the proposed new power station will be located in the southern part of HK, or more precisely, on Lamma. This is not the intention of the Study Brief nor does this facilitate the Stage 1 EIA SMG/Site Search SG's decision on the preferred site(s) for the proposed new power station in terms of air quality impacts.	It has been agreed with EPD that the site located next to the existing Lamma Power Station would present a worst case for the assessment of the photochemistry due to better plume overlapping with other emission sources. Emission from other short-listed sites would not interact with the emission from the urban sources and cannot be considered as worst-case. It has also been agreed that the impact on the Pearl River Delta does not depend on the final choice of the power station site and the photochemical reaction plays a much more important role in this assessment.
25	Plan D		No written response.	
26	BCSB		No written response.	
27	ESB		No written response.	
28	TD		No written response.	
29	EMSD		No comment.	

No.	Department	Reference	Comments	Consultants' Response
30	AFD		No comment.	
31	MD		No comment.	
32	CED		No comment.	
33	Lands D		No comment.	
34	TDD		No comment.	
35	FSD		No comment.	
36	HyD		No comment.	

Power Station Development in the PRD Region

As one of the fastest growing provinces in China, Guangdong's energy demand has risen sharply in the past one or two decades. Majority of these demands are met by large capacity coal or oil-fired power stations. Many of these power plants are located in the PRD region, including:

Shajiao A	Coal	3x200MW + 2x300MW	1987-1993
Shajiao B	Coal	2x350MW	1987
Shajiao C	Coal	3x660MW	1995-1996
Zhujiang I&II	Coal	2x300MW + 2x300MW	1992-97
Huangpu III	Coal	2x300MW	1989-90
Mawan	Coal	2x300MW	1996-97
Zhuhai I	Coal	2x700MW	1999-00
Huangpu	Oil	1x125MW	1995
Nanhai I	Oil	2x200MW	1997
Zhongshan	Oil	2x125MW	1997-98

Above are major fossil-fuelled power plants recently built or still under construction. The total capacity added to the Guangdong grid over the past decade is more than 10,000MW and there are a few more to be constructed within the next decade, eg Zhuhai Phase II (4x600MW coal) and Taishan (8x660MW coal), the plans of which have already been approved but the construction schedules have yet to be fixed.

It should be noted that *none* of the existing power plants in the province have flue gas desulphurization (FGD) or NOx control facilities, making environmental pollution now a major concern in the PRD region. The total acid deposition in Guangzhou in the early 1990's was more than five times that of Hong Kong. Fitting FGDs to the existing power plants is considered to be too capital intensive to be implemented on a large scale. According to the Guangdong Environmental Protection Bureau[(1)] *"In principle, no coal-fired power plants shall be built in the PRD region. Starting from this year no thermal power plants of unit capacity 125MW or less shall be built. Newly constructed power plants of capacity 200MW or above shall be equipped with FGD... Emphasis shall be placed on developing hydro power and nuclear power."* The Guangdong Power Bureau is also implementing similar planning guidelines. Since they presently have surplus capacity in the grid, and there are substantial coal-firing capacities already approved for development within the next century, eg Zhuhai and Taishan, the Guangdong Power Bureau is now shifting to gas-firing as well as nuclear technology for future developments. However, this is only internal policy and is not regulatory. It is based on their study that a coal-firing plant with FGD is not economically attractive.

As the emission loading of HEC's system in 2012, when the new power station is fully developed, is even less than that in 2002, before the 1st unit is built, the contribution of HEC's new power station to the photochemical effect and acid deposition in the PRD region should not be a major concern as analysed in this report.

[(1)] The 7th Guangdong Provincial Environmental Protection Conference (November 1996)

Response to Comments
Stage 1 EIA for a New Power Station
Further Comments on Revised PRD Air Quality Technical Paper

No.	Department	Reference	Comments	Consultants' Response
1.	EPD/Victor Yeung/ 20 October 1997	EP 1/G/160 X	**Revised Technical Paper on PRD Air Quality Assessment contained in the 'Compendium of Technical Papers':** *Consistency in argument* a. In section 6.2.4, pg 43, the consultants suggested that Hong Kong South monitoring station is most likely to be impacted by emissions from Lamma Island because of its proximity. Yet modelling results even at distances of Guangzhou from Hong Kong shows infrequent plume fumigation from HEC's high plume. Can the Hong Kong South station, being so close to HEC's tall stack, be expected to do better and be representative?	We have used the average gas concentrations for the whole Hong Kong to estimate dry deposition impacts. Text will be clarified in the Final Report.
2.			If representing HEC's contribution to Hong Kong by all the Hong Kong stations and not just the Hong Kong South Station is over-estimating, as the consultants claimed, then representing China's utilities with the Guangzhou station would be even worse since it is likely to be subject to greater impacts from local sources. The consultants should revise the paper to improve on the consistency in argument put forward in the assessment.	Yes, representing China's utilities with the Guangzhou station is likely to be a strong overestimate of the impact from Lamma Island since it is likely to be subject to large impacts from local sources. We have no information from other regions in the PRD regarding wet acid deposition. We therefore have proceeded to make an estimate of the greatest possible contribution from Lamma Island to PRD using the Guangzhou data, knowing full well that it is an overestimate. If the prediction is for a small impact then that is the end of the matter; if the prediction is significant, then further work is required. This is the process of "screening" to put the effort where it is important. The discussion in Section 6.10.3 and Section 6.10.4 shows that the expected impact in 2012 from Lamma Island to PRD is no more than 2% of the acid deposition and may well be no more than 1% even if the coal option is used. Noting also the large uncertainly of these estimates, this would surely be in the class of "insignificant" and no further work is required.

No.	Department	Reference	Comments	Consultants' Response
3.			*Technical clarification* b. Section 2.2.1, 3rd para, pg 5 - How good is the R_{smog} value in different situations with diverse combination of VOCs?	The value of 0.0067 quoted is not the value of R_{smog}, but the ratio used to convert VOC to R_{smog}, and is representative of the reactivity of an urban air mass with typical VOC constituents dominated by motor vehicles. For different situations with a different combinations of VOCs, it takes a different value.
4.			c. Section 2.2.1, 4th para, pg 5 - Does IER predict OH? If not, where does the OH concentration for predicting SO_4^{2-} and NO^{3-} come from?	IER does not predict OH, but it does predict the rate of production of nitrates, which is dominated by the OH radical. Sulfate production is also dominated by the OH radical (with one-tenth the reaction rate of the nitrate reaction), so that sulfate production can be scaled against nitrate production, using the ratio of nitrogen dioxide concentration to sulfur dioxide and the one-tenth reaction rate factor.
5.			d. Table 5.1a and 5.1b, pg 19 - As results are presented in ppb units, the criteria in ppb units should be included for easy reference.	Tables will be amended accordingly.
6.			e. Section 5.2, last 3 para, pg 23 - The NO_2 and O_3 concentrations do differ, and also not a minor difference (up to 10% in some areas), according to the results shown across the rows in table 5.1a and 5.2b.	Perhaps the point to make here is that at all times except one, NO_2 glcs are smaller in 2012 than in 2002, and that O_3 glcs are negligibly bigger except at one time. Text will be amended to illustrate this point.
7.			f. Section 5.4.1, last para, pg 33 & 5.4.2, last para, pg 34 - Drawing conclusion based on merely the results at the 1700 LT time frame do not give the complete picture and reference should be made instead to the findings for the hours covered in the assessment.	The aim of this Study is to look at the impact on the PRD. It is not until 1700 LT that Hong Kong emissions reach this area, and that is why we have used 1700 LT to draw our regional perspective conclusions.

Annex D

150m Stack Simulations

INTRODUCTION

In response to concerns from the Civil Aviation Department of the Hong Kong SAR Government, additional simulations were run with a stack height of 150m. This *Annex* focuses mainly on the differences between these runs and those described in the body of this *Technical Paper* (for a 240m stack height). They are presented in the following manner:

- Non-reactive Simulations
- NO_2 and O_3 Simulations
- FSP and SO_2 Simulations
- Summary

The results discussed in this *Annex* are for the 2012 coal option only. All the other parameters used in the simulations are as stated in the body of this *Technical Paper*, particularly *Sections* 2 to 4.

NON-REACTIVE SIMULATIONS

The results of the non-reactive runs, which depict the general dispersion patterns from the proposed New Power Station with a stack height of 150m, are shown in *Figure 1*. The general dispersion pattern is similar to that for a stack height of 240m as shown in *Figure 5.1d* of this *Technical Paper*.

NO_2 AND O_3 SIMULATIONS

Figures 2 and 3 show the results of the simulations for NO_2 and O_3. Again, the dispersion patterns are similar to those for the 240m stack which are shown in *Figures 5.2a* and *5.2b* of this *Technical Paper*.

It can be seen from *Table 1* that the maximum concentrations of NO_2 and O_3 for the 150m stack are also very similar to those for the 240m stack. For NO_2, the maximum concentration was 274 ppb for the 150m stack as compared to 266 ppb for the 240m stack, and both maxima occurred at the same time, 1300LT. The largest difference in maximum concentrations between the two simulations occurred at 1500LT, with a magnitude of 17ppb (approximately 10% of the maximum concentrations), but at all other times, the differences ranged between 0 - 6 ppb (0 - 3% of the maximum concentrations).

For O_3, the two simulations gave almost exactly the same results (see *Table 1*). The absolute maximum concentrations were identical (361 ppb) and they both occurred at 1400LT.

Table 1 ***Maximum concentrations of NO_2 and O_3 for the 2012 coal-fired option (ppb).***

Time	NO_2 *150m Stack*	*240m Stack*	O_3 *150m Stack*	*240m Stack*
0900	135	135	45	45
1000	158	158	88	88
1100	209	209	186	186
1200	228	230	173	173
1300	274	266	356	356
1400	124	121	361	361
1500	181	164	230	227

Time	NO_2 150m Stack	240m Stack	O_3 150m Stack	240m Stack
1600	207	201	230	230
1700	98	97	262	263
1800	41	42	106	109
1900	37	37	34	34
2000	38	38	33	33
2100	39	39	33	33
2200	39	39	33	33

Although the maximum concentrations and general dispersion patterns of the 150m and 240m stack simulations for NO_2 and O_3 are similar, a comparison between the differences between the 150m stack run with the 2002 run and those between the 240m stack run and the 2002 run (see *Table* 2) was made for verification. The slight differences (less than 10 ppb or 4% of the maximum concentrations) between the 150m and 240m comparisons for both NO_2 and O_3, indicate that the geographical dispersion of the maximum concentrations is slightly different.

Table 2 ***Maxima and minima of differences between hourly-averaged ground-level concentrations in O_3 and NO_2 for the 2012 simulation with a coal-fired New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.***

Hour	NO_2 (ppb) 150m Stack		240m Stack		O_3 (ppb) 150m Stack		240m Stack	
	min	max	min	max	min	max	min	max
0900	0	1	0	0	-1	0	0	0
1000	-6	5	-7	2	-5	5	-2	6
1100	-11	10	-8	3	-8	9	-2	6
1200	-34	10	-32	6	-10	32	-5	30
1300	-11	19	-19	10	-17	8	-9	15
1400	-14	5	-21	4	-5	14	-4	20
1500	-17	5	-25	3	-4	16	-3	23
1600	-11	6	-14	7	-6	10	-6	13
1700	-13	3	-18	3	-2	11	-2	17
1800	-6	4	-6	4	-4	5	-3	6

FSP AND SO_2 SIMULATIONS

Figures 4 and 5 show the results of the simulations for FSP and SO_2. Again, the dispersion patterns are similar to those for the 240m stack which are shown in *Figures 5.3a* and *5.3e* of this *Report*.

It can be seen from *Table* 3 that the maximum concentrations of FSP and SO_2 for the 150m stack are practically identical to those for the 240m stack. For FSP, the maximum concentration for both simulations was 223 $\mu g\ m^{-3}$ and it occurred in both cases at 1300LT. The largest difference in maximum concentrations between the two simulations occurred at 1500LT, with a magnitude of 4ppb (approximately 3% of the maximum concentrations).

For SO_2, again the two simulations gave almost exactly the same results (see *Table* 3). The absolute maximum concentrations were slightly different with the 150m stack giving 189 ppb and the 240m stack giving 184 ppb, but both occurred at

1300LT. The largest difference in maximum concentrations between the two simulations occurred at 1200LT, with a magnitude of 11ppb (approximately 7% of the maximum concentrations), but at all other times, the differences ranged between 0 - 6 ppb (but most of the differences were less than 3% of the maximum concentrations).

Table 3 ***Maximum concentrations of FSP and SO_2 for the 2012 coal-fired option (ppb).***

Time	FSP *150m Stack*	*240m Stack*	SO_2 *150m Stack*	*240m Stack*
0900	103	103	77	77
1000	138	138	61	61
1100	177	177	87	81
1200	181	181	164	153
1300	223	223	189	184
1400	205	205	165	169
1500	121	125	181	183
1600	133	129	174	175
1700	148	149	162	162
1800	56	56	102	101
1900	25	25	19	19
2000	29	29	25	25
2100	30	30	27	27
2200	32	32	31	31

Although the maximum concentrations and general dispersion patterns of the 150m and 240m stack simulations for FSP and SO_2 are similar, a comparison between the differences between the 150m stack run with the 2002 run and those between the 240m stack run and the 2002 run (see *Table 4*) was made for verification. The close correlation between the 150m and 240m FSP comparisons, indicates that the geographical dispersion of the maximum concentrations is almost identical. The slight differences for the SO_2 results (less than 11 ppb or 7% of the maximum concentrations) between the 150m and 240m comparisons, indicate that the geographical dispersion of the maximum concentrations is slightly different.

Table 4 ***Maxima and minima of differences between hourly-averaged ground-level concentrations in FSP and SO_2 for the 2012 simulation with a coal-fired New Power Station and the 2002 simulation. Positive values indicate that concentrations are higher for the 2012 simulation.***

Hour	FSP ($\mu g\ m^{-3}$) 150m Stack		240m Stack		SO_2 (ppb) 150m Stack		240m Stack	
	min	max	min	max	min	max	min	max
0900	0	0	0	0	0	0	0	0
1000	-4	0	-5	0	-36	2	-42	1
1100	-8	1	-9	1	-104	1	-111	1
1200	-13	1	-14	1	-219	2	-230	0
1300	-13	3	-14	2	-161	4	-167	3
1400	-7	1	-7	1	-116	0	-117	0
1500	-8	4	-7	4	-73	10	-74	10
1600	-9	8	-8	2	-96	3	-95	4
1700	-11	9	-8	2	-82	6	-80	5
1800	-13	2	-12	2	-19	10	-20	10

SUMMARY

In general, the dispersion patterns for NO_2, O_3, FSP and SO_2, are similar regardless of the stack height. There were slight differences in the locations of the maxima and minima concentrations for NO_2, O_3 and SO_2, but no significant differences prevailed for FSP. The absolute maximum concentrations were also similar for both the 150m and 240m stack heights. This implies that the major contributors of all four pollutants are the existing sources. Hence, it can be concluded that different stack heights would have negligible impacts on the results of the simulations.

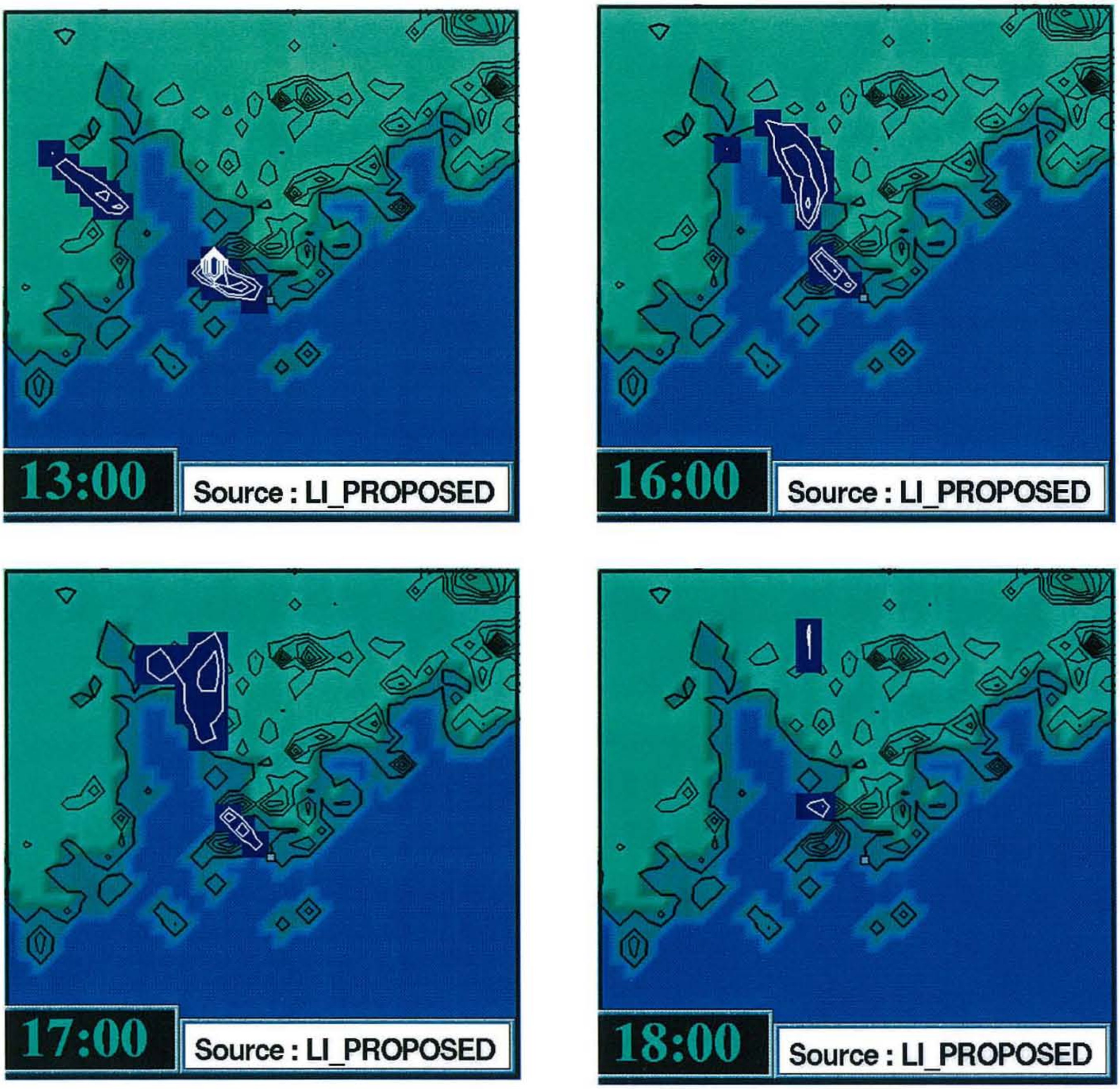

Figure 1: The distribution of emissions from the Proposed New Power Station with 150m stack at 1300, 1600, 1700 and 1800 LT under Scenario 1. The ground-level concentration contours are for NOx from a non-photochemistry simulation, and are merely to indicate where the emissions are reaching the ground. Contour values for NOx are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

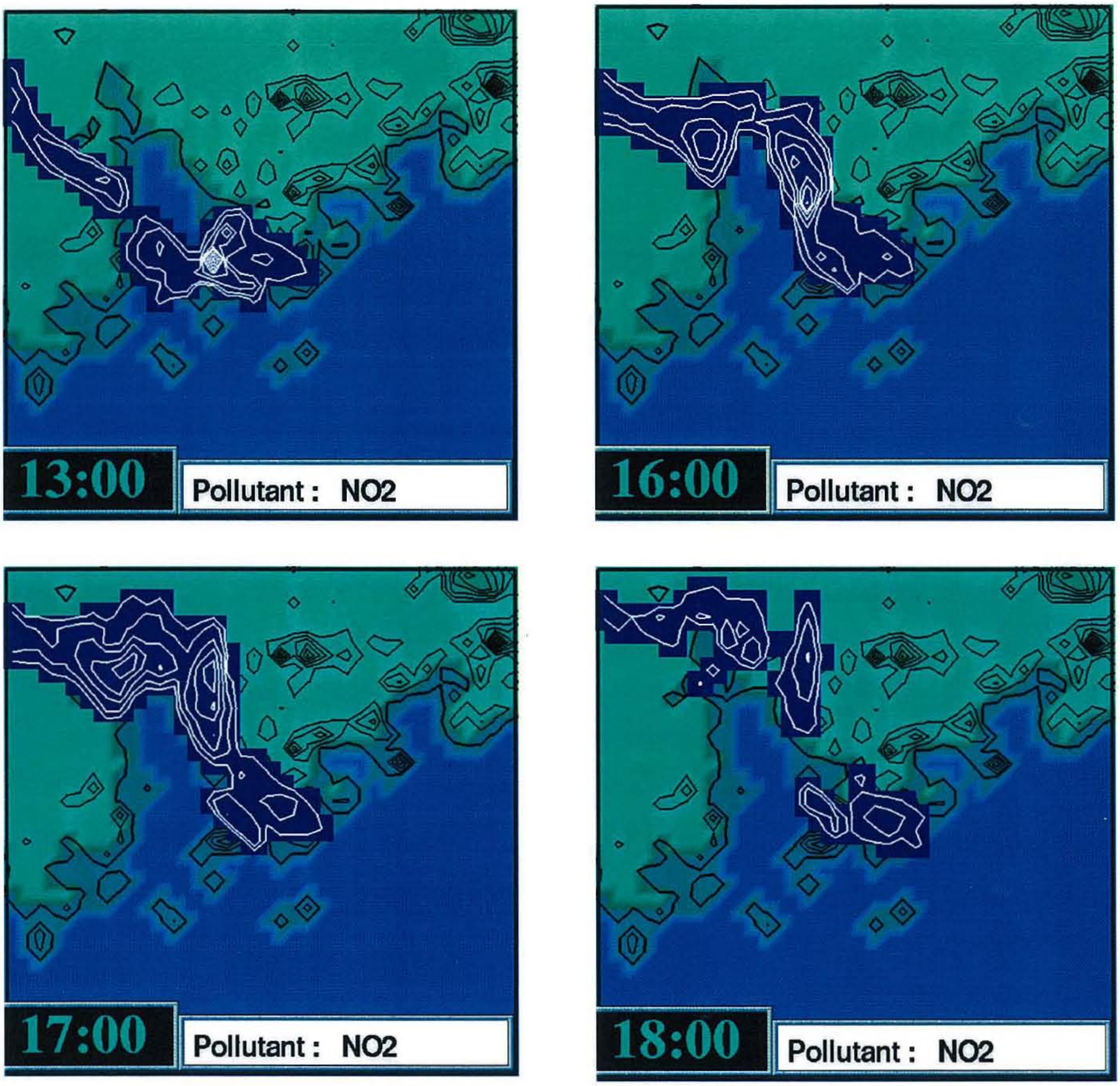

Figure 2: The distribution of NO2 emissions in 2012 with a Coal-fired New Power Station with 150m stack at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for NO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

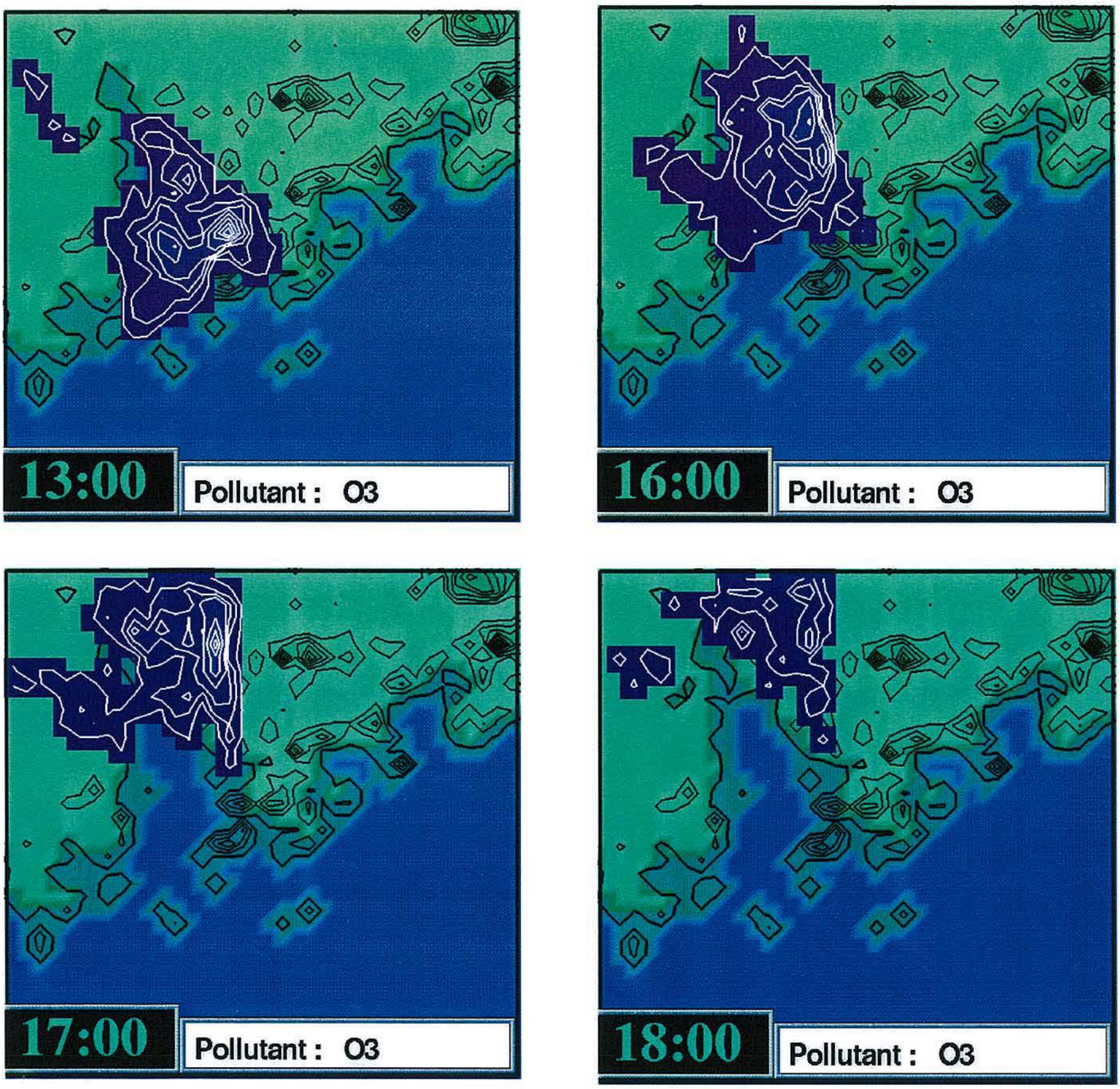

Figure 3: The distribution of O3 emissions in 2012 with a Coal-fired New Power Station with 150m stack at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for O3 are 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

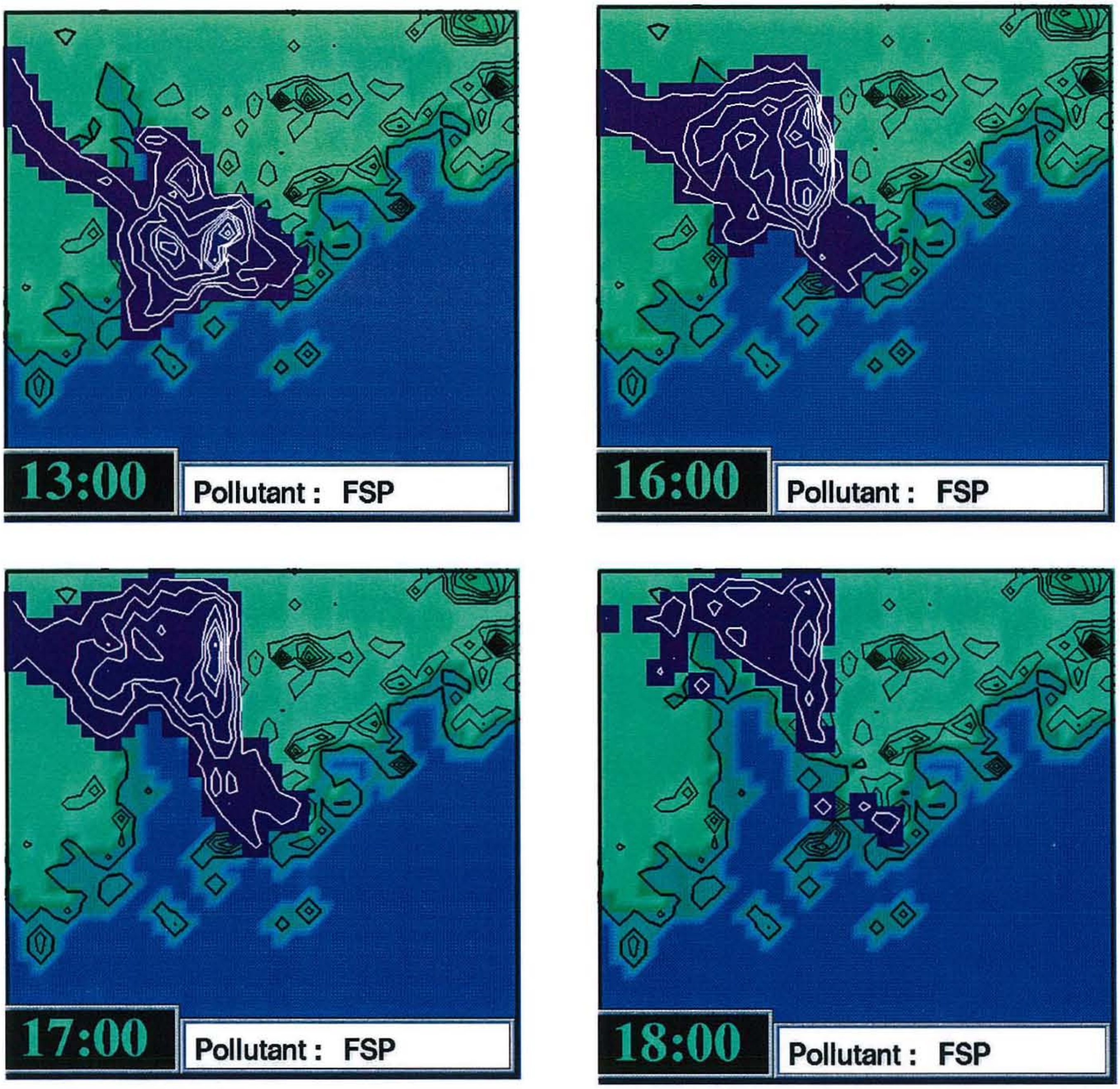

Figure 4: The distribution of FSP emissions in 2012 with a Coal-fired New Power Station with 150m stack at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for FSP are 20, 30, 40, 60, 80, 100, 150, 200 and 250 µg/m3.

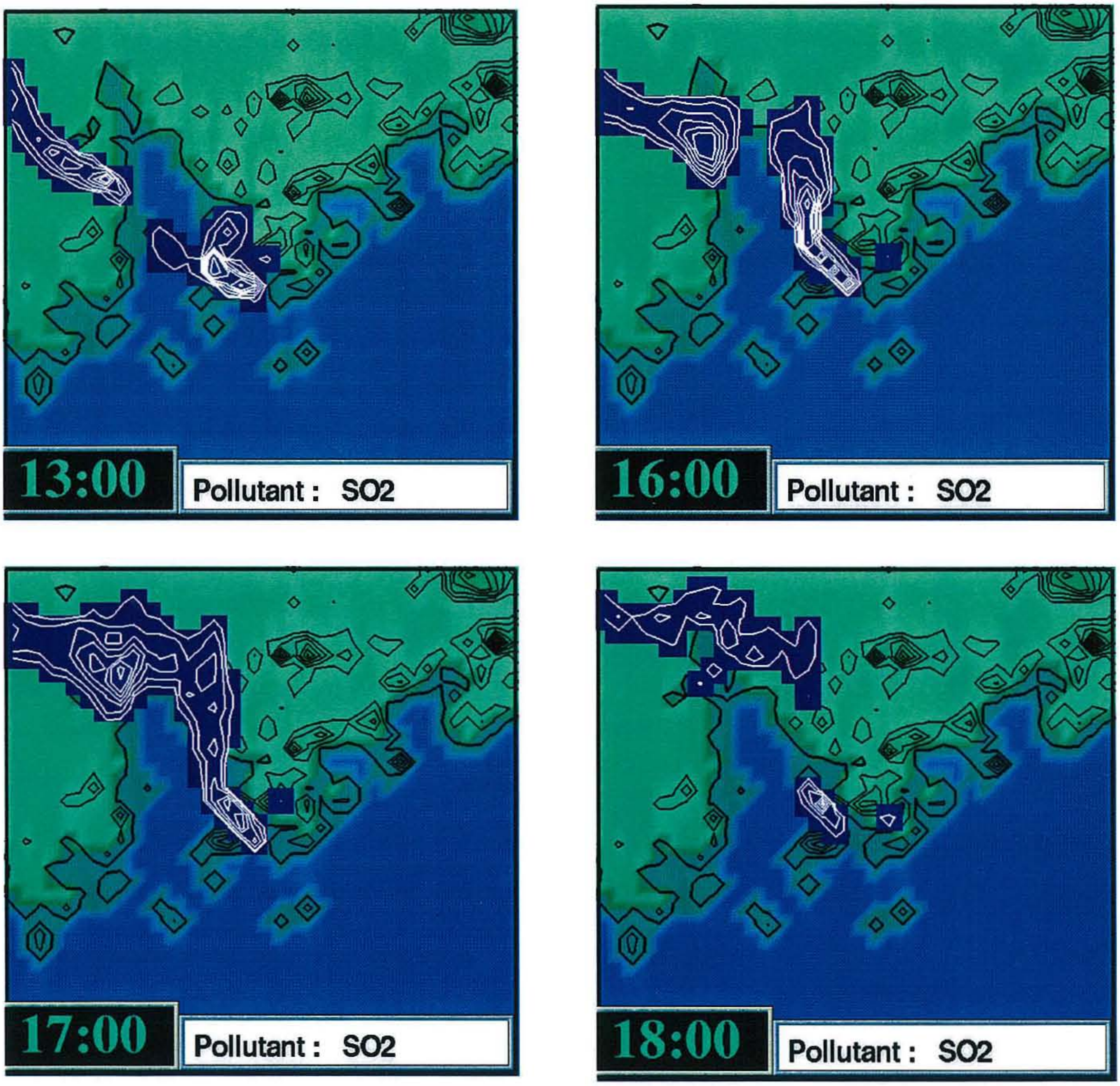

Figure 5: The distribution of SO2 emissions in 2012 with a Coal-fired New Power Station with 150m stack at 1300, 1600, 1700 and 1800 LT under Scenario 1. Contour values for SO2 are 10, 20, 40, 60, 80, 100, 150, 200, 250, 300 and 400 ppb.

TECHNICAL PAPER

The Hongkong Electric Company, Limited

Stage 1 EIA for a New Power Station : *Greenhouse Gas Study*

November 1997
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CONTENTS:

1 INTRODUCTION

1.1 BACKGROUND

This Technical Paper has been prepared by Environmental Resources Management (ERM-Hong Kong), on behalf of The Hongkong Electric Co. Ltd (HEC) as part of the Stage I Environmental Impact Assessment (EIA) Study of HEC's proposed new power station.

The Study Brief for the Stage 1 EIA requires that HEC carries out a study of the total emissions of so-called greenhouse gases (GHG) in Hong Kong over the period from 1990 to 2012. Although particular attention is to be paid to the contribution of the electricity generating sector to the total carbon dioxide (CO_2) and methane (CH_4) emissions, all major sources of these two GHGs are to be addressed.

This Technical Paper has been prepared in response to the Study Brief requirement and presents the findings of the greenhouse gas study.

Much of the impetus for the examination of GHG emissions comes from the United Nations conference in Rio de Janeiro in 1992. From this conference came the Framework Convention on Climate Change (FCCC), a series of guidelines and commitments to which many countries became signatories (the United Kingdom upon ratification of the FCCC in 1992 and China in 1993). The FCCC ultimately requires signatories to reduce their emissions of GHGs to 1990 levels, although the timing differs among countries. The FCCC is further described in *Section 2*.

There has been considerable international debate regarding elevated levels of GHG and the extent to which such rising levels may impact upon established climate patterns. This ongoing debate is beyond the scope of this report, as is an assessment of the potential effects (if any) of elevated GHG emissions. The study focuses on actual and projected emissions of two main greenhouse gases - CO_2 and CH_4; these emissions are quantified, presented and evaluated.

1.2 GENERAL FINDINGS

There appears to be an ongoing correlation between the continued growth of Hong Kong and a consequent growth in emissions of both CO_2 and CH_4.

Historically, CO_2 emissions exhibited a decline from the period 1993 through 1996, but thereafter, the emissions of CO_2 have been projected to resume a rate of continuous growth. By the year 2012, total CO_2 emissions are projected to range from 46.2 to 62.2 million tonnes (Mt). This represents an increase of 26% and 70% respectively over the 1990 level (36.6 Mt). Over the same period population growth estimates ranges from 7.52 to 8.10 million, increases of 32% and 42% respectively, over the 1990 population of 5.7 million.

After reaching a peak of 0.19 Mt in 1993, CH_4 emissions in Hong Kong experienced a dramatic decrease between 1993 and 1996 (at approximately 0.02 Mt/year). This decrease has been projected to continue until the year 2000, at which time CH_4 levels will stabilise at about 0.05 - 0.04 Mt.

1.3 STRUCTURE OF REPORT

The remainder of this Technical Paper is structured as follows:

- *Section 2* examines established regional and international policies for the control or stabilisation of greenhouse gases;
- *Section 3* provides details of the assumptions used in the analysis of Hong Kong greenhouse gas emissions;
- *Section 4* presents the analysis of the study results;
- *Section 5* discusses possible measures that might be employed to mitigate the possible effects of identified emission levels; and
- *Section 6* presents the study conclusions.

2 GREENHOUSE GAS EMISSIONS POLICIES

2.1 BACKGROUND

2.1.1 Global Conventions

The potential impact on climate change of GHGs is the second major environmental issue to be addressed in a global convention, the first being the Montreal Protocol that sought to phase out the use of chlorofluorocarbons (CFCs) which are associated with the depletion of the stratospheric ozone layer.

The Montreal Protocol indicated the difficulties inherent in seeking to achieve global agreement to basic principles and commitments, even where there is a high level of scientific agreement regarding the causes and effect as was the case with the linking of CFC release with the continued depletion of the ozone layer.

2.1.2 The Greenhouse Gas Debate

There is a far wider spectrum of opinion regarding the potential influence on climate patterns of the so-called GHGs and hence much more difficulty in getting countries to agree to reduce the emission levels of GHGs. As stated previously, an examination of the science underlying potential links between GHGs and climate change is beyond the scope of this study.

It should be noted that the wide-ranging nature of the debate has resulted in some countries withholding their agreement to reductions in their emissions of GHGs, particularly as it is feared that sharp reductions in GHGs may damage economic growth. This issue is reflected in the recent discord within the Group of Seven Nations at the 1997 Summit in Colorado, USA, where the US, Canada and Japan resisted signing an agreement to 15% reductions in CO_2 emissions by 2010, due to concerns over the economic impact of the agreement. At a subsequent special session of the UN General Assembly, President Clinton refrained from committing the US to specific targets for cutting greenhouse gas emissions, to the applaud of US business leaders who believe that the pollution cuts urged by the Europeans represented "draconian measures that would be harmful to our economy and harmful to the American people" (Gail McDonald, Global Climate Coalition).

2.2 INTERNATIONAL POLICIES

The Framework Convention on Climate Change (FCCC) is the primary international agreement on the control of GHGs to which many countries have become signatories.

The Convention comprises twenty-six articles, which set out the commitments of the signatories, and two annexes which list the signatory countries. The People's Republic of China became a signatory to the Convention in 1993, although, as China is considered a lesser developed country, its obligations as a signatory allows it more time to meet the commitments than developed countries. The United Kingdom became a signatory to the Convention in 1992. Hong Kong was not included in the signatory commitments given by either China or the United Kingdom.

The main commitment of the FCCC is summarised in the following extract from Article 4 (please see *Annex A* for the introduction to the FCCC):

> ... each of these Parties shall communicate ... detailed information on its policies and measures, ... as well as on its resulting projected anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol, ... ***with the aim of returning individually or jointly to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases*** not controlled by the Montreal Protocol (emphasis added).

However, it should be noted that the actual international GHG 'standards' themselves have yet to be determined. This is mostly related to a lack of consensus as to what should be used as the index, for instance, whether to use per capita emissions or absolute emissions, and whether to consider each gas separately or as a "basket" of greenhouse gases weighted by their global warming potential (GWP)[1].

2.3 *HONG KONG POLICIES*

To date, the only official reference to Hong Kong Government's policy on the FCCC can be inferred from paragraph 9.13 of *The Hong Kong Environment: A Green Challenge for the Community - Second Review of the 1989 White Paper on Pollution in Hong Kong - A Time To Act*, November 1993. In this review, the Hong Kong Government states that its "view is that the immediate need is to assess and improve Hong Kong's performance in line with the principles of the Conventions."

However, Hong Kong is presently not a signatory to the Convention as it was not included under the commitment made by the United Kingdom in 1992. In addition, it is unclear whether, following the return of sovereignty to China, Hong Kong is covered under China's participation in the FCCC.

(1) Global warming potential is defined as the radiative forcing effect that a gas has and is usually measured in either CO2 or C (carbon) equivalents.

3 DEFINITIONS, METHODOLOGY & ASSUMPTIONS

3.1 INTRODUCTION

In this section, the terms used in the Study are defined, the methodology of analysis is presented and the assumptions upon which the analysis is based are explained.

3.2 DEFINITIONS

The gases generally considered to comprise the so-called greenhouse gases (GHGs) are as follows:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- non-methane volatile organic compounds (NMVOC);
- oxides of nitrogen (NO_x); and
- carbon monoxide (CO).

After consultations, EPD and ERM agreed that only carbon dioxide (CO_2) and methane (CH_4) would be assessed in this Study for the following reasons:

- to date, scientific evidence linking global warming to these two gases (and nitrous oxide, N_2O) is the strongest as they are shown to have a direct effect, while gases like NMVOCs, NOx and CO have indirect impacts that are not well established at this time;
- in terms of GWP, CO_2 and CH_4 has been estimated to account for approximately 80% of the total GWP;
- CO_2 is the most abundant of all the GHGs and is the main power station emission;
- emission calculations for CO_2 are relatively more accurate than the others as they and can mostly be accounted for by looking at fuel consumption (fuel and energy consumption statistics are readily available in most countries, whilst information regarding the consumption of less common products such as solvents and details of emitting facilities and activities, which are required for a more accurate assessment of the other GHGs, is either non-existent or difficult to obtain); and
- calculations for CH_4 are also relatively less prone to inaccuracies as the major sources are from the waste sector alone, hence even if only information regarding solid waste and sludge is available, a relatively accurate estimate of CH_4 can be calculated.

Sulfur dioxide (SO_2) is considered to have an impact on global climate, but its effects have yet to be established and is therefore not included in this Study. However, it should be noted the Report of the Twelfth Session of the Intergovernmental Panel on Climate Change (IPCC) in Mexico City, 11-13 September 1996), stated: "Although SO2 is not a direct GHG, it is an aerosol precursor, and as such has a cooling effect on climate."

3.3 *METHODOLOGY*

The methodology used to calculate the greenhouse gas emissions was the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. The Hong Kong Environmental Protection Department (EPD) has indicated the Guidelines have been utilised in their calculations of greenhouse gas emissions.

The IPCC member organisations include:

- United Nations Environment Programme (UNEP);
- the Organisation for Economic Co-operation and Development (OECD); and
- the International Energy Agency (IEA).

The Guidelines are internationally accepted and are designed to allow all countries to determine their GHG emissions. As data availability varies significantly between countries, the Guidelines have been designed as follows:

- Tier 1: At this level specific consumption or activity data may not be available (eg fuel, number of livestock, etc). The Guidelines have default values that can be used to provide a rough estimate of results.

- Tier 2: This level is where more specific information is available such as fuel consumption, emissions rates or amount of sludge digested anaerobically (hence producing methane).

Solely relying on Tier 1 information (eg default values only) would give results with very high margins of error. Consequently, a combination of Tier 1 and Tier 2 methods has been used in this study (as practised in most countries). For example, we know the consumption of coal in 1990, the calorific value of the coal and the carbon content from measurements taken. These actual data are then used with formulas that assume the amount of carbon that is oxidised and turned into CO_2 to calculate total emissions.

It should be noted that although the IPCC Guidelines are already being followed by many countries, revision of the Guidelines continues as issues regarding the underlying science, categorisation, terms and details of application have yet to be finalised.

3.4 *ASSUMPTIONS*

Table 3.4a provides the sources of all data and describes the methods used to calculate historical emissions and projections of CO_2 and CH_4 emissions over the study period. Please see *Annex B* for examples of how the GHG emissions were calculated.

It should be noted that every effort was made to incorporate as many different sources as possible. Although not every source of CO_2 and CH_4 emissions in Hong Kong was included, every major source and many minor sources were. For example, CO_2 is released during the production of beer, but production figures were not readily available and hence CO_2 from beer production was not included.

Table 3.4a *Sources and Projection Methods*

Fuel	Method
Coal and Natural Gas	Provided by HEC and Energy Statistics 1995. Assumed that all coal consumed in Hong Kong was utilised in the electric utility sector. The projection of the fuel consumption by HEC and CLP, for the period 1997 to 2012, is based on the forecasts of the demand for electricity of the two power companies, and the various scenarios of the types of fuel and plants to be employed in meeting future demand. Both CLP and HEC's load forecasts are based on the Assignment 23 Study (Study of Demand for Electricity in Hong Kong from 1995 to 2005 and Ways of Meeting Demand), endorsed by Government Consultants, Burns and Roe. The efforts of Demand Side Management (DSM), which will have some negative impacts on the load growth, have also been duly reflected in the system load projection.
Petrol	Comprehensive Transport Study II Update (CTS II Update) daily person trips were extrapolated using the Territorial Development Strategy Review's (TDSR) updated estimates of population for both TDSR Scenario A and TDSR Scenario B. CTS II Update contains the most recent official government figures for increases in transport activity. However, the CTS II Update figures are based on population assumptions from 1993 and had to be modified to match current population growth estimates. Hence the extrapolation with TDSR population estimates. Historical data from the Hong Kong Energy Statistics 1995. Assumed all petrol was used in the transport sector.
Diesel	Diesel consumption was divided into two categories, road transport; and other uses. Assumptions for road transport projections were the same as for petrol. The Airport Core Projects (ACP) have had a significant impact on the consumption of diesel in Hong Kong that is unlikely to be sustained or repeated. Consequently, the 'other' diesel consumption category was fixed at the 1991 level to adjust for the temporary nature of the increased level of consumption. It was also assumed that industrial activity remains static at 1991 levels due to a diminishing industrial base and that no diesel-to-petrol switch would take place over the study period. Historical data from the Hong Kong Energy Statistics 1995.
Towngas/Naphtha	Assumed to grow at the same rate as electricity consumption. Towngas historical consumption figures were derived from the Hong Kong Yearbooks (1996 & 1993). In the Hong Kong Energy Statistics naphtha and diesel were combined under one category. The Towngas consumption figures were subtracted from this combined category to derive total diesel consumption.
LPG	Assumed no growth from 1995 due to loss of market share to Towngas. Historical data from the Hong Kong Energy Statistics 1995. Assumed that LPG was used in the residential sector.
Solid Waste	Figures supplied by EPD.
Sludge	Figures supplied by EPD.

3.5 STUDY CONSTRAINTS

The determining factor for achieving accuracy in analytical exercises based on an internationally recognised methodology is the data input.

Hence, the major study constraint lies in the availability of quality data. For example, data may exist but due to the sensitivity of the data, permission for their use is not readily obtained. When data are available, these may be inaccurate, outdated, incomplete or not in the required format or level of detail. This study has encountered each challenge.

Table 3.5a summarises the main constraints influencing the accuracy of the study findings.

Table 3.5a ***Study Constraints***

Issue	Constraint
Categorisation of data	For calculations of CO_2 emissions, relying on the Hong Kong Energy Statistics for data does not present a significant problem as the emissions of carbon are similar no matter how the fuel is burned. However, the other GHGs have very different emissions rates depending on the way in which it is consumed. Without detailed categorisations by industry accurate fuel related non-CO_2 emissions totals will have a high margin of error. The Electrical and Mechanical Services is currently developing an Energy End-use Database which will provide detailed estimates of energy consumption by sector and energy supplied under different fuels. As many assumptions were made in this study due to lack of information on sector-by-sector fuel consumption, access to the EMSD study's data may allow future GHG emissions studies to achieve a higher level of accuracy.
Projections of diesel and petrol	The CTS will be updated with the new population forecasts as this study is being written. Extrapolating the three year old CTS II Update daily person trip estimates based on the TDSR population estimates may or may not cause inaccuracies in the projections. Once the new CTS is completed more accurate projections will be available. If there was further breakdown of the other diesel uses and more information on the projection of industrial activity in Hong Kong, a more accurate projection of diesel consumption could have been calculated.

4 ANALYSIS OF RESULTS

4.1 SCENARIOS

The two main scenarios (lowest case and highest case) selected for the study are intended to provide the widest range of feasible estimates of the emissions of CO_2 and CH_4 from Hong Kong. The lowest scenario is based on the low population growth estimate in the TDSR (TDSR Scenario A) with HEC burning gas at its new plant, China Light and Power Co Ltd (CLP) burning gas to meet post-Black Point (units 7 and 8) demands and no waste incineration. The highest scenario is based on the high population estimate (TDSR Scenario B) with HEC burning coal at its new plant, CLP burning coal to meet its post-Black Point demands and the presence of waste incineration (the incinerator is assumed to have a capacity of 150 MW).

To understand the impact of HEC burning gas versus coal at its proposed power plant, four categories of sub-scenarios were considered: TDSR population scenario A (7.52 million in 2011) or B (8.10 million in 2011); HEC burning coal or HEC burning gas at its new plant; CLP burning coal or burning gas to meet post-Black Point units 7 and 8 demands; and the absence or presence of solid waste incineration after 2005.

Please see *Table 4.1a* for a description of the scenarios processed. The lowest and highest scenarios are italicised.

Table 4.1a *Scenarios*

Scenario		Assumptions
I	*Lowest Case*	*TDSR A; HEC burning gas at its new plant; CLP burning gas to meet post- Black Point demands; no incineration.*
II		TDSR A; HEC burning gas at its new plant; CLP burning coal to meet post- Black Point demands; no incineration.
III		TDSR A; HEC burning gas at its new plant; CLP burning coal to meet post- Black Point demands; with incineration.
IV		TDSR A; HEC burning gas at its new plant; CLP burning gas to meet post-Black Point demands; with incineration.
V		TDSR A; HEC burning coal at its new plant; CLP burning gas to meet post-Black Point demands; no incineration.
VI		TDSR B; HEC burning gas at its new plant; CLP burning coal to meet post-Black Point demands; with incineration.
VII		TDSR B; HEC burning coal at its new plant; CLP burning gas to meet post-Black Point demands; no incineration.
VIII		TDSR B; HEC burning coal at its new plant; CLP burning gas to meet post-Black Point demands; with incineration.
IX	*Highest Case*	*TDSR B; HEC burning coal at its new plant; CLP burning coal to meet post-Black Point demands; with incineration.*

4.2 *GENERAL TRENDS*

Historically, Hong Kong experienced a steady increase in CO_2 and CH_4 emissions between 1990 and 1993. Between 1993 and 1997, a significant drop in both CO_2 and CH_4 emissions occurred (see *Figures 4.2a* and *4.2b*). This is due to four main causes:

- The Daya Bay nuclear power station coming on line;
- a decrease in electricity sales to China by CLP;
- CLP beginning to burn gas; and
- significant decreases in the amount of landfill gas produced at older landfills.

Population growth estimates range from 7.52 to 8.10 million (TDSR 2011 projections), with increases of 32% and 42% respectively over the 1990 population of 5.7 million.

Emission projections from 1997 onwards show a continual increase in total CO_2 emissions for all scenarios (see *Figure 4.2c* and *Table 4.2a*), moderate increases in per capita emissions for the highest case, and small decreases for the lowest case (see *Figure 4.2d*). By 2012, total GHG emissions for the lowest and highest cases are expected to increase 26% and 70% respectively over the 1990 levels, while the changes in per capita emissions will be a decrease of 5% and an increase of 18% (see *Table 4.2c*) respectively. Between 1997 and 2003, the per capita CO_2 emissions for the lowest scenario are higher than for the highest scenario due to the high population growth rate for the highest scenario during that period. After 2003, the per capita CO_2 emissions for the highest scenario remain higher than those for the lowest scenario.

For CH_4 emissions, both the total for all scenarios (see *Figure 4.2e*) and per capita emissions for the lowest and highest cases (see *Figure 4.2f*) have been projected to decrease at a dramatic rate until the year 2000, at which time the levels continue to decrease but at a very minimal rate (see *Tables 4.2b* and *4.2c*). Total CH_4 emissions have been projected to level out at about 33% and per capita emissions at around 24% of the 1990 levels for both the lowest and highest cases.

The drop between 1993 and 1997 has allowed Hong Kong to achieve an emissions level below its 1990 level in 1997, however, it has been projected that CO_2 levels will rise back to the 1990 level by 1999 and that by the year 2000, Hong Kong will again exceed the 1990 goal and not be able to return to such a level at any time over the study period (see *Figure 4.2a*). As mentioned above, CH_4 emissions will continue to decline and stay at a level well below the 1990 level (see *Figure 4.2b*).

For comparison, *Figure 4.2g* shows 1990 per capita CO_2 emissions of selected countries around the world and Hong Kong was found to be at the low end of the range. This is most likely due to Hong Kong's small size, diminishing industrial base, high use of mass transit and low use of automobiles per capita.

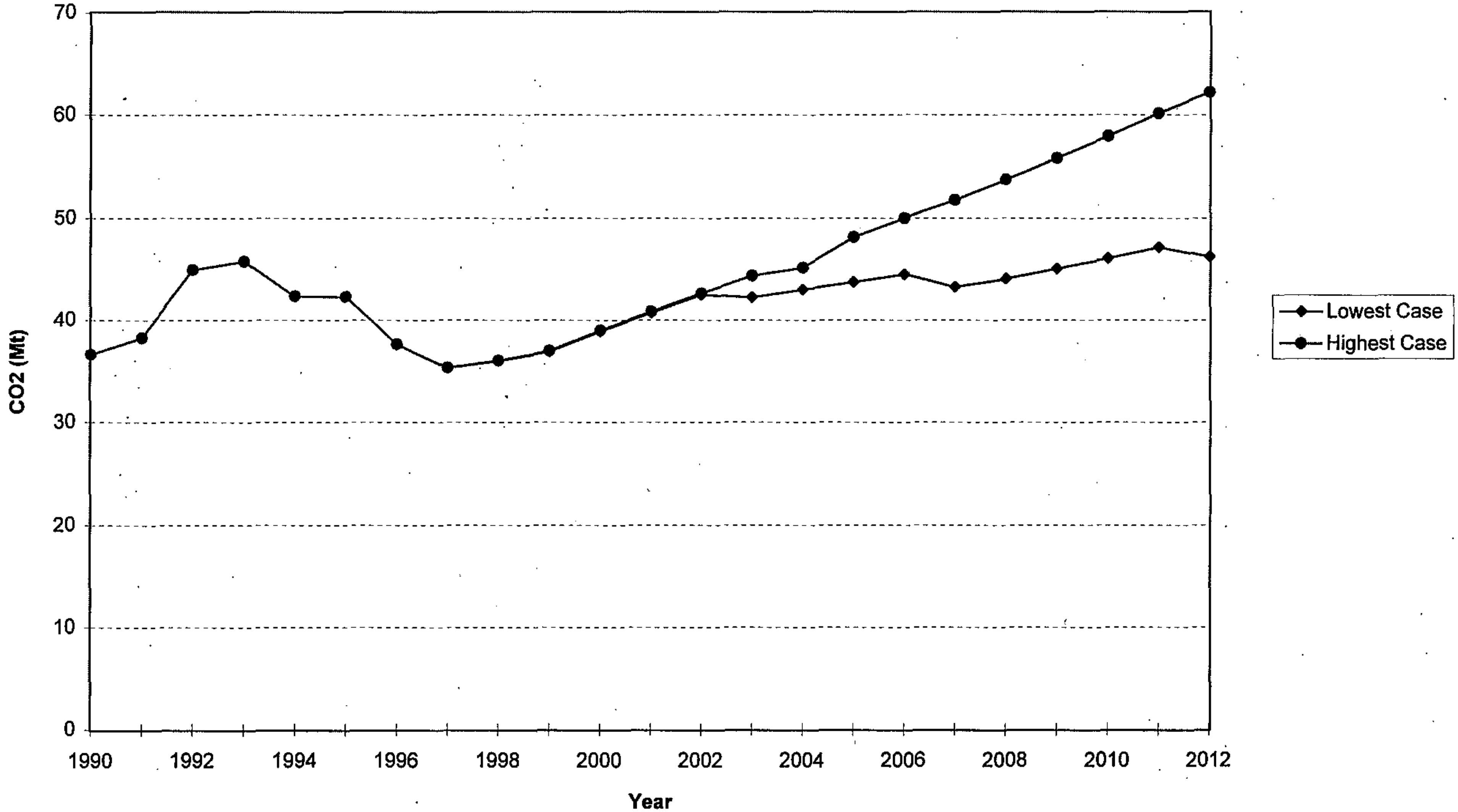

Figure 4.2a   Total Hong Kong CO2 Emissions - Lowest and Highest Cases

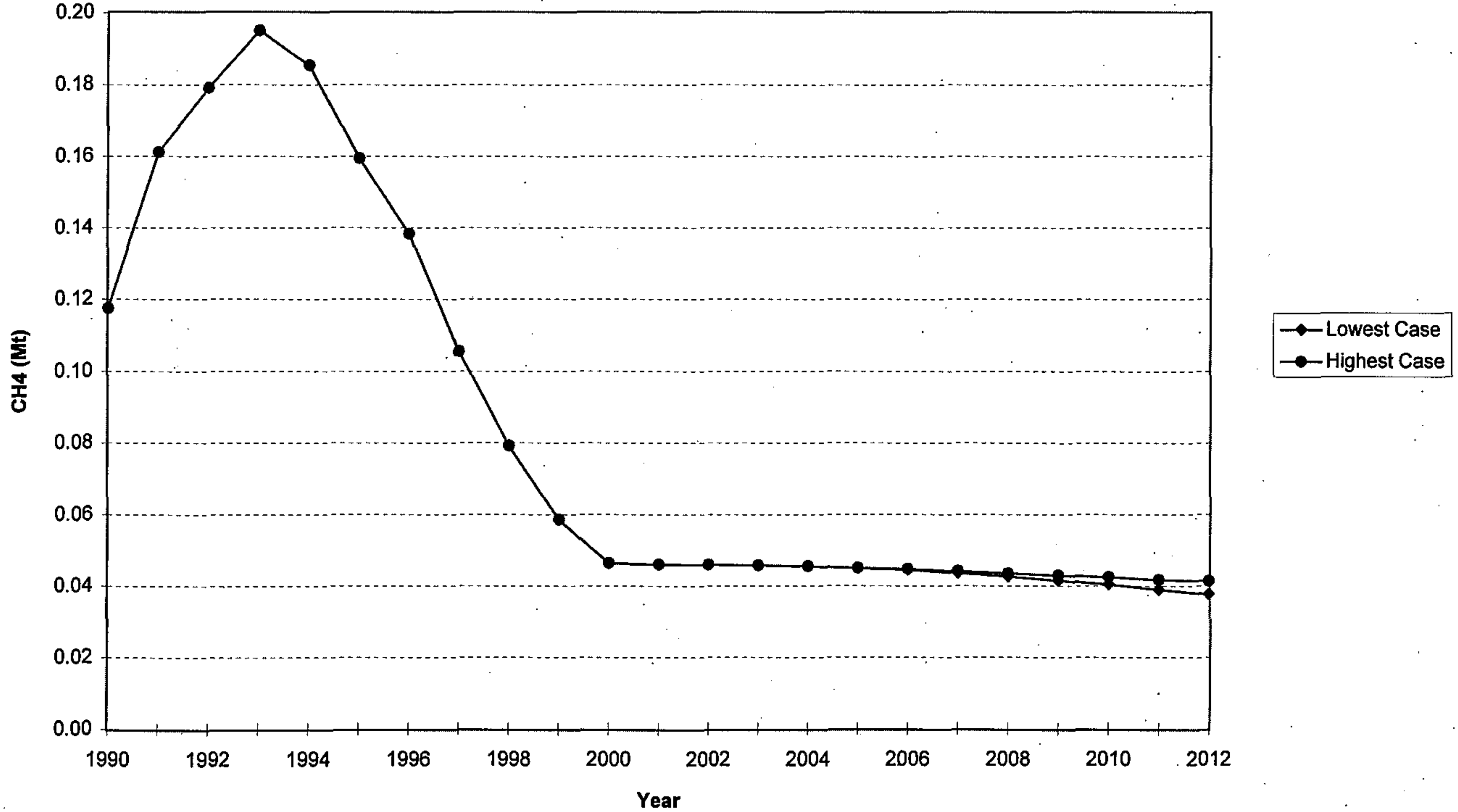

Figure 4.2b Total Hong Kong CH4 Emissions - Lowest and Highest Cases

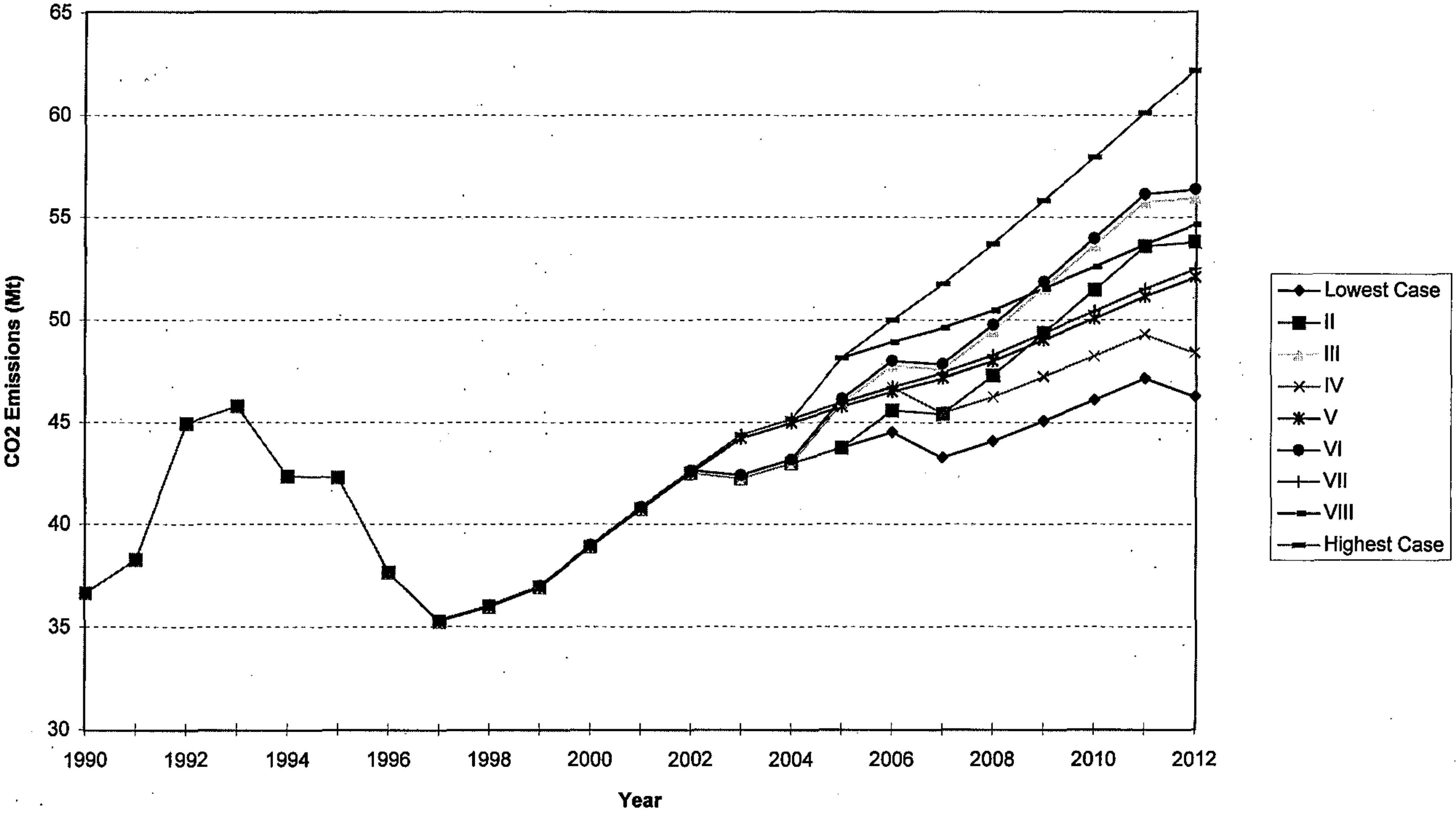

Figure 4.2c Total Hong Kong CO2 Emissions By Scenario

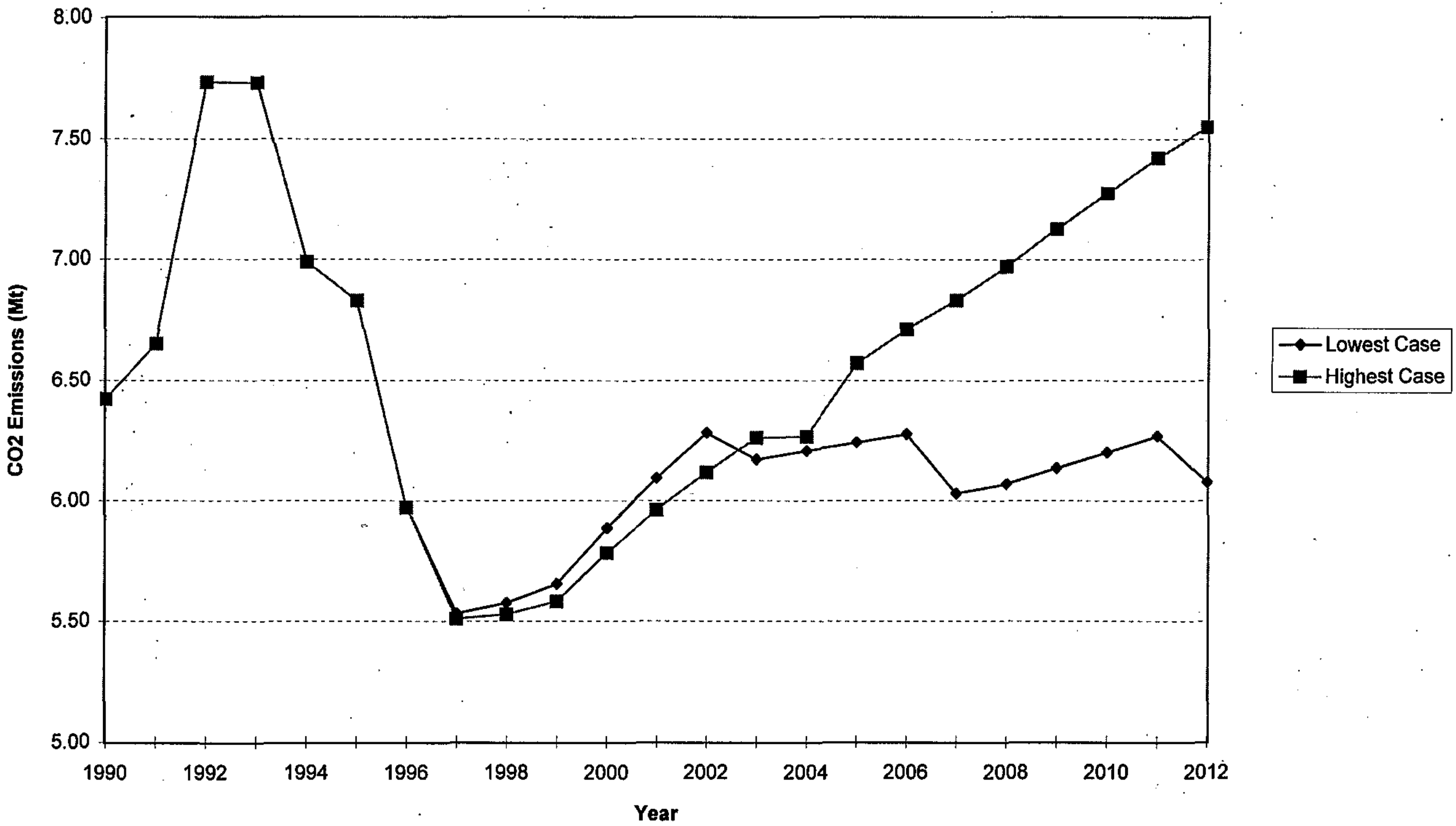

Figure 4.2d Hong Kong Per Capita CO2 Emissions From All Sources

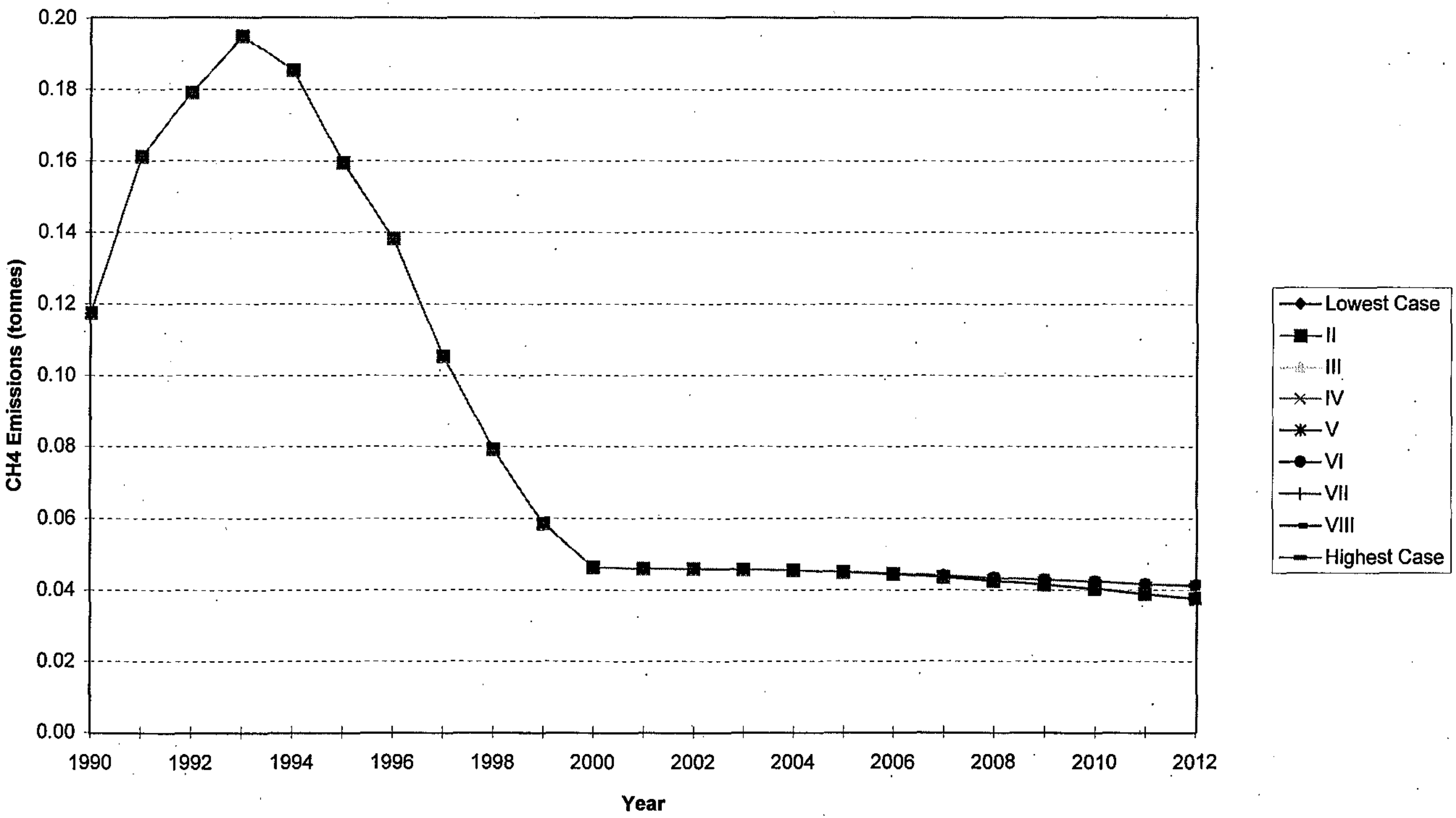

Figure 4.2e Total Hong Kong CH4 Emissions By Scenario

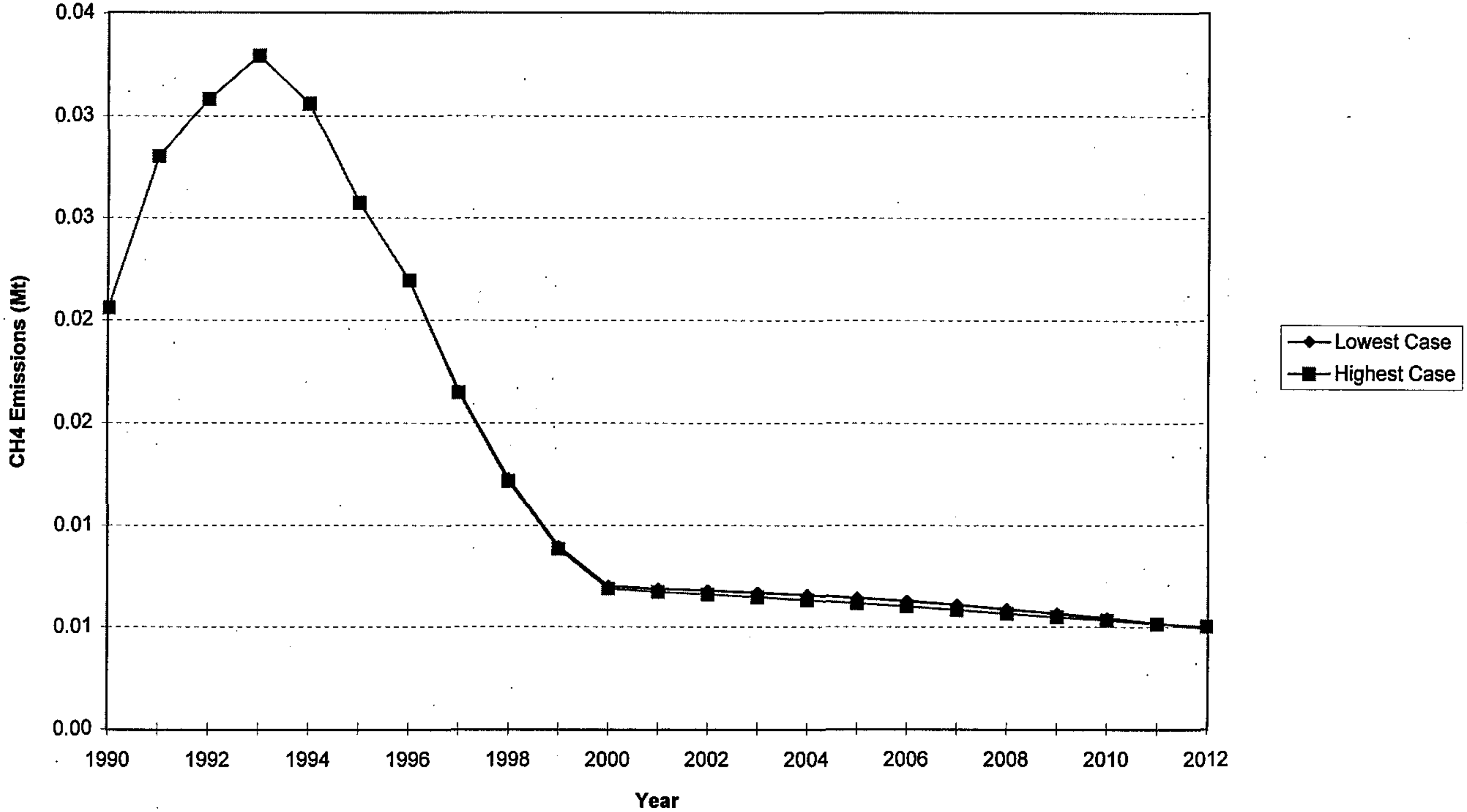

Figure 4.2f Hong Kong Per Capita CH4 Emissions From All Sources

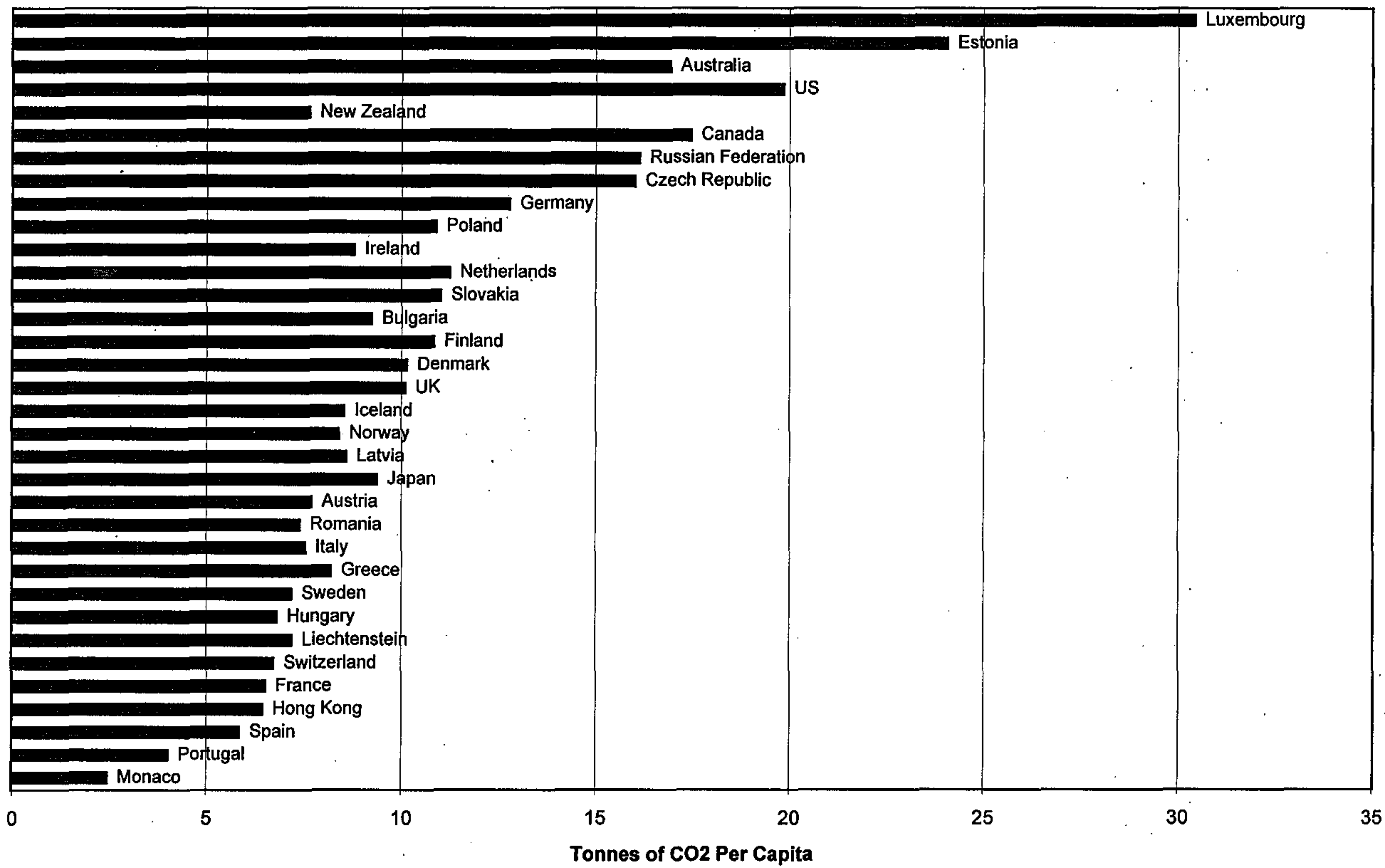

Figure 4.2g Per Capita CO2 Emissions For Various Countries in 1990

Table 4.2a *Total Hong Kong CO2 Emissions By Scenario (Mt)*

Scenario	Population	HEC New Plant	CLP after Black Point	Waste Incineration	1990	2000	2010	2012
I *Lowest*	TDS A	HEC Gas	CLP Gas	No Incin	36.61	38.87	46.08	46.25
II	TDS A	HEC Gas	CLP Coal	No Incin	36.61	38.87	51.45	53.79
III	TDS A	HEC Gas	CLP Coal	With Incin	36.61	38.87	53.62	55.94
IV	TDS A	HEC Gas	CLP Gas	With Incin	36.61	38.87	48.24	48.40
V	TDS A	HEC Coal	CLP Gas	No Incin	36.61	38.87	50.07	52.08
VI	TDS B	HEC Gas	CLP Coal	With Incin	36.61	38.96	53.97	56.35
VII	TDS B	HEC Coal	CLP Gas	No Incin	36.61	38.96	50.42	52.49
VIII	TDS B	HEC Coal	CLP Gas	With Incin	36.61	38.96	52.58	54.64
IX *Highest*	TDS B	HEC Coal	CLP Coal	With Incin	36.61	38.96	57.95	62.18

Table 4.2b *Total Hong Kong CH4 Emissions By Scenario (Mt)*

Scenario	Population	HEC New Plant	CLP after Black Point	Waste Incineration	1990	2000	2010	2012
I *Lowest*	TDS A	HEC Gas	CLP Gas	No Incin	0.12	0.05	0.04	0.04
II	TDS A	HEC Gas	CLP Coal	No Incin	0.12	0.05	0.04	0.04
III	TDS A	HEC Gas	CLP Coal	With Incin	0.12	0.05	0.04	0.04
IV	TDS A	HEC Gas	CLP Gas	With Incin	0.12	0.05	0.04	0.04
V	TDS A	HEC Coal	CLP Gas	No Incin	0.12	0.05	0.04	0.04
VI	TDS B	HEC Gas	CLP Coal	With Incin	0.12	0.05	0.04	0.04
VII	TDS B	HEC Coal	CLP Gas	No Incin	0.12	0.05	0.04	0.04
VIII	TDS B	HEC Coal	CLP Gas	With Incin	0.12	0.05	0.04	0.04
IX *Highest*	TDS B	HEC Coal	CLP Coal	With Incin	0.12	0.05	0.04	0.04

Table 4.2c *Per Capita Emissions for the Lowest and Highest Scenarios*

Year	CO_2 Emissions (tonnes)		CH_4 Emissions (tonnes)	
	Lowest Case	*Highest Case*	*Lowest Case*	*Highest Case*
1990	6.42	6.42	0.0206	0.0206
2000	5.89	5.78	0.0070	0.0069
2010	6.20	7.27	0.0054	0.0053
2012	6.08	7.55	0.0049	0.0050

4.3 SECTOR ANALYSIS

Figures 4.3a and *4.3b* show CO_2 emissions by fuel type for the lowest and highest scenarios. The main fuel source contributors to total emissions in Hong Kong are coal, natural gas and diesel. For the highest scenario, coal is by far the largest contributor to CO_2 emissions, while in the lowest case, there is a switch of the dominant contributor from coal to natural gas due to the choice of gas over coal for power generation.

Figures 4.3c and *4.3d* show CO_2 emissions by sector type for the lowest and highest scenarios. The most significant sector contributors to Hong Kong's total CO_2 emissions are the electric utilities, industrial and commercial use of diesel and road transport (see *Table 4.3a*).

Figures 4.3e and *4.3f* show CH_4 emissions by sector type for the lowest and highest scenarios. The most significant sector contributors to Hong Kong's CH_4 emissions are solid waste and sludge. CH_4 emissions from the electric utility sector are negligible and are incorporated into the 'Other sectors' category (see *Table 4.3b*).

Table 4.3c shows the total contribution of solid waste to Hong Kong's CO_2 and CH_4 emissions under two scenarios: with and without incineration starting in 2005. The significant decrease from 1993 to 2000 is the result of:

- the capping of old landfills;
- significant decreases in the production of methane from the old landfills; and
- increased capture of gas at the new strategic landfills.

There is a significant increase in CO_2 emissions from solid waste in 2005, with the commissioning of a waste-to-energy facility in Hong Kong (the two scenarios are the same prior to 2005). The reason for this being that the carbon in the waste that would otherwise take 30 to 50 years to fully decompose into CH_4 and CO_2, is converted into CO_2 instantly upon combustion. As electricity is generated by the combustion of waste, an offset for the reduced combustion of coal is included in the total CO_2 and CH_4 emissions of solid waste after 2005.

The continued decrease after 2005 in GHG emissions from solid waste is due to the increased capture of gas from the strategic landfills.

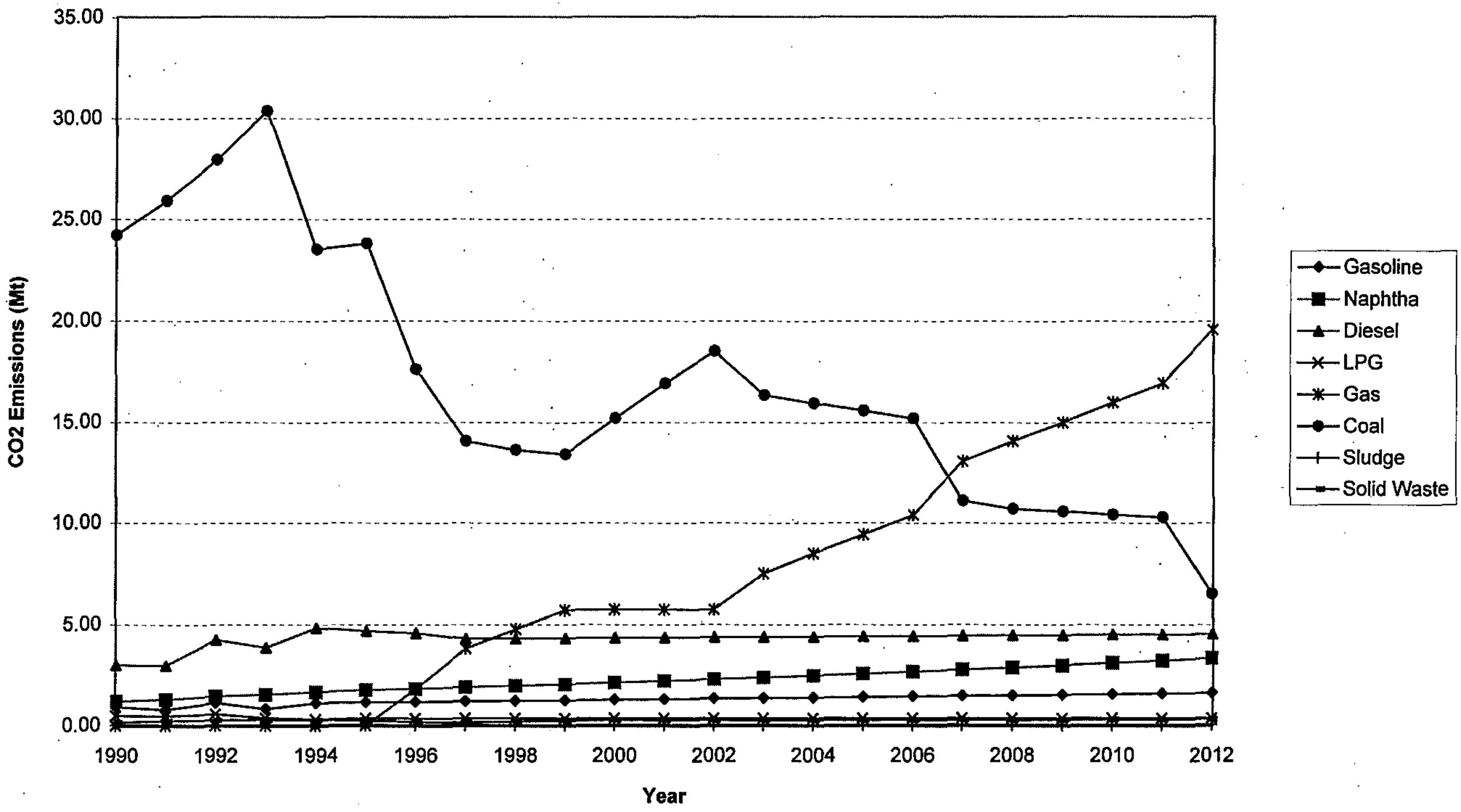

Figure 4.3a CO2 Emissions By Fuel Type - Lowest Case

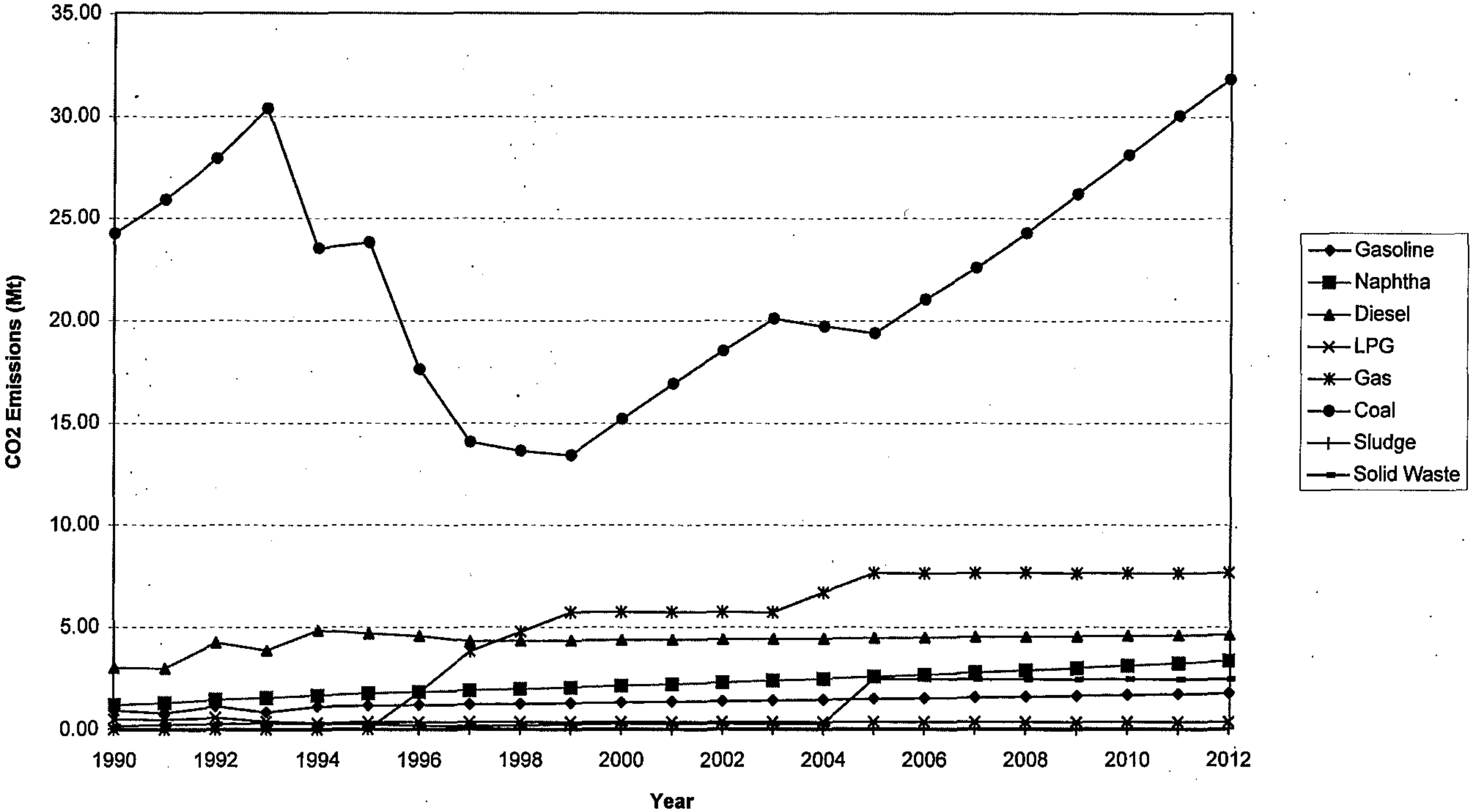

Figure 4.3b CO2 Emissions By Fuel Type - Highest Case

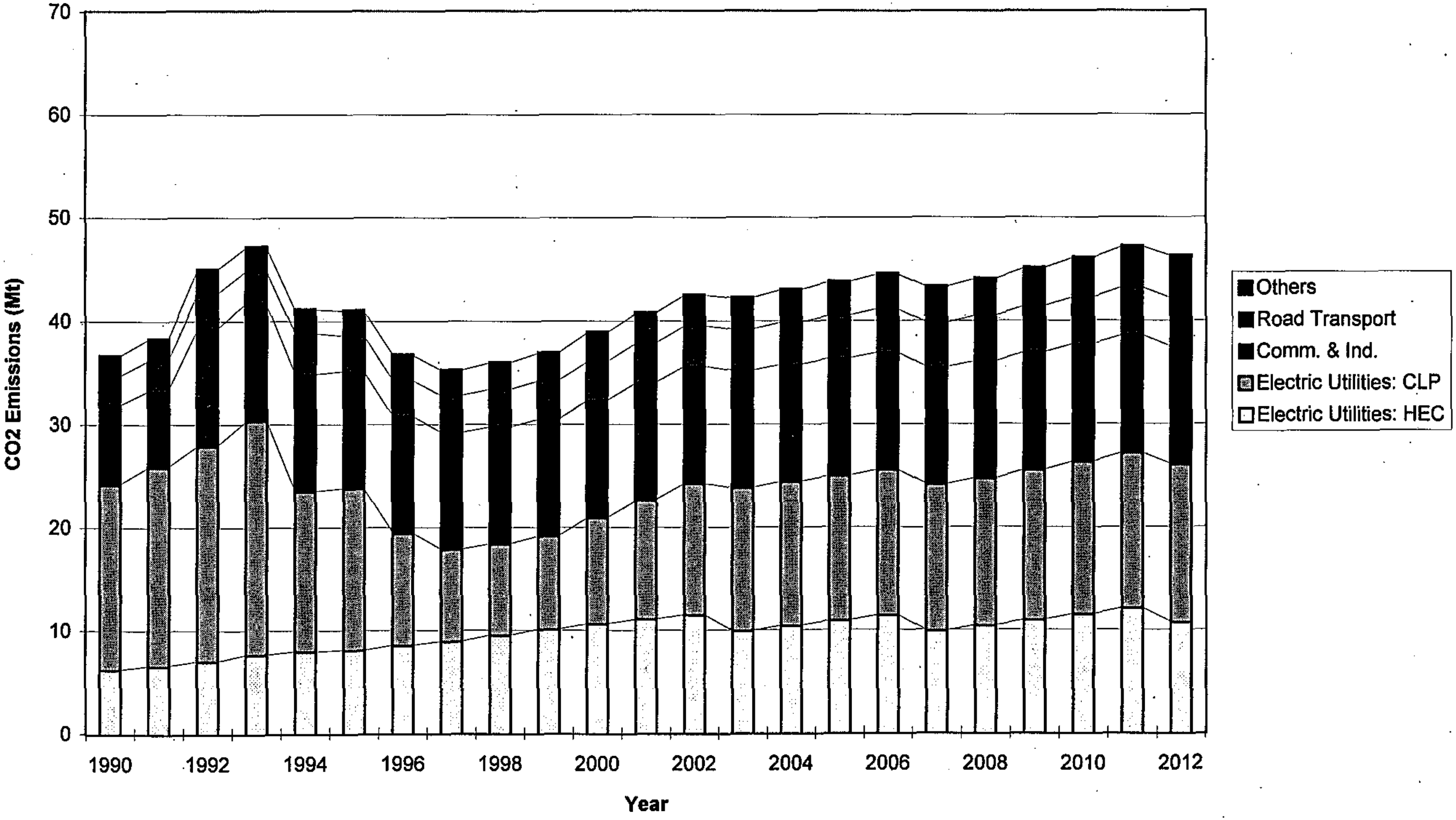

Figure 4.3c Major Sector Contributors To CO2 Emissions - Lowest Case

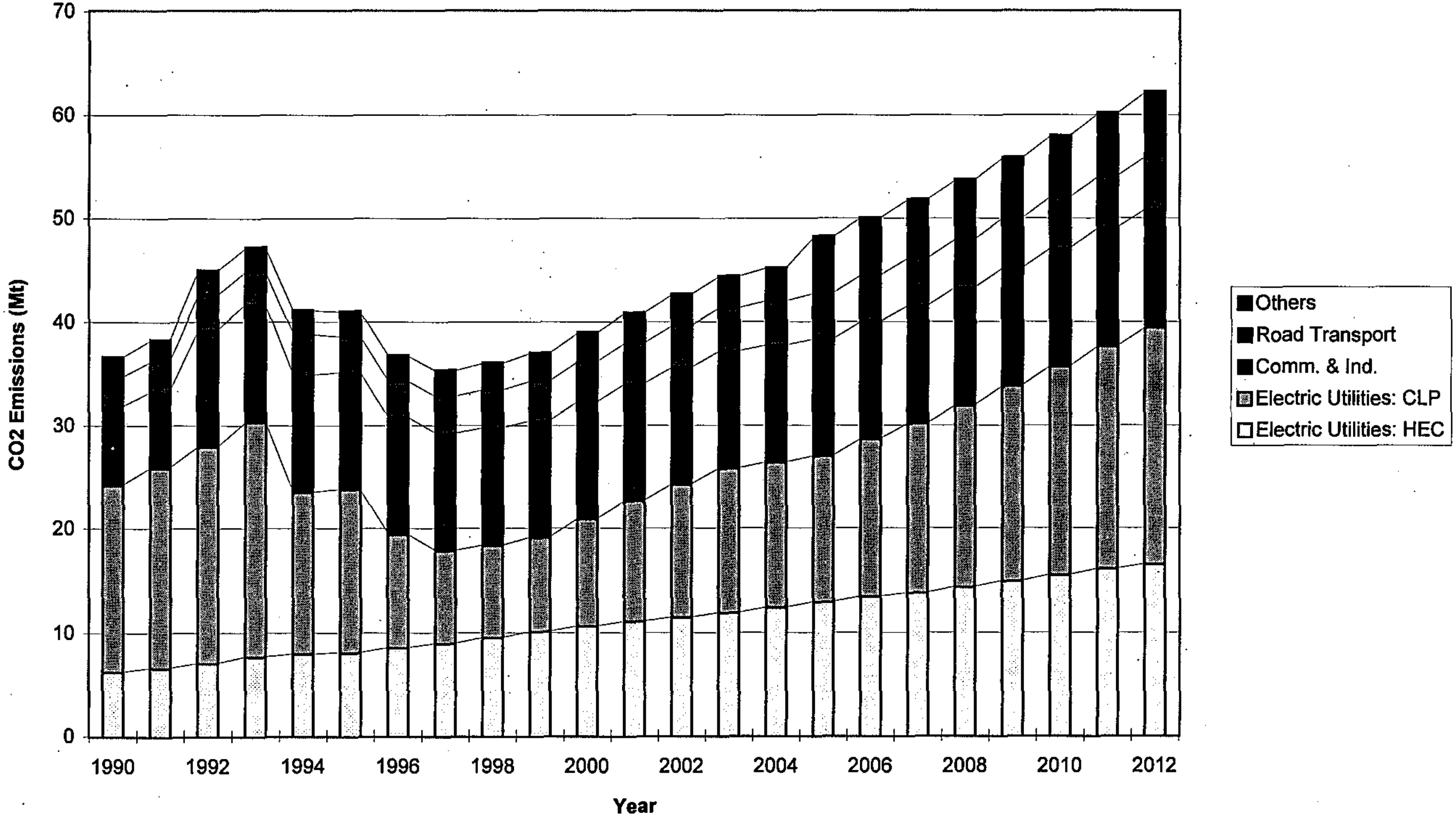

Figure 4.3d Major Sector Contributors To CO2 Emissions - Highest Case

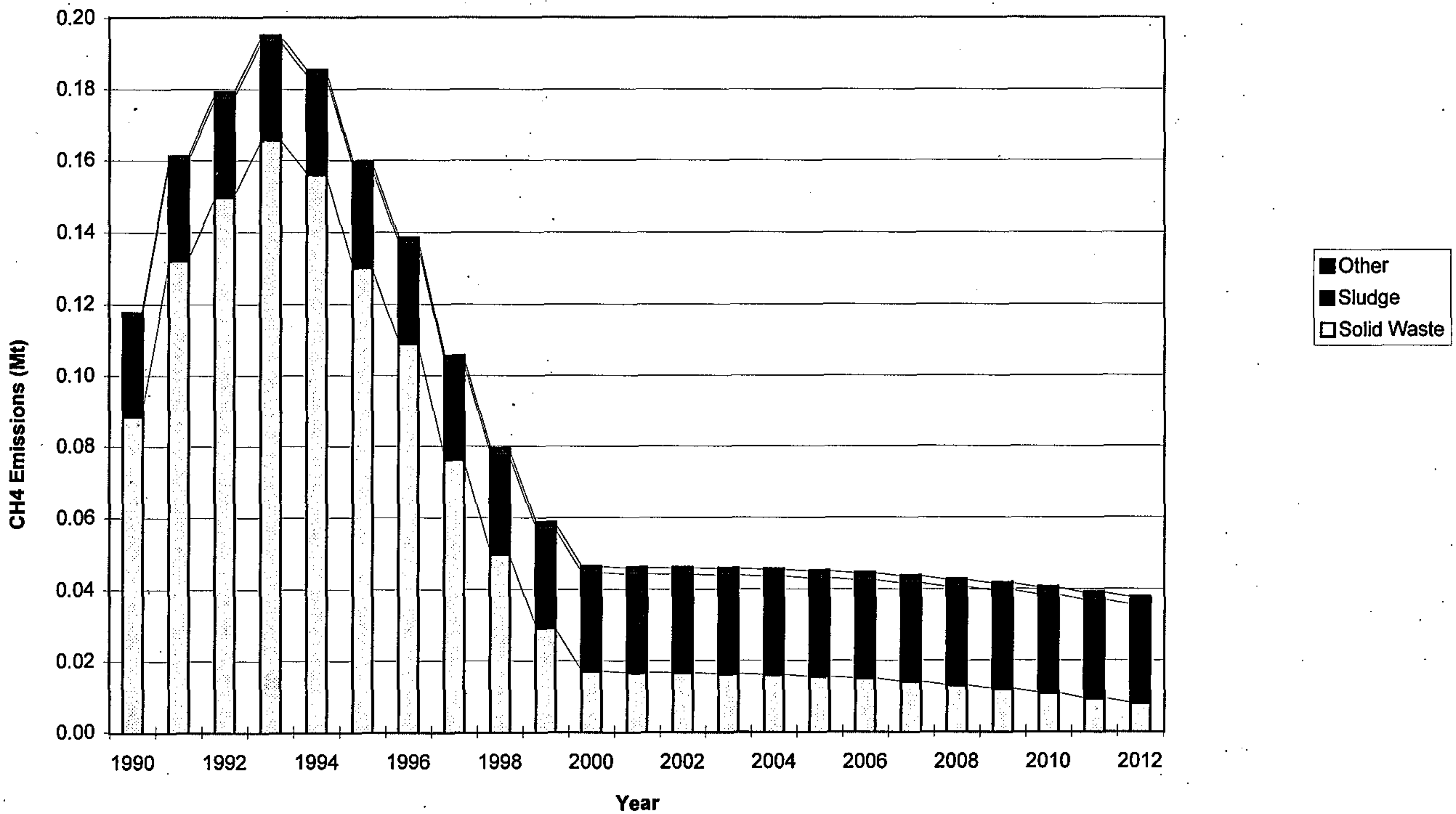

Figure 4.3e Major Sector Contributors To CH4 Emissions - Lowest Case

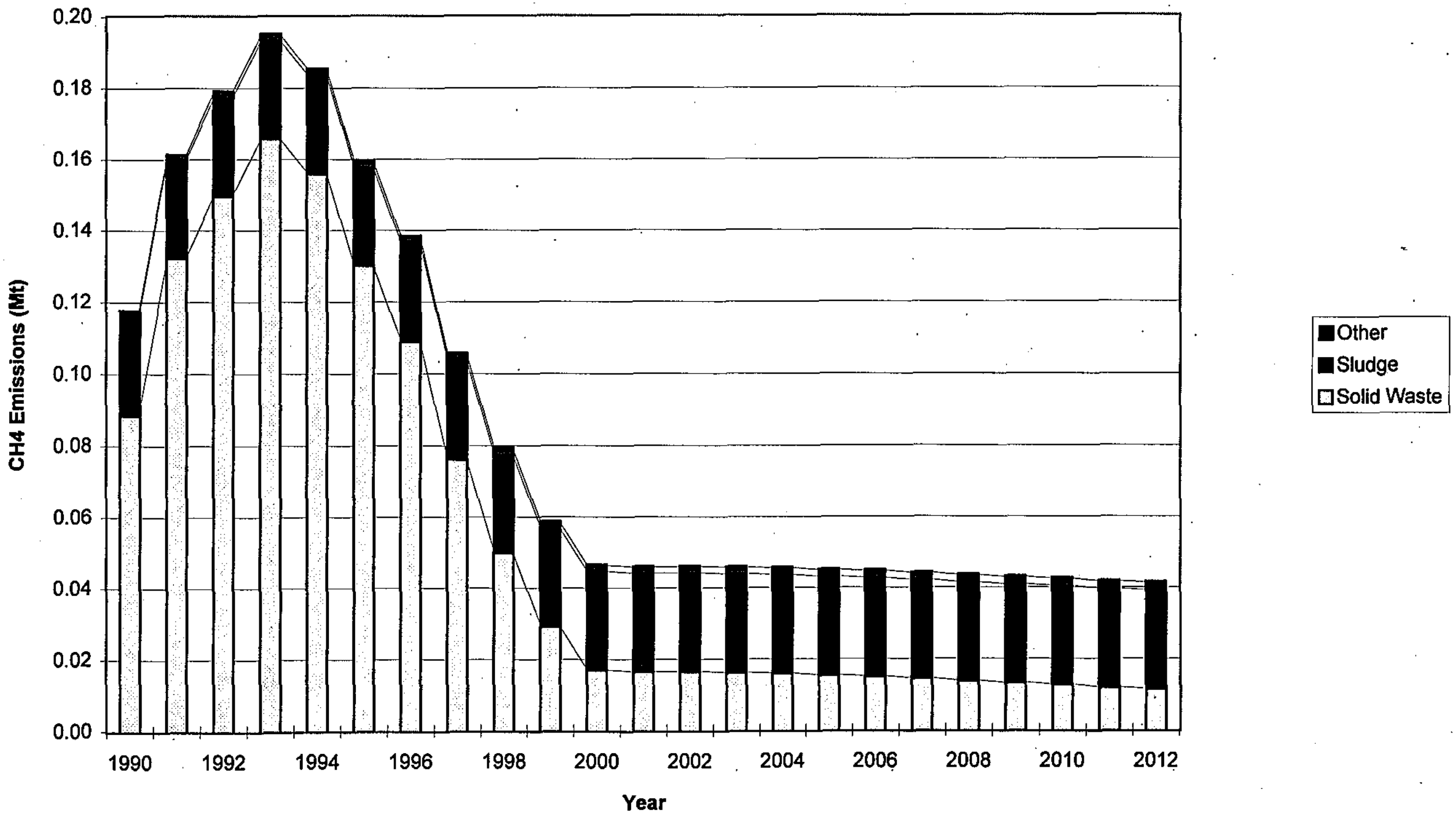

Figure 4.3f Major Sector Contributors To CH4 Emissions - Highest Case

Table 4.3a ***Major Contributors To Hong Kong CO2 Emissions By Sector (Mt)***

Scenario	Sector		1990	2000	2010	2012
I	Road Transport:	Gasoline & Diesel	2.86	3.77	4.54	4.72
Lowest	Comm. & Ind.:	Diesel	7.62	11.34	11.34	11.34
Case	Electric Utilities:	HEC	6.26	10.65	11.56	10.73
	Electric Utilities:	CLP	17.96	10.30	14.83	15.38
	Others:	Naphtha, LPG, Sludge & Waste	1.91	2.80	3.81	4.08
IX	Road Transport:	Gasoline & Diesel	2.86	3.87	4.89	5.13
Highest	Comm. & Ind.:	Diesel	7.62	11.34	11.34	11.34
Case	Electric Utilities:	HEC	6.26	10.65	15.54	16.56
	Electric Utilities:	CLP	17.96	10.30	20.20	22.92
	Others:	Naphtha, LPG, Sludge & Waste	1.91	2.80	5.97	6.22

Table 4.3b ***Major Contributors To Hong Kong CH4 Emissions By Sector (Mt)***

Scenario	Sector	1990	2000	2010	2012
I	Other Sectors	0.001	0.002	0.002	0.002
Lowest	Sludge	0.028	0.028	0.028	0.028
Case	Solid Waste	0.089	0.017	0.011	0.008
IX	Other Sectors	0.001	0.002	0.002	0.002
Highest	Sludge	0.028	0.028	0.028	0.028
Case	Solid Waste	0.089	0.017	0.013	0.012

Table 4.3c *Solid Waste Emissions of CO_2 and CH_4 (Mt)*

Year	CH_4 Emissions		CO_2 Emissions	
	No Incineration	*With Incineration*	*No Incineration*	*With Incineration*
1990	0.0885	0.0885	0.1623	0.1623
2000	0.0170	0.0170	0.2727	0.2727
2010	0.0108	0.0128	0.2987	1.3820
2012	0.0080	0.0116	0.3219	1.3896

4.4 *HEC CONTRIBUTIONS*

It should be emphasised that CO_2 is the main GHG from power generation. CH_4 emissions from the power sector are negligible.

It should be noted that at present, the electric utility sector as a whole is emitting 74% of their 1990 level (see *Figures* 4.3c and *4.3d*). This reduction in emissions is due mainly to the commencement of gas use by CLP and CLP's decreased sales of electricity to China.

Figure 4.4b shows HEC's percent contribution to total Hong Kong CO_2 emissions for the lowest and highest scenarios. In 1990, HEC contributed approximately 17% of the total CO_2 emissions in Hong Kong. Although the absolute CO_2 contributions from HEC have been increasing steadily (at approximately 0.4 Mt/year), percentage contributions have only increased over the 1990 level by less than 3%. There was a temporary dip in HEC percentage contribution in 1992 due to a sharp rise in the total CO_2 emissions. HEC percentage contributions are forecasted to increase until the year 1999, at which point it will level off in the highest scenario (approximately 27% or 10.13 Mt) or, under the lowest scenario from around 2003, contributions will decrease to a slightly lower level (approximately 24% or 9.95 Mt) before levelling off.

Figure 4.4a shows HEC's CO_2 contribution according to the use of coal versus gas at its new plant (see also *Figure 4.3c* and *4.3d*). It can be seen that the absolute emissions due to the use of coal will rise steadily to over 16Mt by the year 2012, while the use of gas will limit the absolute emissions to a range between 10 and 12 Mt. The 'dips' in the gas scenario reflect the commissioning of the various gas units of the new plant (in 2003, 2007 and 2012). This is due to shifting of the load from the existing coal-fired units to the new gas units, resulting in the subsequent reductions in CO_2 emissions.

Table 4.4.a presents the CO_2 and CH_4 emissions from HEC in the lowest and highest scenarios. *Figures 4.4c* and *4.4d* compare HEC CO_2 emissions with the total CO_2 emissions, in the lowest and highest scenarios respectively. It can be seen from *Table 4.4b* that the use of gas would, by the year 2012, bring CO_2 emissions to about 11Mt, which is about 1.8 times the 1990 HEC CO_2 emissions of 6Mt, while the coal option, at over 16Mt, would bring it to over 2.5 times that of the 1990 level.

Table 4.4a *Total HEC Emissions with a New Coal or Gas Fired Plant*

Year	CO_2 Emissions (Mt)		CH_4 Emissions (Mt)	
	Coal	*Gas*	*Coal*	*Gas*
1990	6.26	6.26	0.000067	0.000067
2000	10.65	10.65	0.000115	0.000115
2010	15.54	11.56	0.000168	0.000150
2012	16.56	10.73	0.000179	0.000153

Table 4.4b *Comparison of Total and HEC CO_2 Emissions (Mt)*

Year	Lowest Scenario		Highest Scenario	
	Total	*HEC*	*Total*	*HEC*
1990	36.61	6.26	36.61	6.26
2000	38.87	10.65	38.96	10.65
2010	46.08	11.56	57.95	15.54
2012	46.25	10.73	62.18	16.56

Figure 4.4a HEC Percent Contribution To Total Hong Kong CO2 Emissions - Lowest and Highest Cases

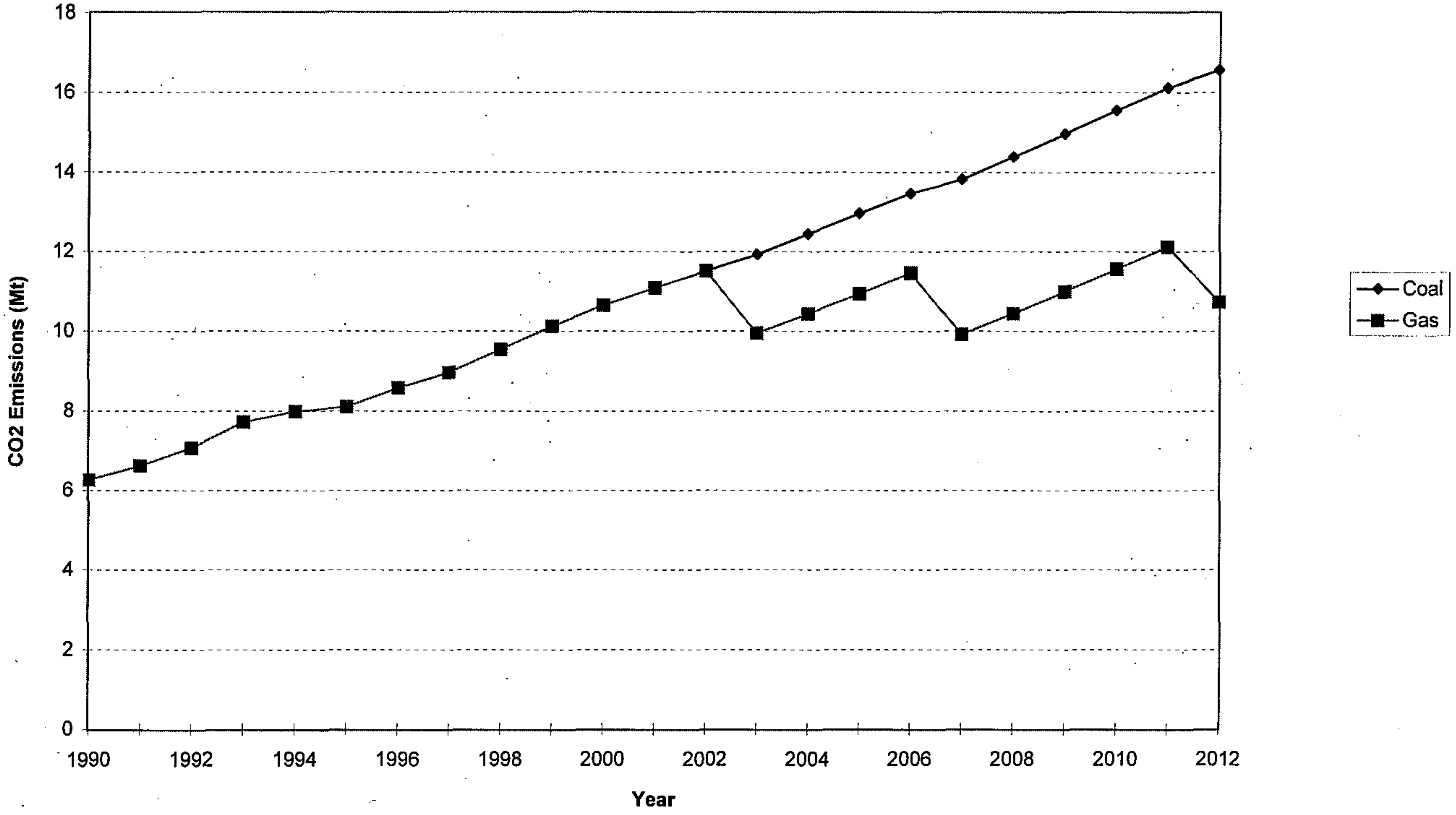

Figure 4.4b Total HEC CO2 Emissions By New Plant's Fuel Source

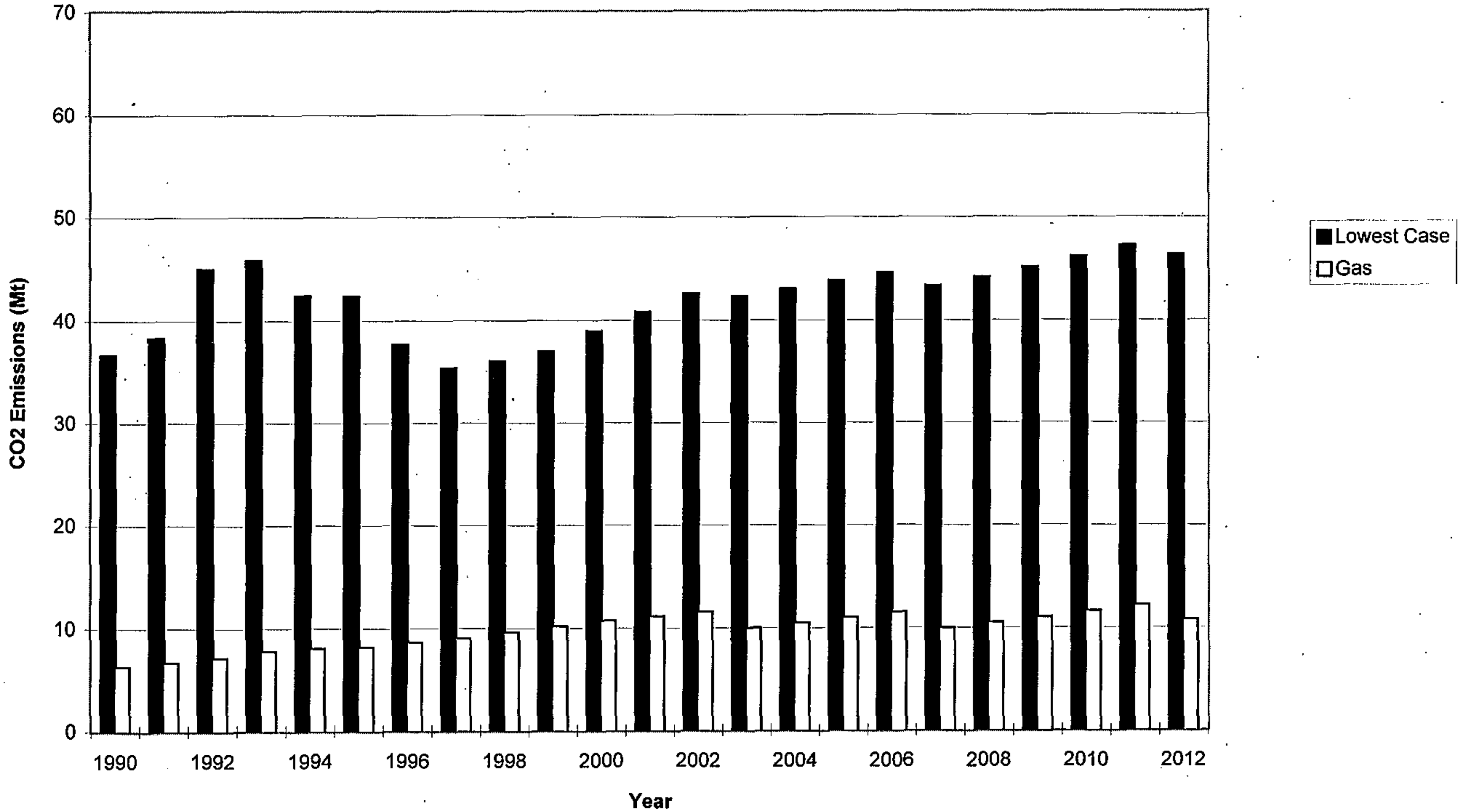

Figure 4.4c HEC Gas Option's Contribution To Total Hong Kong CO2 Emissions - Lowest Case

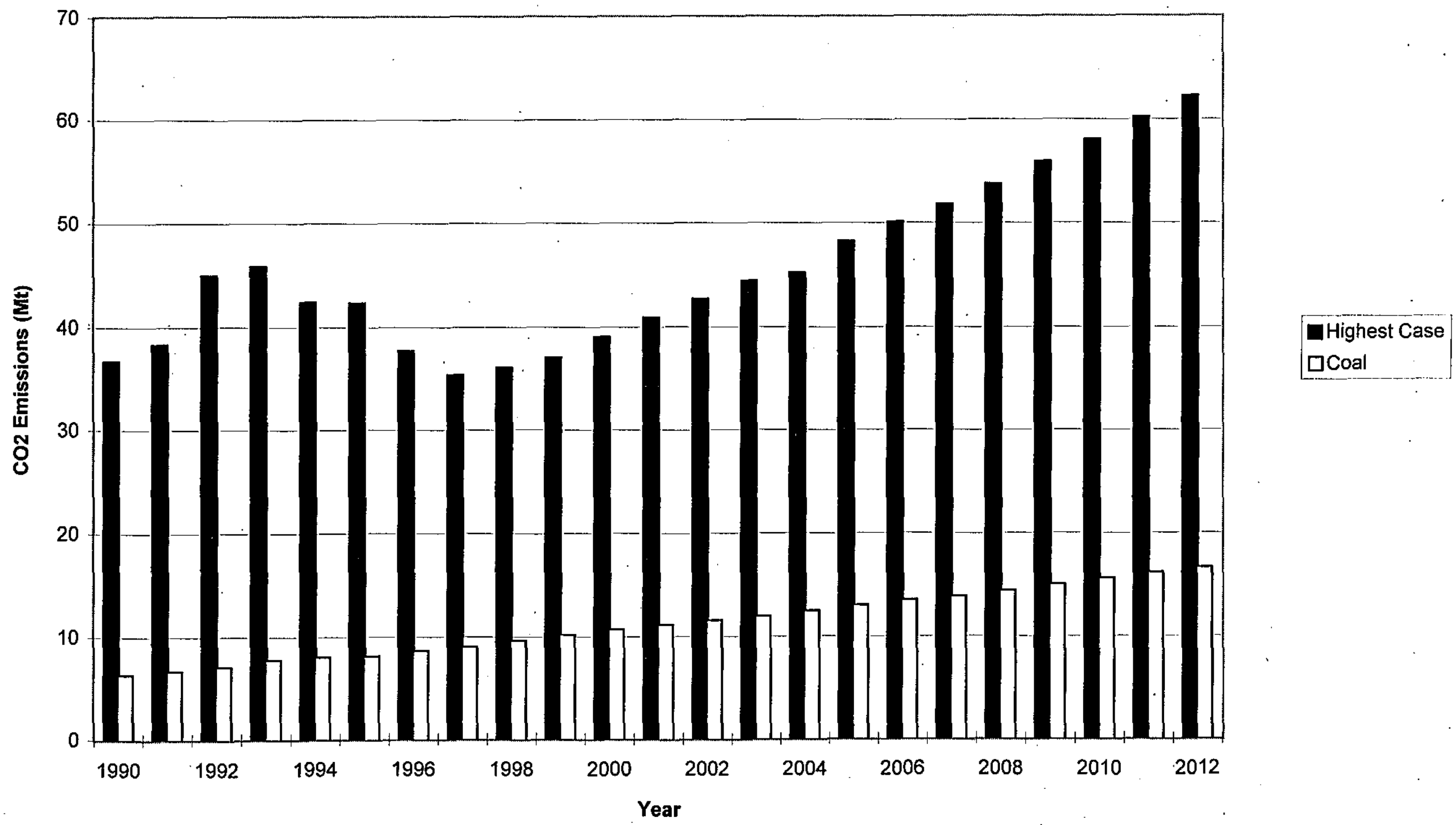

Figure 4.4d HEC Coal Option's Contribution To Total Hong Kong CO2 Emissions - Highest Case

5 OPTIONS FOR MITIGATION

5.1 INTRODUCTION

There are a number of options for the mitigation of GHG emissions from the electric utility sector, namely:

- increase the efficiency of electricity production from conventional fossil fuels (eg coal and gas);
- increase the efficiency of electricity consumption through improved lighting, air conditioning, motors, etc;
- switch to fuels that have lower GHG emissions than those currently in use (eg gas instead of coal); and
- sequester the GHG emissions.

These four options are discussed briefly in the following sections. Other electricity generation technologies are not discussed in this Study as they are either not feasible for Hong Kong or have not been developed enough for application in Hong Kong.

5.2 INCREASED EFFICIENCY OF ELECTRICITY PRODUCTION

Technologies to convert fuel into electricity have theoretical limitations. Although neither plant proposed by HEC reaches these limitations, the proposed plants are at the high end of currently available technologies in regards to efficiency.

Table 5.2a shows representative efficiencies for various types of power plants, as detailed in *Annex B* of *Technical Paper: Power Generation Technology Review*. As can be seen from the table, gas plant efficiencies range from 41% to 53%, while coal plant efficiencies range from 36% to 43%.

Table 5.2a ***Efficiencies for Various Types of Power Plants***

Type of Power Plant		Efficiency	Higher/ Lower Heat Value
Advanced Pulverised Coal	APC	40%	HHV
Integrated Gasification Combined Cycle	IGCC	43%	HHV
Pressurised Fluidised Bed Combustion	PFBC	42%	HHV
Circulating Fluidised Bed Combustion	CFBC	36%	HHV
Gas Fired Combined Cycle	GFCC	53%	LHV
Gas Fired Steam Cycle	GFSC	41%	LHV

Utilising GFCC over simple cycle GFSC results in a nearly 30% increase in efficiency, while utilising PFBC or IGCC results in a 15% increase over CFBC.

5.3 *INCREASED EFFICIENCY OF ELECTRICITY CONSUMPTION*

With certain exceptions, the end users of electricity in Hong Kong determine the end-use efficiency of electricity consumption. The users are left to determine the trade-off between higher capital costs and less expensive electricity bills.

As the determination of this trade-off has been left to free market operation, the following inherent problems arise:

- most consumers are unaware of the options for improving end-use efficiency;
- there are many institutional barriers to the implementation of energy efficiency measures (eg most office space in Hong Kong is rented for short periods making improvements uneconomic); and
- landlords determine the specifications for equipment, but the tenant often pays the bills.

In order to overcome these barriers and to improve the efficiency of electricity consumption, governments in other countries have instituted some of the following measures:

- energy efficiency standards for appliances and other electricity consuming items;
- requirements that electric utilities subsidise the installation of energy efficient items (lighting, motors, appliances, etc, also called demand-side management); and
- improved building codes and standards.

Hong Kong currently has a voluntary energy efficiency labelling programme for refrigerators and has implemented building codes (OTTV or overall thermal transfer value). However, the refrigerator labelling programme has lacked participation (three refrigerators were registered as of early this year) and the OTTV is only applicable to new buildings.

5.4 *SWITCHING FUELS*

Switching to fuels with lower GHG emissions is one of the most effective, and often least expensive, ways to reduce GHG emissions. Adjusting for efficiency, gas has approximately 50% of the GHG emissions when compared to coal. The increased use of gas by CLP is one of the main reasons there is a significant drop in GHG emissions from the electric utility sector between 1993 and 1997. Switching to fuels with no GHG emissions obviously has an even bigger impact.

However, switching fuels requires careful consideration as their are clear implications for the price of fuel (and hence electricity tariffs); the security of supply; and the technical feasibility.

5.5 *SEQUESTRATION*

Sequestration of carbon can reduce the amount of GHG in the atmosphere. Sequestration can be accomplished through either the removal of CO_2 from smoke stacks and the subsequent storage of the CO_2, or forestry programmes that increase the amount of carbon absorbed and store in the biomass.

5.5.1 *Removal From Smokestacks*

The removal of CO_2 from smokestacks is still in the conceptual stage and has not yet been tried on a large scale basis. Some of the different theories put forth include:

- low temperature (cryogenic) separation;
- polymeric membrane separation; and
- absorption in chemicals such as aqueous amine.

Once the CO_2 has been removed by one of these methods, it must be stored in such a way that it is not released back into the atmosphere. Some of the proposed methods of storage include:

- deep saline aquifers;
- depleted oil and gas reservoirs; and
- underground cavities.

Current estimates of the cost of removing CO_2 by each of these methods is significant, requiring high capital cost investment, as well as considerable amounts of energy to run the systems (eg liquefying the CO_2 by cooling it as it leaves the smokestack). Given the current level of technology, none of the above options should be considered feasible on a large scale basis.

5.5.2 *Afforestation*

A number of utility companies worldwide currently have programmes to sequester carbon in trees through a number of methods, including:

- paying logging companies to modify the way in which they manage their forests to preserve non-harvested biomass;
- purchasing land and turning it into park land which will never be developed; and
- planting trees.

As estimated by the Edison Electric Institute (an association of electric utilities in the USA), the cost of sequestering one tonne of CO_2 through the above methods costs from US $1 to $4. However, it should be noted that up to 1000 square kilometres could be needed to sequester the carbon released by one 250 MW power plant over its 30 year operational lifetime (the size of Hong Kong).

Major challenges with afforestation programmes include the development of mechanisms for monitoring implementation and maintenance, the lack of benchmarks to determine the contribution of the afforestation programme to GHG levels and the need to manage the programme in perpetuity.

5.5.3 *HEC's Compensation Plan*

In seeking to develop cost-effective approaches to offset greenhouse gas emissions from its operations, HEC is open to the concept of setting up sponsorship and/or funding the implementation of afforestation programmes. HEC has been researching successful experiences as reported by a number of US utility companies pursuing forestry strategies, including New England Power's Reduced-Impact Logging Project in Malaysia, American Electric Power's

Climate Challenge Tree Planting Project, and Southern California Edison Company's "Welcome Home 2000" Tree Planting Programme.

HEC intends to further explore the feasibility of compensation programmes to offset its greenhouse gas emissions by:

- providing funding to local activists such as green groups and Government Departments concerned for projects and campaigns involving tree planting and/or preservations; and

- taking a pro-active approach in searching for participation opportunities in forestry improvement programmes including forest conservation and rehabilitation, sustainable management of timber plantation, and controlled logging, especially in the area of Pearl River Delta, China.

6 *CONCLUSION*

This study has examined the contribution of a new power station fuelled by coal or gas to Hong Kong's projected GHG emissions over the period 1990 to 2012 for a range of population and infrastructure development scenarios. The principal conclusions are as follows:

- the major fuel source contributors to CO_2 emissions from Hong Kong are coal, natural gas, diesel and petrol (aircraft emissions, although significant, are excluded from this study as per IPCC guidelines);
- the main greenhouse gas emitted from electric utilities is CO_2 with only minor emissions of CH_4;
- electric utilities contribute 56% of total CO_2 emissions in 2012 in the lowest case scenario and 64% in the highest case scenario;
- the decline in CO_2 emissions from 1993 to 1997 is a consequence of clearly identifiable events that are not likely to be repeated;
- in the period 1996 to 1999, emissions of CO_2 are at or slightly below the 1990 emissions, but by 2000 and thereafter, exceed 1990 emissions;
- if HEC utilises gas for its new plant instead of coal, Hong Kong's 2012 CO_2 emissions will be reduced by approximately 5.8 million tonnes, or a reduction of 9.3% from the high case;
- under the lowest scenario with HEC utilising gas, Hong Kong's CO_2 emissions in 2012 will exceed 1990 emissions by 26% (9.6 million tonnes) and the per capita emissions will be below the 1990 level by 5% (0.34 tonnes per capita);
- under the highest scenario with HEC utilising coal, Hong Kong's CO_2 emissions in 2012 will exceed 1990 emissions by 70% (25.6 million tonnes) and the per capita emissions will be above the 1990 level by 18% (1.1 tonnes per capita).

Given that even under the low case scenario (which assumes the new station is gas fired) Hong Kong's 2012 CO_2 emissions will still exceed the 1990 emissions by 9.6 million tonnes. By burning gas for the new power station alone, it will not be able to return the Greenhouse Gas emissions to the 1990 levels.

Annex A

Framework Convention on Climate Change

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

The Parties to this Convention,

Acknowledging that change in the Earth's climate and its adverse effects are a common concern of humankind,

Concerned that human activities have been substantially increasing the atmospheric concentrations of greenhouse gases, that these increases enhance the natural greenhouse effect, and that this will result on average in an additional warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and humankind,

Noting that the largest share of historical and current global emissions of greenhouse gases has originated in developed countries, that per capita emissions in developing countries are still relatively low and that the share of global emissions originating in developing countries will grow to meet their social and development needs,

Aware of the role and importance in terrestrial and marine ecosystems of sinks and reservoirs of greenhouse gases,

Noting that there are many uncertainties in predictions of climate change, particularly with regard to the timing, magnitude and regional patterns thereof,

Acknowledging that the global nature of climate change calls for the widest possible cooperation by all countries and their participation in an effective and appropriate international response, in accordance with their common but differentiated responsibilities and respective capabilities and their social and economic conditions,

Recalling the pertinent provisions of the Declaration of the United Nations Conference on the Human Environment, adopted at Stockholm on 16 June 1972,

Recalling also that States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction,

Reaffirming the principle of sovereignty of States in international cooperation to address climate change,

Recognizing that States should enact effective environmental legislation, that environmental standards, management objectives and priorities should reflect the environmental and developmental context to which they apply, and that standards applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries,

Recalling the provisions of General Assembly resolution 44/228 of 22 December 1989 on the United Nations Conference on Environment and Development, and resolutions 43/53 of 6 December 1988, 44/207 of 22 December 1989, 45/212 of 21 December 1990 and 46/169 of 19 December 1991 on protection of global climate for present and future generations of mankind,

Recalling also the provisions of General Assembly resolution 44/206 of 22 December 1989 on the possible adverse effects of sea-level rise on islands and coastal areas, particularly low-lying coastal areas and the pertinent provisions of General Assembly resolution 44/172 of 19 December 1989 on the implementation of the Plan of Action to Combat Desertification,

Recalling further the Vienna Convention for the Protection of the Ozone Layer, 1985, and the Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, as adjusted and amended on 29 June 1990,

Noting the Ministerial Declaration of the Second World Climate Conference adopted on 7 November 1990,

Conscious of the valuable analytical work being conducted by many States on climate change and of the important contributions of the World Meteorological Organization, the United Nations Environment Programme and other organs, organizations and bodies of the United Nations system, as well as other international and intergovernmental bodies, to the exchange of results of scientific research and the coordination of research,

Recognizing that steps required to understand and address climate change will be environmentally, socially and economically most effective if they are based on relevant scientific, technical and economic considerations and continually re-evaluated in the light of new findings in these areas,

Recognizing that various actions to address climate change can be justified economically in their own right and can also help in solving other environmental problems,

Recognizing also the need for developed countries to take immediate action in a flexible manner on the basis of clear priorities, as a first step towards comprehensive response strategies at the global, national and, where agreed, regional levels that take into account all greenhouse gases, with due consideration of their relative contributions to the enhancement of the greenhouse effect,

Recognizing further that low-lying and other small island countries, countries with low-lying coastal, arid and semi-arid areas or areas liable to floods, drought and desertification, and developing countries with fragile mountainous ecosystems are particularly vulnerable to the adverse effects of climate change,

Recognizing the special difficulties of those countries, especially developing countries, whose economies are particularly dependent on fossil fuel production, use and exportation, as a consequence of action taken on limiting greenhouse gas emissions,

Affirming that responses to climate change should be coordinated with social and economic development in an integrated manner with a view to avoiding adverse impacts on the latter, taking into full account the legitimate priority needs of developing countries for the achievement of sustained economic growth and the eradication of poverty,

Recognizing that all countries, especially developing countries, need access to resources required to achieve sustainable social and economic development and that, in order for developing countries to progress towards that goal, their energy consumption will need to grow taking into account the possibilities for achieving greater energy efficiency and for controlling greenhouse gas emissions in general, including through the application of new technologies on terms which make such an application economically and socially beneficial,

Determined to protect the climate system for present and future generations,

Have agreed as follows: (the articles followed).

Annex B

Example IPCC Worksheet Calculations

IPCC CO2 - 1990

			B	C	D	E	F	G	H	I	J	K	L	M	N	O	P		
FUEL TYPES			Imports	Exports	International Bunkers	Stock Change	Apparent Consumption	Conversion Factor[b]	Apparent Consumption	Carbon Emission Factor	Carbon Content	Carbon Content	Carbon Stored	Net Carbon Emissions	Fraction of Carbon Oxidised	Actual Carbon Emissions	Actual CO2 Emissions	Actual CO2 Emissions	Actual CO2 Emissions
			Kt	Kt	Kt	Kt		TJ / Kt	TJ	tonnes/TJ	tonnes	Gg	Gg	Gg		Gg	Gg CO2	Kg CO2	tonnes CO2
Liquid Fossil	Primary	Crude Oil					0		0	20	0	0		0	0.99	0	0	0	0
		Natural Gas Liquids					0		0	17.2	0	0		0	0.99	0	0	0	0
	Secondary	Gasoline	301.805				301.805	44.8	13520.864	18.9	255544.33	255.54433		255.54433	0.99	253	928	927625916	927626
		Jet Kerosene	1832.015				1832.015	44.59	81689.54885	19.5	1592946.2	1592.9462		1592.9462	0.99	1,577	5,782	5782394715	5782395
		Other Kerosene					0		0	19.6	0	0		0	0.99	-	-	0	0
	see note[a]	Gas / Diesel Oil	3007.738				3007.738	43.33	130325.2875	20.2	2632570.81	2632.57081		2632.57081	0.99	2,606	9,556	9556232034	9556232
		Residual Fuel Oil					0	40.19	0	21.1	0	0		0	0.99	-	-	0	0
		LPG	169.224				169.224	47.31	8005.98744	17.2	137702.984	137.702984		137.702984	0.99	136	500	499861832	499862
		Ethane					0		0	16.8	0	0		0	0.99	0	0	0	0
	see note[a]	Naphtha	370.411				370.411	45.01	16672.19911	20	333443.982	333.443982		333.443982	0.99	330.109542	1210.40166	1210401655	1210402
		Bitumen					0		0	22	0	0		0	0.99	0	0	0	0
		Lubricants					0		0	20	0	0		0	0.99	0	0	0	0
		Other Oil					0		0	20	0	0		0	0.99	0	0	0	0
LIQUID FOSSIL TOTALS							5681.193		250213.8869	252.5	4952208.31	4952.20831		4952.20831		4,903	17,977	1.7977E+10	17976516
Solid Fossil	Primary	Anthracite					0	20.25	0	26.8	0	0		0	0.98	-	-	0	0
		Coking Coal					0		0	25.8	0	0		0	0.98	0	0	0	0
		Other Bit. Coal	9905.775				9905.775	26.38	261314.3445	25.8	6741910.09	6741.91009		6741.91009	0.98	6,607	24,226	2.4226E+10	24225930
		Sub-Bit. Coal					0		0	26.2	0	0		0	0.98	0	0	0	0
		Lignite					0		0	27.6	0	0		0	0.98	0	0	0	0
		Peat					0		0	28.9	0	0		0	0.98	0	0	0	0
	Secondary	BKB & Patent Fuel					0		0	25.8	0	0		0	0.98	0	0	0	0
		Coke Oven / Gas Coke					0	28.47	0	29.5	0	0		0	0.98	-	-	0	0
SOLID FOSSIL TOTALS							9905.775		261314.3445		6741910.09	6741.91009		6741.91009		6,607	24,226	2.4226E+10	24225930
GASEOUS FOSSIL		Natural Gas (Dry)					0		0	15.3	0	0		0	0.995	0	0	0	0
TOTAL							15586.968		511528.2314		11694118.4	11694.1184		11694.1184		11,510	42,202	4.2202E+10	42202446
Biomass	Solid	Charcoal	16.252				16.252	20.52	333.49104	29.9	9971.3821	9.9713821		9.9713821	0.98	9.77195445	35.8304997	35830499.7	35830
BIOMASS TOTAL							16.252		333.49104		9971.3821	9.9713821		9.9713821		9.77195445	35.8304997	35830499.7	35830
Note: a Since the energy statistics have classified gas/diesel oils with naphtha and no further info was available at the time of these calculations, the numbers for this category was placed under the gas/diesel oil category as it is the less efficient.																			
Note: b Hong Kong imports, for each type of solid fuel, from a variety of sources, hence the conversion factors of the least efficient source were used.																			
Specific Gravity of fuel / diesel and gas oils = 0.8251																			

Conversion From Mass to Energy Units

OIL		Aviation Kerosene			Motor Gasoline			Diesel / Gas / Fuel Oils			Naphtha		LPG		TOTAL
Conversion Factor				44.59			44.8			43.33		45.01		47.31	
		Ml	Kt	TJ	Ml	Kt	TJ	Ml	Kt	TJ	Kt	TJ	Kt	TJ	
SECTOR															
Energy						0	0		0	0	370.411	16672.1991		0	16672.1991
Industrial									0	0		0		0	0
Comm/Domestic									0	0		0	169.224	8005.9874	8005.98744
T: Aviation	domestic		0	0					0	0		0		0	0
	national	2303.262	1832.0146	81689.531					0	0		0		0	81689.5308
T: Road					388.524	301.80544	13520.884	3588.98	2996.7983	129851.27		0		0	143372.154
TOTAL				81689.531			13520.884			129851.27		16672.1991		8005.9874	249739.872

COAL		Anthracite		Bituminous		Coke Oven Coke		TOTAL
Conversion Factor			20.25		26.38		28.47	
		Kt	TJ	Kt	TJ	Kt	TJ	
SECTOR								
Energy			0	9905.775	261314.34		0	261314.34
Industrial			0		0		0	0
Comm/Domestic			0		0		0	0
Aviation	domestic							
	national							
Transport								
TOTAL			0		261314.34		0	261314.34

For converting mass to energy units.

IPCC CH4 - 1990

9/12/97			FUEL CONSUMPTION							EMISSION FACTORS							EMISSIONS BY FUEL							TOTAL EMISSIONS	TOTAL EMISSIONS
			TJ							Kg / TJ							Kg							Gg	Kg
			A1	A2	A3		A4	A5	A6	B1	B2	B3		B4	B5	B6	C1	C2	C3		C4	C5	C6	D	E
ACTIVITY			Coal	Natural Gas	Oil		Wood / Wood Waste	Charcoal	Other Biomass & Wastes	Coal	Natural Gas	Oil		Wood / Wood Waste	Char-coal	Other Biomass & Wastes	Coal	Natural Gas	Oil		Wood / Wood Waste	Charcoal	Other Biomass & Wastes		
Energy Industries			261314		16672					1	1	3		30	200	30	261314	0	50017		0	0	0	0.311330942	311331
Manufacturing Industries & Construction										10	5	2		30	200	30	0	0	0		0	0	0	0	0
Transport	Domestic Aviation											0.5					0	0	0		0	0	0	0	0
	Road (Gasoline/Diesel)				13521	129851.3					50	20	5				0	0	270417.677	649256	0	0	0	0.919674029	919674
	Railways									10		5					0	0	0		0	0	0	0	0
	National Navigation				81690					10		5					0	0	408447.654		0	0	0	0.408447654	408448
Other Sectors	Commercial / Institutional									10	5	10		300	200	300	0	0	0		0	0	0	0	0
	Residential				8006					300	5	10		300	200	300	0	0	80060		0	0	0	0.080059874	80060
	Agriculture / Forestry / Fishing	Stationary								300	5	10		300	200	300	0	0	0		0	0	0	0	0
		Mobile									5	5					0	0	0		0	0	0	0	0
TOTAL																	261314	0	808942	649256	0	0	0	1.719512499	1719512
																									0
International Marine Bunkers																	0	0	0	0	0	0	0	0	0
International Aviation Bunkers																	0	0	0	0	0	0	0	0	0

TABLE I-2
CARBON EMISSION FACTORS (CEF)

Fuel	Carbon Emission Factor (t C/TJ)
LIQUID FOSSIL	
Primary fuels	
Crude oil	20.0
Orimulsion	22.0
Natural Gas Liquids	17.2
Secondary fuels/products	
Gasoline	18.9
Jet Kerosene	19.5
Other Kerosene	19.6
Shale Oil	20.0
Gas/Diesel Oil	20.2
Residual Fuel Oil	21.1
LPG	17.2
Ethane	16.8
Naphtha	(20.0) (a)
Bitumen	22.0
Lubricants	(20.0) (a)
Petroleum Coke	27.5
Refinery Feedstocks	(20.0) (a)
Refinery Gas	18.2 (b)
Other Oil	(20.0) (a)
SOLID FOSSIL	
Primary Fuels	
Anthracite	26.8
Coking Coal	25.8
Other Bituminous Coal	25.8
Sub-bituminous Coal	26.2
Lignite	27.6
Oil Shale	29.1
Peat	28.9
Secondary Fuels/Products	
BKB & Patent Fuel	(25.8) (a)
Coke Oven / Gas Coke	29.5
Coke Oven Gas	13.0 (b)
Blast Furnace Gas	66.0 (b)
GASEOUS FOSSIL	
Natural Gas (Dry)	15.3
BIOMASS	
Solid Biomass	29.9
Liquid Biomass	(20.0) (a)
Gas Biomass	(30.6) (a)

(a) This value is a default value until a fuel specific CEF is determined. For Gas biomass, the CEF is based on the assumption that 50% of the carbon in the biomass is converted to methane and 50% is emitted as CO_2. The CO_2 emissions from biogas should not be included in national inventories. If biogas is released and not combusted 50% of the carbon content should be included as methane.
(b) For use in the sectoral calculations.

TABLE I-3
SELECTED NET CALORIFIC VALUES

	Factors (TJ/10^3 tonnes)
Refined Petroleum Products	
Gasoline	44.80
Jet Kerosene	44.59
Other Kerosene	44.75
Shale Oil	36.00
Gas/Diesel Oil	43.33
Residual Fuel Oil	40.19
LPG	47.31
Ethane	47.49
Naphtha	45.01
Bitumen	40.19
Lubricants	40.19
Petroleum Coke	31.00
Refinery Feedstocks	44.80
Refinery Gas	48.15
Other Oil Products	40.19
Other Products	
Coal Oils and Tars derived from Coking Coals	28.00
Oil Shale	9.40
Orimulsion	27.50

See the *Greenhouse Gas Inventory Reference Manual* for sources.

Hongkong Electric
Coal 26.38

TABLE I-4
FRACTION OF CARBON OXIDISED

Coal[1]	0.98
Oil and Oil products	0.99
Gas	0.995
Peat for electricity generation[2]	0.99

1 This figure is a global average but varies for different types of coal, and can be as low as 0.91.

2 The fraction for peat used in households may be much lower.

Other Assumptions

ASSUMPTION		SOURCE
Specific gravity of jet fuel	0.7954	*Mobil Oil Hong Kong Ltd. (1996)*
Specific gravity of gasoline	0.7768	*Mobil Oil Hong Kong Ltd. (1996) - average of LP and ULP gasoline*
Specific gravity of diesel	0.835	*Mobil Oil Hong Kong Ltd. (1996)*
Specific gravity of naphtha	0.8499	*ASTM D396 (No. 1 Distillate Oil)*
Molecular weight of CO2	44.0	
Molecular weight of CH4	16.0	

Annex C

Reponses to Comments

Response to Comments
Technical Paper on Greenhouse Gas Study for the Stage 1 EIA for its Proposed New Power Station

No.	Department	Reference	Comments	Consultants' Response
1.	EPD/H M Wong/ 20 June 1997	General Comments	It is noted that there are a number of areas where HEC/the consultants' assumption in estimating the GHG emission which we considered to be NOT appropriate (please see our detailed comments below). Hence we cannot accept the paper at this stage and the consultants are requested to revise and amend the GHG inventory.	Clarification meetings have been held with EPD which have produced a modified set of assumptions and further information. These have been used to revise the GHG inventory, and the discussion and conclusions of the Technical Papaer (see attached)
2.			Section 6, page 15 - Conclusion - Whilst we agree in general with the conclusion that gas is the much better fuel option than coal from the perspective of greenhouse gas impact subject to revision of the inventory estimation stated above, HEC, in drawing the conclusion, should focus on comparing the impacts of the two fuel and technology options which is one of the key objectives of the study rather than commenting on policy issues which are outside the scope of the study.	Noted, the emphaisi of the report will be modified as requested.
			Furthermore, HEC should quantify and present clearly how much better is the gas option in terms of minimising greenhouse gas impact; and possibly enabling Hong Kong to meet the target of keeping greenhouse gas emissions at or below 1990 levels. This information is important for the government to consider on the type of fuel for the propose power plant.	Figure 4.3d (Total GHG emissions from HEC) presents the difference in GHG emissions from gas and coal firing of the new station in easily comparable bar chart form. The difference between the two bars indicates the reduced GHG emissions from gas fired plant. The quantities concerned will be stated in the text.

No.	Department	Reference	Comments	Consultants' Response
8.			Section 2.1.2, last sentence, page 3 - The comment made in the last sentence is irrelevant to the study. Notwithstanding this, if comments are made, then HEC should give a balance picture by also citing examples of countries where success was recorded on GHG reduction programs and targets.	It is appropriate that the Client and the Administration are made aware of the degree of debate and lack of concensus associated with the GHG issue in both the scientific and political spheres. Citing examples of 'success stories' would not give a balanced view since these examples are relatively isolated.
9.			Section 2.3. last para., page 4 - An official reference to Hong Kong Government's policy on the FCCC could be found at para. 9.13 of "The Hong Kong Environment: A Green Challenge for the Community - Second Review of the 1989 White Paper Pollution in Hong Kong - A time to Act" (PELB 1993), which says "...Our view is that the immediate need is to assess and improve Hong Kong's performance in line with the principles of the Conventions." (FCCC is one of the Conventions).	Thank you for the reference which will be included in the report, and which acknowledges the need to assess and improve HK's performance, while not providing a binding agreement or commitment to achieving the 1990 GHG levels post 2000, as stated in the report.
10.			Figure 4.2b - HEC should explain why for the period 1997 - 2003 the per capita GHG for the "lowest case" are even higher than that for the "highest case".	The per capita GHG emissions were calculated by dividing the total emissions by population. In the high case scenario population grows faster than in the low case. Since the high scenario *population* grew at a faster rate than the emissions in the period quoted, they appeared lower than the low scenario where the *emissions* grew faster than the population in the period quoted (eg the relative size of the denominator grew faster in the high scenario).
11.			2nd last para., page 11 - HEC should indicate what is the generating capacity of the incinerator(s) assumed in arriving at the offset on coal consumption.	The assumed capacity is 200 MW as provided by EPD. A reference will be made in the text.
12.			Figure 4.3d - It is not clear from the paper how the results of the "HEC Coal" and "HEC Gas" are arrived at. HEC should provide detailed data, explanation and assumptions. Also, does "HEC Gas" means "HEC Coal plus HEC Gas (new station)"? HEC should state clearly the meaning of the terms used in the paper.	HEC Gas means the pre existing HEC system (which is coal fired) with the new plant utilising gas, whilst HEC Coal means the HEC system with the new plant utilising coal. Further information regarding the assumptions for these categories will be provided.
13.			Section 5.1, last sentence, page 12 - Discussion on the "last option" quoted cannot be found in the technical paper referred. HEC should explain.	The 'last option' was included in error and the reference will be deleted.

No.	Department	Reference	Comments	Consultants' Response
18.			Section 3.2 - I was advised by the Royal Observatory that NMVOC, NO_x and CO are not important GHG in their own right but indirectly influence the concentration of some other GHG through atmospheric chemistry. The indirect effects for these gases are complex and depend on when and where they are emitted. In recent studies, the GWP of these gases are still under a lot of debate and the figure of GWP is not well established. In addition, the presentation of SO_2 as a "climate cooler" but without stressing its contribution to acid rain and other air quality deterioration is unacceptable. Is the consultant proposing that more SO_2 should be emitted by the electric utilities to combat global climate change?	The IPCC guidelines recommend the calculation of emissions of gases included in the report. The Royal Observatory is correct in its advise. However, we were requested by EPD to include the other gases. The other gases will be discussed but not included in the calculations. This report has only addressed GHGs and not the other environmental issues associated with the gases analysed, eg the ground level impacts of ozone formation from NOx, etc. The comment that SO2 can potentially reduce the impacts of global warming is illustrative of the multiplicity of impacts from the new plant.
19.			In Table 3.4a, diesel is assumed to be used by transport sector only is totally wrong. I was advised by EPD Mr Raymond Leung that vehicle usage of diesel is only one sixth of the total consumption. In fact, industrial consumption of fossil fuel was decreasing since 1990 due to the migration of industry out of Hong Kong.	Please see comment No.4 above.
20.			In table 3.5a, I could not agree that the projection of diesel consumption should be based solely on transport studies as the consumption by non-transport sector such as construction and industries is not reflected appropriately. In fact with annual growth rate of registered vehicles declined from 7.8% in 1990 to 1.3% in 1996, and the total number of registered vehicles only increased by less than one-third, it is hardly convincing that the growth of CO_2 emission from ground transport sector should almost double the 1990 levels by 1996 (as shown in figure 4.3e).	Please see comment No.4 above.

Response to Comments
Technical Paper on Greenhouse Gas Study
for the Stage 1 EIA for its Proposed New Power Station

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1.	EPD/H M Wong/ 20 June 1997	General Comments	It is noted that there are a number of areas where HEC/the consultants' assumption in estimating the GHG emission which we considered to be NOT appropriate (please see our detailed comments below). Hence we cannot accept the paper at this stage and the consultants are requested to revise and amend the GHG inventory.	Clarification meetings have been held with EPD which have produced a modified set of assumptions and further information. These have been used to revise the GHG inventory, and the discussion and conclusions of the Technical Papaer (see attached)
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No.	Department	Reference	Comments	Consultants' Response
3.			Table 3.2b, page 6 - Compliance by individual gas - FCCC requires that every greenhouse has shall be returned, individually or jointly, to 1990 levels [Article 4, para. 2(b)]. HEC should, in addition to the "joint" picture presented, address the emission of the major greenhouse gases, namely carbon dioxide and methane, individually and present graphs separately. To avoid misinterpretation, explanation for not presenting information on other less important greenhouse gases, such as NO_x, should be provided in the paper, the Stage 1 EIA report if appropriate.	Noted, explanation will be provided.
4.			Table 3.4a, page 7 - Diesel - To assume that all diesel to be used in the transport sector would grossly overestimate future emissions because diesel from sectors other than transport, like form industry and infrastructure, would not undergo the rates of growth as high as that projected by CTS-II. Hong Kong's industrial sector's diesel consumption has been declining and there are no future projects planned that are comparable in size and scale with the construction and reclamation activities of the Airport Core Projects.	Following the most recent consultations with EPD and with the benefit of additional information regarding diesel consumption, the assumptions have been revised.
5.			Table 3.4a, page 7 - Aviation Fuel - Aviation fuel should not be included in the calculation according to the assessment guidelines on national greenhouse gas inventories by the Intergovernmental Panel on Climate Change (IPCC).	Noted and will not be included in the Final Report.
6.			Table 4.1a, page 9 - Scenarios - The assumptions underlying the various scenarios are not stated clearly (e.g. what is the picture of sharing of load of the power plants in Hong Kong assumed? What is assumed for the solid waste and sludge disposal in Hong Kong? What is meant by "CLP meets all new needs after completion of Black Point with Coal?",...etc). HEC should provide more detailed information on the assumptions made with the various scenarios for consideration.	Noted and further explanation will be incorporated into the report.
7.		Specific Comments	The title page should be 'HEC New Power Station Stage 1 EIA: Technical paper on the Greenhouse Gas Study' instead of 'Site Search for a New Power Station Stage 1 EIA: Greenhouse Gas Study - Final Report'.	Noted and title will be changed.

No.	Department	Reference	Comments	Consultants' Response
8.			Section 2.1.2, last sentence, page 3 - The comment made in the last sentence is irrelevant to the study. Notwithstanding this, if comments are made, then HEC should give a balance picture by also citing examples of countries where success was recorded on GHG reduction programs and targets.	It is appropriate that the Client and the Administration are made aware of the degree of debate and lack of concensus associated with the GHG issue in both the scientific and political spheres. Citing examples of 'success stories' would not give a balanced view since these examples are relatively isolated.
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No.	Department	Reference	Comments	Consultants' Response
14.			Section 5.2, page 12 - The section should also cover discussion on efficiency of gas-fired power generation as compared with coal-fired one.	Noted and reference will be included.
15.	PELB		In section 2.1.1, the reference to Montreal Protocol and its difficulties in achieving a global agreement is irrelevant because the United Nations Framework Convention on Climate Change (UNFCCC) also requires action by individual member parties to take action to reduce the greenhouse gas (GHG) emissions.	It is relevant to note that despite there being general concensus on the causes, effects and neeed for action relating to CFCs and ozone depletion, the Montreal Protocol has not been consistently responded to and that this is being mirrored in the difficulties encountered in the GHG debate, which, as pointed out in response 8, does not enjoy even the same level of scientific and political concensus.
16.			In section 2.1.2, the last statement is a speculative statement which the consultants should not base their assessment on. It is disappointing to note that a reputable consultants in environmental assessment should made such statement as implying that environmental protection would damage economic growth. The purpose of this EIA exercise is to provide objective, well informed expert advice to both the Client and the Administration. The balance between environmental concern and economic growth is a policy issue for the Administration.	Rather than speculation, it is unrealistic not to acknowledge that for certain issues, the costs and provision of environmental protection may affect economic growth. GHG emissions are such an issue. The IPCC Second Assessment on Climate Change, 1995 illustrates this point, with the costs of stabilising at 1990 levels being as much as 2% of GDP for OECD countries, with greater implications for developing countries. The comment itself acknowledges the sometimes antagonistic nature of environmental protection and economic growth by refering to 'the balance' between the two being a policy issue - if there was not a degree of conflict between the two, then there would be no need for a 'balance'. This issue is also reflected in the recent discord between the Group of Seven nations at the summit in Colorado, USA. The United States, Canada and Japan resisted signing an agreement to reduce CO_2 emissions by 15% by 2010 due to concerns over the economic impact of the agreement.
17.			Accordingly to the final IR of the Stage 1 EIA, the report should contains findings on the GHG emission targets and policies of China and Guangdong. The consultants should but do not provide these in section 2.2.	The IR states that the GHG study would review inter alia existing and planned Chinese and Guandong targets. This has been done, with the conclusion that whilst China is one of the signatory countries to the Convention, it is classified as a developing country and as such GHG reduction targets are still under development.

No.	Department	Reference	Comments	Consultants' Response
18.			Section 3.2 - I was advised by the Royal Observatory that NMVOC, NO_x and CO are not important GHG in their own right but indirectly influence the concentration of some other GHG through atmospheric chemistry. The indirect effects for these gases are complex and depend on when and where they are emitted. In recent studies, the GWP of these gases are still under a lot of debate and the figure of GWP is not well established. In addition, the presentation of SO_2 as a "climate cooler" but without stressing its contribution to acid rain and other air quality deterioration is unacceptable. Is the consultant proposing that more SO_2 should be emitted by the electric utilities to combat global climate change?	The IPCC guidelines recommend the calculation of emissions of gases included in the report. The Royal Observatory is correct in its advise. However, we were requested by EPD to include the other gases. The other gases will be discussed but not included in the calculations. This report has only addressed GHGs and not the other environmental issues associated with the gases analysed, eg the ground level impacts of ozone formation from NOx, etc. The comment that SO2 can potentially reduce the impacts of global warming is illustrative of the multiplicity of impacts from the new plant.
19.			In Table 3.4a, diesel is assumed to be used by transport sector only is totally wrong. I was advised by EPD Mr Raymond Leung that vehicle usage of diesel is only one sixth of the total consumption. In fact, industrial consumption of fossil fuel was decreasing since 1990 due to the migration of industry out of Hong Kong.	Please see comment No.4 above.
20.			In table 3.5a, I could not agree that the projection of diesel consumption should be based solely on transport studies as the consumption by non-transport sector such as construction and industries is not reflected appropriately. In fact with annual growth rate of registered vehicles declined from 7.8% in 1990 to 1.3% in 1996, and the total number of registered vehicles only increased by less than one-third, it is hardly convincing that the growth of CO_2 emission from ground transport sector should almost double the 1990 levels by 1996 (as shown in figure 4.3e).	Please see comment No.4 above.

No.	Department	Reference	Comments	Consultants' Response
21.			In Table 3.5a, I could not agree with the claim that energy projection is difficult because of different population scenarios. During 1990 - 1996, the average increase in local electricity consumption (measured at meter point) and our Gross Domestic Product (GDP) at constant 1990 market prices were both 5.1%. Furthermore, the percentage of domestic, commercial, and industrial consumption in 1990 and 1996 are 22% and 26%, 49% and 57%, and 29% and 18% respectively. These figures indicated that commercial consumption, which is related to our level of economic activities, is more significant that our domestic consumption which reflects our population situation.	To conclude that commercial consumption and population are not correlated would be difficult from the statistics provided in the comment. Many developed countries have seen a divergence between their GDP growth rates and their electricity growth rates, with electricity growing more slowly. Much of the divergence is due to the move away from heavy industry and towards services, a situation which is occuring in Hong Kong. Electricity growth rates of between 3.3% and 4.4% have been assumed in the study. These will be included in a table in the report.
22.			Furthermore, I understand that both electric utilities have submitted sets of electricity load forecast, based on with and without Demand Side Management, for 1997 - 2005 to the Economic Service Branch. Therefore, I have serous doubt why the consultants consider ti is the Government's responsibility to *"provide a forecast of expected consumption under different population estimates in TDSR"*.	The load forecast that has been submitted to ESB includes HEC's estimates of Demand Side Management (DSM), hence all projections of GHGs include the effects of DSM.
23.			The total GHG emissions stated in Table 4.2a is much higher than the figures provided by EPD's inventories for 1990 - 1995. Even allowing for GWP factorisation of different GHG, the equivalent CO_2 is still significantly greater than EPD's figures. In addition, the so called Airport Core Projects effect should not be included in the long term forecast of GHG emissions as reoccurrence of such high level of construction activities is highly unlikely.	Noted. Historical source data will be provided in the appendices of the report. The ACP adjustments have been made as per a previous comment.
24.			In section 4.3, the consultants claims that diesel and jet fuel are significant contributors of GHG emission. However, based on EPD's 1990 GHG emission inventory, CO_2 accounts for 98.9% by weight of all GHG emissions and the power generation account for two-thirds of such emission. I would like to have the consultant's detailed explanation and substantiation on how the consumption of diesel and jet fuel contributing significantly to the GHG emission.	The report analysed the weight of the gases and then converted the weight into the global warming potential. Referring to Figure 4.3c, and eliminating the air transport sector, the electric utility sector appears to contribute approximately 60% of the total GHG emissions. Jet fuel projections were provided by the Airport Authority and will not be included in the Final Report. Diesel projections are being modified as previously discussed.

No.	Department	Reference	Comments	Consultants' Response
25.			In section 4.3, whether the statement that "in 2000 the contribution to total GHG emissions by the electric utility sector is less than it was in 1990 in all scenarios" stands is highly dependent on the validity of the assumptions used in projecting the contributions of GHG by ground transport, air transport and others. HEC should support the assumptions with more historical data, trends and/or empirical evidence.	The statement quoted in the comment is an absolute statement and not made relative to the other sectors. The GHG emissions as calcuated for all the gases covered in the original report show that the emissions from the electric utility sector in 2000 are less than they are in 1990 on an absolute basis.
26.			In figure 4.3a, I could not understand how aviation could produce 3.5 times the current emission by 2012. I would appreciate it if the consultants could provide detailed figures to substantiate such prediction.	The projections of fuel consumption at the new airport were provided by the Airport Authority, but will be removed from the revised analysis as per earlier comments.
27.			In section 5.3, there is no discussion on Electricity Demand Side Management, the implementation of Building Energy Codes other than OTTV, and the greatly improved response on the Energy Efficiency Labelling Scheme for Air-conditioners and future extension of the Scheme to other household appliances.	Demand-side management is already included in the estimates used (see point 22) Since they are not within HEC's control as a mitigation option, consideration of BECs and EELSs is not considered within the scope of the study.
28.			In section 5.3, what re the "certain exceptions" in the first sentence? I do not think it is necessary that "most office space in HK is rented for short periods making improvements uneconomic". Energy improvement schemes are uneconomic for the property owners if the tenants are short-term and at the same time the vacancy of the office space is high (such that the rate of return of the investment in the energy improvement schemes is uncertain). This does not seem to be the situation in Hong Kong.	The certain exceptions refer to owner occupants (eg Hongkong & Shanghai Bank, Cathay Pacific, etc) who build the building and occupy it. Most commercial buildings in Hong Kong are not owner occupied. Only certain energy improvement schemes are economic for the owners if they do not occupy the space. Tenants often pay for air-conditioning running costs and almost always for the lighting. As tenants only stay for a few years on average they tend not to spend the money to re-fit energy efficient equipment.
29.			Section 6, HEC concludes that neither the elimination of all generating plant GHG emissions nor the development of gas-fired instead of coal-fired generating facilities would enable Hong Kong to meet the FCCC objective. This comment is noted but does not make the use of a fuel which would worsen the GHG problem in Hong Kong legitimate nor acceptable.	Noted.

No.	Department	Reference	Comments	Consultants' Response
30.			In general, I find the technical report unsatisfactory. The report does not provide adequate figures and substantiations as stated above and it does not provide any breakdown of the portion of various GHG emissions in it "*equivalent emissions*" figures. In the assumptions section, it only quoted the name of the sources but did not state or explain what the assumptions area, in particular the consumption of aviation fuel. Furthermore, the tone of the report is often bias towards pessimism without indicating what could and should be done to improve the situation. It is important to note that China is also one of the parties to the UNFCCC, and the international obligations arising from the convention might one day apply to the future HKSAR government.	Following clarification meetings with the EPD, revised emission projections have been obtained and will be presented in total tonnes of the specific emission. Assumptions will be clarified where the figures concerned were not provided by Government. The report is appropriately cautious rather than pessimistic, and the measures to 'improve the situation' that are within HEC's influence are discussed in Section 5. What should be done, as SPEL has stated in item 16, is a matter for the Administration. The fact that China is a signatory to the Convention is stated in Section 2.2. The final clause of comment 30 states that the UNFCC obligations 'might one day apply to the HKSAR government'. It follows that the obligations do not apply at present. Would SPEL please confirm if this is the case, and if so, when will the convention be applied, or whether the statement in their comment is simply speculation.
31.	EMSD		Table 3.5a (pg 8) - the 3rd sentence of the 'Constraint' for the 'Categorisation of data' should be amended to read "The Electrical and Mechanical Services is currently developing an Energy End-use Database which will provide detailed estimates of energy consumption by sector and energy supplied under different fuels."	Noted and text will be changed.
32.			Section 5.3, (pg 12) - As the objective of the GHG emissions study is mainly related to the HEC's proposed new power station, the options for mitigating GHG emissions as stated in Section 5 of the subject paper should have focused only on the aspects associated with the proposed generation technologies (i.e. the supply side) rather than ways of electricity consumption by end users (i.e. the demand side). In this respect, it is considered that the option as stated in Section 5.3 on "Increased Efficiency of Electricity Consumption" falls outside the scope of this EIA Study and should not be incorporated in this particular technical paper.	Noted and the text will be edited.

No.	Department	Reference	Comments	Consultants' Response
33.	AFD		Among the options for mitigation of greenhouse gas (GHG) emission discussed in the paper, it is interesting to note that a number of utility companies elsewhere have adopted programmes to sequester carbon in trees through "purchasing land and turning it into park land which will never be developed" and "planting trees" (sections 5.5 and 5.5.2 of the technical paper are relevant).	Noted.
34.			In Hong Kong, there are already existing country parks and urban parks as well as tree planting programmes which are managed by various government departments but their purposes are not for mitigation of GHG emission.	Noted.
35.			Given that large new land areas will be required for such programmes, there is no established "benchmarks to determine the contribution of the afforestation programme to GHG levels" and "the need to manage the programme in perpetuity", it has yet to determine the practicality and resources implication of adopting such programme for mitigation of GHG in Hong Kong situation.	Because of the limited areas of land available, the afforrestation of Hong Kong is unlikley to be a practical option. However, the development of afforrestation schemes in areas outside of Hong Kong, for example in the PRC may be possible.
36.	MD		I believe that while the major cause of GHG emissions comes within the territory, possible effects may also come from areas near Hong Kong, for instance, the Shenzhen City.	Noted.
37.	Plan Dept		No comment.	Noted.
38.	Lands Dept		No comment.	Noted.
39.	TDD		No comment.	Noted.
40.	HyD		No comment.	Noted.
41.	BCSB		No written response received.	Noted.
42.	ESB		No written response received.	Noted.
43.	TD		No written response received.	Noted.
44.	CED		No written response received.	Noted.
45.	FSD		No written response received.	Noted.

TECHNICAL PAPER

The Hongkong Electric Company, Limited

Stage 1 EIA for a New Power Station : *Waste-to-Energy Incineration Study*

November 1997
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CONTENTS:

1 INTRODUCTION

1.1 BACKGROUND

This Technical Paper has been prepared by Environmental Resources Management (ERM-Hong Kong), on behalf of the Hongkong Electric Co Ltd (HEC) as part of the Stage 1 EIA Study of HEC's proposed new power station.

The Study Brief for the Stage 1 EIA indicates that there may be benefits in co-siting the proposed new power station with a Waste-to-Energy Incineration Facility (WEIF) which has similar physical, infrastructure and environmental requirements, particularly given the acute shortage of potential sites in Hong Kong.

This Technical Paper has been prepared in response to the Study Brief and presents the preliminary site requirements for a WEIF; it is intended to form the basis for the further assessment of the feasibility of co-siting the power station with a WEIF.

1.2 OBJECTIVES

The primary objective of this Technical Paper is to present the Study Team's assumptions with regard to the WEIF site constituents; these assumptions will form the basis of the facility's defined landtake requirements and the evaluation of opportunities for co-siting with the proposed new power station.

In addition, an overview will be provided of the justification for a WEIF, the specification of the plant, the physical, infrastructure and environmental requirements of the site and the environmental issues which would arise as a consequence of co-siting a WEIF with HEC's proposed new power station.

In establishing the primary assumptions, a qualitative assessment of the general feasibility of the co-siting option will be made. Whilst co-siting of the WEIF with the new power station is not a site screening criterion (i.e. sites will not be screened out from the power station site selection due to non-compatibility with co-siting requirements), an initial evaluation of shortlisted power station sites against WEIF landtake and marine access criteria and of the preferred site against air and water quality impacts associated with a WEIF has been undertaken during the site selection process. The findings of these evaluations are presented in *Annex A*.

1.3 STRUCTURE OF THE TECHNICAL PAPER

Following this introductory section, this Technical Paper contains six further sections, as follows:

- *Section 2* describes the WEIF technical assumptions including the need for the facilities, the preferred technology to be implemented and potential designs for WEIFs;

- *Section* 3 presents the physical requirements for a WEIF in terms of landtake requirement and geotechnical characteristics of the site necessary to support the structure;

- *Section 4* provides the infrastructure requirements including road access, marine access, waste reception and storage facilities, provision of utilities and emergency services;

- *Section 5* presents the environmental requirements for the site, in particular the need for good atmospheric dispersion, the availability of a suitable discharge point for cooling water and other aqueous discharges and the proximity or otherwise of other potentially hazardous installations;

- *Section 6* presents the implications of co-siting the new power station and the WEIF; and

- *Section 7* provides a summary of the review.

2 TECHNICAL ASSUMPTIONS

2.1 BACKGROUND

2.1.1 *General*

The WEIF is the subject of current evaluation by the Hong Kong Government's Environmental Protection Department (EPD). As such, detailed requirements for the facility have not yet been developed and therefore in order to enable the requirements for the future WEIF to be determined, as a basis for co-siting with HEC's new power station, various assumptions have been made regarding the plant and its capabilities. These assumptions are described in this section.

2.1.2 *The Waste Reduction Study*

The need for a WEIF capacity was identified in the Waste Reduction Study[1] which was conducted to determine an integrated strategy for the sustainable management of municipal and commercial waste arisings in Hong Kong. It was recognised that increases in projected waste arisings would considerably reduce the anticipated lifetime of the strategic landfills (SENT, WENT and NENT landfills) in the absence of waste reduction measures. The study proposed a combination of measures to reduce waste including bulk waste reduction using waste-to-energy incineration. The Government is currently preparing a Waste Reduction Plan that will specify how waste reduction is to be achieved and it will include a recommendation for the introduction of a waste-to-energy incineration facility.

2.2 WASTE-TO-ENERGY INCINERATION FACILITY

2.2.1 *Waste Reduction Study's Recommendations*

The Waste Reduction Study concluded that waste-to-energy incineration offered the greatest potential for the bulk reduction of wastes that would otherwise be sent to landfill for the following reasons:

- the technologies are well developed and wastes of suitable calorific value are generated in the Hong Kong SAR;
- WEIFs are operated worldwide including in the Asia Pacific region;
- environmental issues associated with WEIFs are well understood and provided that a suitable site is selected and that the design incorporates modern pollution control technologies, it should be possible to reduce environmental impacts to acceptable levels; and
- given the prohibitive cost of the future development landfill void space in addition to that which is already available, incineration should have the potential to be economically viable.

[1] ERM (1995) **Waste Reduction Study** for the Environmental Protection Department, Hong Kong Government

These considerations will be addressed in greater detail in the forthcoming Feasibility Study on Waste-to-Energy Incineration Facilities[2].

The first step in further development of this capacity will be a Feasibility Study for Waste-to-Energy Facilities which has recently been put to tender by Government. The objective of the Study will be to comprehensively assess the potential for a WEIF(s) in Hong Kong, including detailed assessments of the technical feasibility, identification and evaluation of suitable sites, assessment of potential environmental impacts at selected sites, the preparation of an outline design, capital and operating cost estimates for the facility and the preparation of an implementation plan.

2.3 *WASTE-TO-ENERGY TECHNOLOGY*

This section presents the background information on waste-to-energy incineration in order to introduce site requirements for a WEIF.

2.3.1 *General Arrangements*

Waste-to-energy incineration typically allows waste volumes to be significantly reduced, with the additional benefit of the recovery of energy. The technology is well-proven and detrimental environmental impacts which were previously associated with WEIFs have been considerably reduced in recent years. This has principally been achieved through improvements in combustion and to emissions controls which means that WEIFs can now be designed to meet extremely strict atmospheric emission standards.

Two alternative combustion technologies were evaluated during the Waste Reduction Study: mass burn incineration and fluidised bed incineration. Although the nature of the combustion chambers is different in these two types of WEIF, the process of receiving, feeding, and burning waste, and the treatment and disposal of the various waste streams that arise are broadly similar. A schematic of the key processes involved in incineration is presented in *Figure 2.3a*.

Waste is delivered to the site by barge or road and weighed before being transferred into a storage bunker in an enclosed hall. Waste is then transferred, via a processing step in the case of fluidised bed incineration, to the combustion chamber where it is burnt autothermically. Flue gases and ash are generated by the cumulative process. Flue gases passed through a heat exchanger/boiler which is used to recover energy and then through a flue gas cleaning system which is designed to remove particulates and other pollutants such as acidic gases from the combustion exhaust before emission to atmosphere via a tall stack. Energy is typically recovered as hot water or steam which is either used directly (eg municipal heating/cooling systems) or used to drive turbines and generate electricity.

The polluting potential of gaseous emissions is limited by ensuring adequate oxygen supply, high combustion temperatures and flue gas cleaning which partitions the majority of the pollutants with the exception of water vapour, carbon monoxide and carbon dioxide, to the liquid and solid phases. Flue gas cleaning processes typically include particulate removal and one or more

[2] Environmental Protection Department (1997) **Draft Brief Feasibility Study of Waste-to-Energy Incineration Facilities Agreement No. CE 97/96**

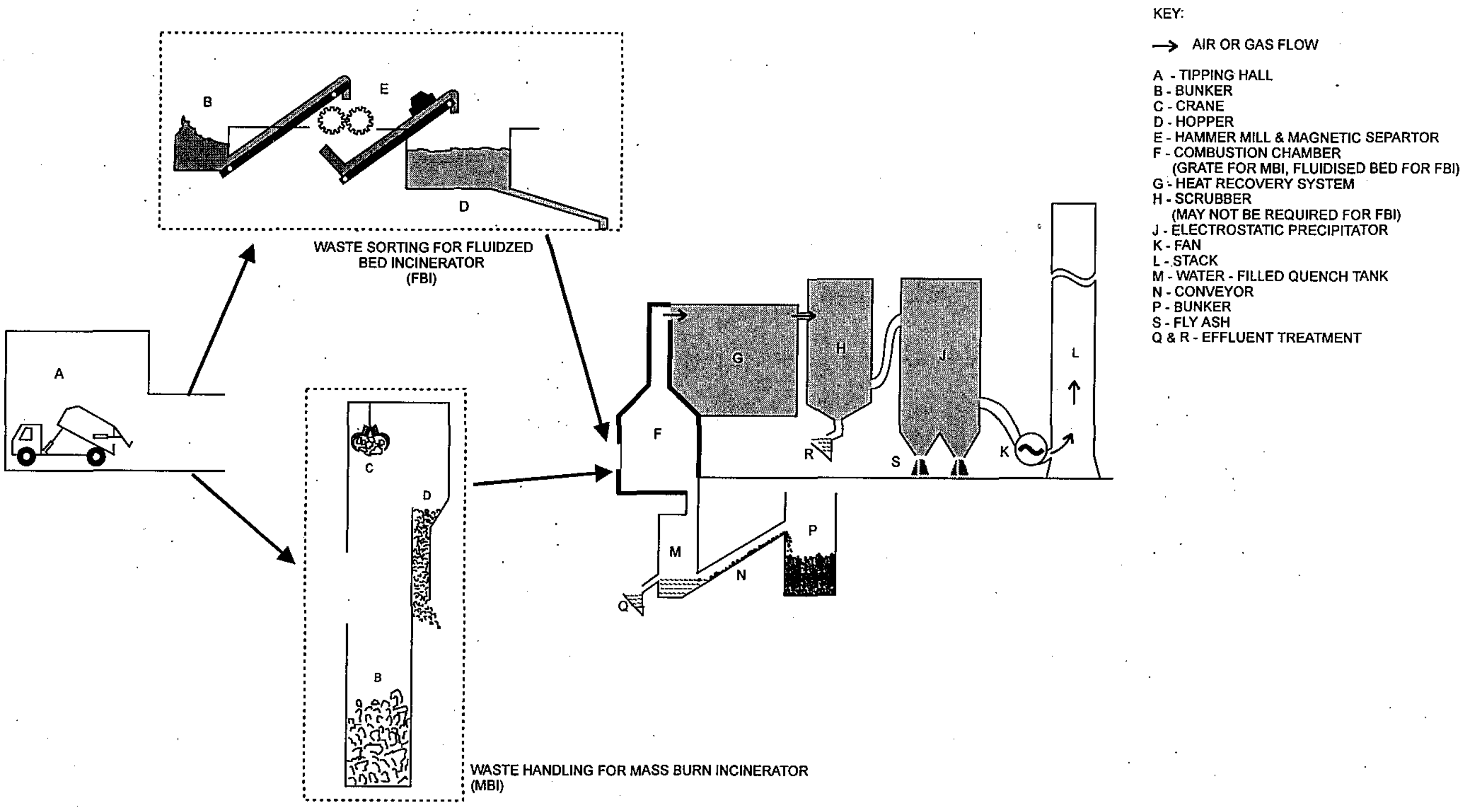

FIGURE 2.3a - GENERALISED SCHEMATIC FOR A WASTE TO ENERGY INCINERATION FACILITY

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scrubbers to take out gaseous pollutants. Particulate removal is frequently achieved with electrostatic precipitators (ESP) or fabric filters. Acid gases are removed using one of three forms of scrubbers: wet scrubbers, semi-dry scrubbers and dry scrubbers. The basic process is to introduce a substance into the flue gases that combines with the pollutants of concern and is subsequently removed.

In addition to gaseous emissions solid and liquid waste streams are also generated. Solid waste comprises bottom ash in various forms, non-combustible materials or bulky items unsuitable for the technology, fly ash, scrubber residues, maintenance wastes and any sludges generated from the treatment of wastewater. Liquid waste comprises any leachate from the waste storage areas, ash quenching water, flue gas residue if wet scrubbers are used and cooling waters.

2.3.2 *Mass Burn Technology*

Mass burn technology was identified in the Waste Reduction Study as having the greatest potential for bulk reduction of municipal and commercial wastes. The technology is relatively simple and allows volume reductions of around 90% and weight reductions of around 75%[3]. The technology is well proven at a range of capacities including at the large scale (> 1 million tpa).

Two generic combustion technology options predominate for mass burn plants, grate systems and rotary kiln systems. In grate systems, which are by far the more common, waste is burned by being passed down a steel grate which is typically set on an incline. In rotary kiln systems the waste tumbles down the length of a rotating barrel progressively drying and burning.

2.3.3 *Fluidised Bed Technology*

Fluidised bed WEIFs have been developed and comprehensively tested over the last ten years, and have proved to be flexible in operation. They are an extremely effective method for incinerating either difficult wastes (where quantities are relatively low) or wastes with a highly unpredictable calorific value (such as plastics and wood). They have however only been used for relatively low waste throughput when compared to larger mass burn plants. Manufacturers have been increasing the capacity of fluidised bed plants and they can now compete with mid range capacity mass burn WEIFs (ie around 300,000 to 400,000 tpa). However, they have not yet been scaled up to a throughput comparable with the larger mass burn plants and they are less well established for the incineration of municipal wastes.

An additional important difference between fluidised bed plants and mass burn plants is that for most fluidised bed furnaces, raw municipal wastes have to be pre-processed into a form suitable for injection into the furnace. Pre-processing can involve the removal of certain components from the waste stream and the shredding of the remaining material prior to its introduction to the combustion chamber. The combustion process itself can be more closely controlled than in mass burn plants and this can mean that less add-on air pollution control technology is required due to lower primary pollutant emissions from the combustion chamber.

[3] ERM (1995) **Waste Reduction Study**

2.4 *WEIF DESIGN*

This section presents design aspects of the WEIF that may affect the site requirements for the WEIF. Potential sites for the new power station will be suitable for the WEIF as well if they comply with these requirements.

2.4.1 *Design Determinants*

The design of the WEIFs will depend on a variety of factors which include:

- the required capacity of the plant;
- the combustion technology used for the incinerator, eg mass burn or fluidised bed;
- economic/financial consideration;
- the method of transporting the waste to the WEIF;
- the method of transport used to remove incineration residues from the site;
- the area of land required for the plant, for the reception and storage of waste and for the storage and removal of incineration residues. Given the severe pressure on space that prevails in Hong Kong, the cost of land and the paucity of suitable sites for major developments of this type of facility, a particular concern will be to minimise the size of the site;
- the method used for the export of energy from the plant, eg electricity to the Hong Kong grid, electricity to a local major user or hot water stream either in isolation or in combination with electricity;
- the level of emissions that can be sustained without exceeding appropriate criteria and causing unacceptable environmental impact.

Information on these factors has been provided by the EPD and drawn from the Waste Reduction Study for this technical paper.

2.4.2 *EPD Preliminary Specifications for WEIFs*

The EPD has specified certain characteristics of the WEIF in the document *'Information on Intended Capacity & Basic Siting Requirements of Waste-to-Energy Incinerator'*. These are presented below in italics with consequences for the design of the WEIF.

Intended capacity: *'2 incinerators, each with a capacity of one million tonnes per year or one incinerator with a capacity of 2 million tonnes per year will need to be built'*

Each WEIF will receive approximately 2,740 tonnes of waste per day (based on 1 million tpa) either via marine vessels or road vehicles or a combination of the two. Assuming that incineration achieves a 75% reduction of mass, in the order of 685 tonnes per day of residue will be exported from the site for landfill disposal.

The facility may receive waste from the existing marine-based refuse transfer stations (eg West Kowloon RTS) and will therefore have to include an area to berth vessels, facilities to unload them and to transfer the waste to the incinerator. The EPD has specified:

Berthing Facilities: *To accommodate vessels from existing marine-based refuse transfer station about 200 m vertical seawall length or equivalent in the form of a jetty is required. The normal water draft should preferably be no less than 4.5m, otherwise, dredging of a fairway down to -4.5 m PD may be required. The incineration can be located in isolated islands but the sites should be located such that it is less exposed to the waves or typhoon.*

The facility may also be required to receive waste and export residues by road. The EPD has specified:

Road Access: *Both marine access and road access need not be mutually inclusive. However, incinerator sites with good road access are obviously preferred irrespective of the operation mode of the incinerators. On the basis that a road-based refuse transfer station with throughput of 1,800 tonnes per day will deliver waste to the incinerator, the no. of container vehicle trips per day is about 100 round trips (ie 100 x 2) trips) and the maximum number of container vehicles visiting the site during the peak hours is expected to be about 20 per hour.*

It should be noted that the number of trips is based on an assumption of container loading of 18 tonnes. If the payload of the container is lower than 18 tonnes, more than 100 vehicle deliveries would be required each day.

Other benefits of road access would include flexibility in the transport of waste and residues to the plant and ease of access for staff and emergency services.

The potential impact of emissions from the WEIF on air quality is likely to be a major factor in the selection of a suitable site and the design of the facility. A stack will be required to maximise dispersion although it is likely to be visually intrusive. The presence of other major sources of emission in the SAR will also have a strong influence on siting as they may result in deleterious cumulative impacts. The EPD has specified:

Stack Height: *It is expected that the incinerator stack will be in the order of 150 m to 200 m.*

2.4.3 *Notional Layouts Developed During the Waste Reduction Study*

Notional layouts for a mass burn WEIF with a capacity of 1 million tpa and a fluidised bed WEIF with a capacity of 300,000 tpa were developed in the Waste Reduction Study and presented in *Working Paper C3: Waste Reduction Facility Layouts and Siting Issues*. They are presented here to illustrate the components of a WEIF and to provide an estimate of the additional landtake that would be required if the new power station is co-sited with the WEIF.

Information on the various aspects of the layouts was drawn from:

- existing facilities;
- suppliers' notional layouts;
- manufacturers' and suppliers' published information; and
- ERM in-house experience.

In both cases, the plant layouts were designed on the basis that wastes would be delivered by road using heavy goods vehicles. It should be noted that the EPD's initial specification allows for wastes to be delivered from the marine transfer stations.

Mass Burn WEIF

Figure 2.4a presents a notional layout for a 1 million tpa mass burn WEIF. The elevation of the plant is presented in *Figure 2.4b*. The layout is based on the same capacity as specified by the EPD (1 million tpa) and hence the site requirement could be expected to be very similar. There is, however, an important difference, as the EPD specification was based on the assumption that at least part of the waste will be delivered by barge, whereas the notional layout was designed to receive all waste by road. This probably accounts for some of the difference between the estimated site areas for the notional layout of 5.8 ha and the EPD's site specification of 9 to 10 ha. Additional area would be required for the reception and storage of containerised waste from the marine transfer stations and it should also be recognised that the notional layout is very compact; for example the Senoko plant, which is of similar capacity and is served by road, has a site area of approximately 7 ha.

The layout was based on the following predictions of vehicle movements which were in turn based on experienced norms and actual observations at facilities of a similar type elsewhere in the world:

- the annual capacity of a 1 million tpa equates to 2,740 tonnes per day;
- waste will be delivered by road using Refuse Collection Vehicles (RCV) which have a payload of approximately 5 tonnes and therefore there will be a total of 548 deliveries to the site each day, (note that this is fairly conservative because larger vehicles are also likely to be used for delivery of containerised waste to the WEIF);
- the rate of waste delivery will not be uniform and the peak hourly rate is likely to be 30% of the total daily throughput, the peak rate will therefore be 165 vehicles per hour (=548 x 0.3);
- this volume of traffic will necessitate two weighbridges for incoming vehicles and two weighbridges for outgoing vehicles; and
- there will need to be queuing space for 37 vehicles to prevent vehicles queuing onto the highway.

Examination of actual and proposed facilities of a similar scale during the development of the layout for the plant showed that the size of the actual 'blocks' for waste reception, storage, combustion, ash handling and flue gas cleaning were remarkably consistent throughout. However the actual site areas occupied for these facilities varied considerably depending on the configuration of the various parts of the plant, the shape of the site available and the space allowed around the various 'blocks'.

The layout of the blocks in *Figure 2.4a* reflects the standard adopted by most mass burn WEIF built to date. In some respects the layout shown resembles the similarly sized Senoko plant in Singapore, where land constraints are similar to those in Hong Kong.

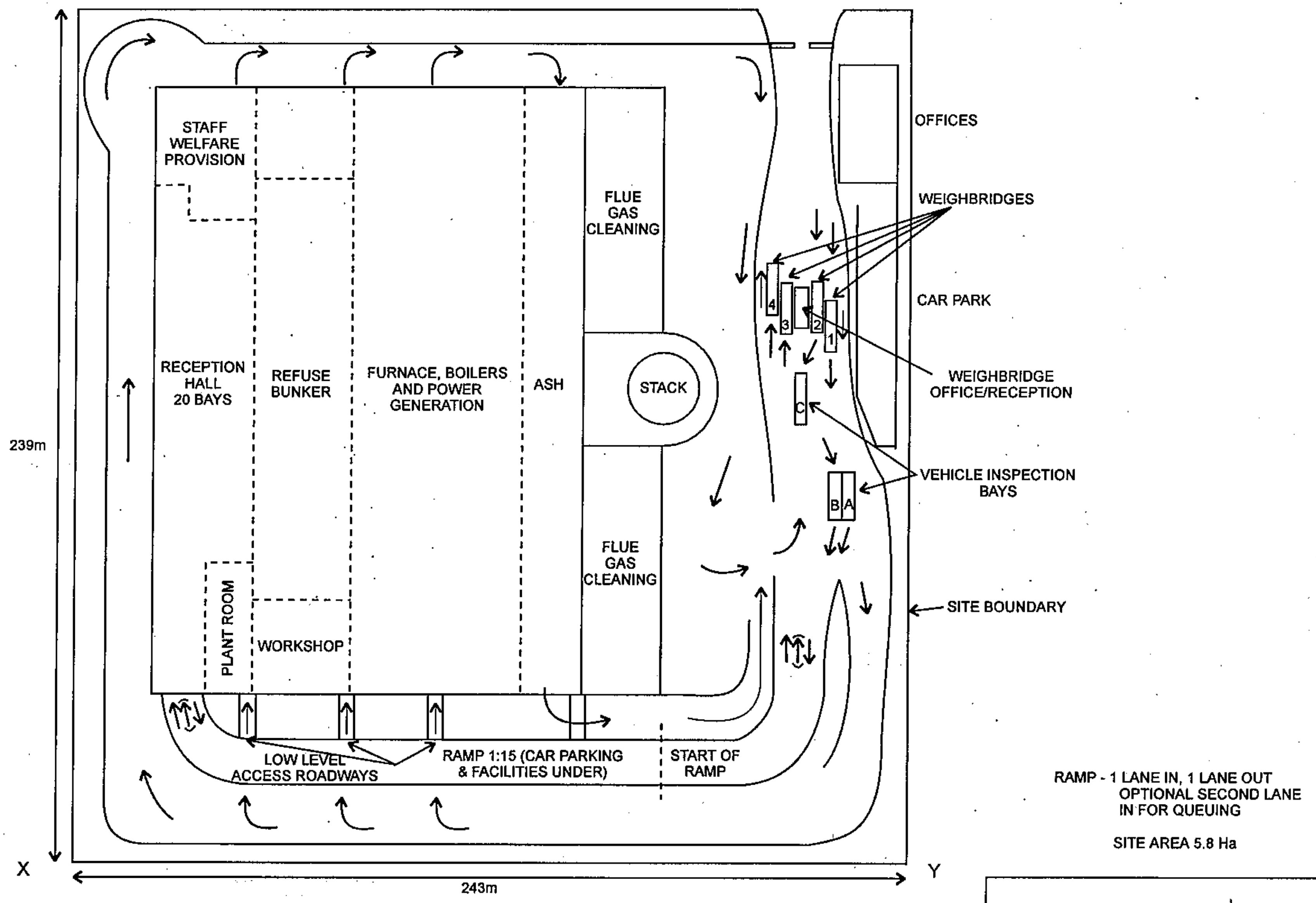

FIGURE 2.4a - 1,000,000 TPA MASS BURN INCINERATOR NOTIONAL LAYOUT (CONDENSED)

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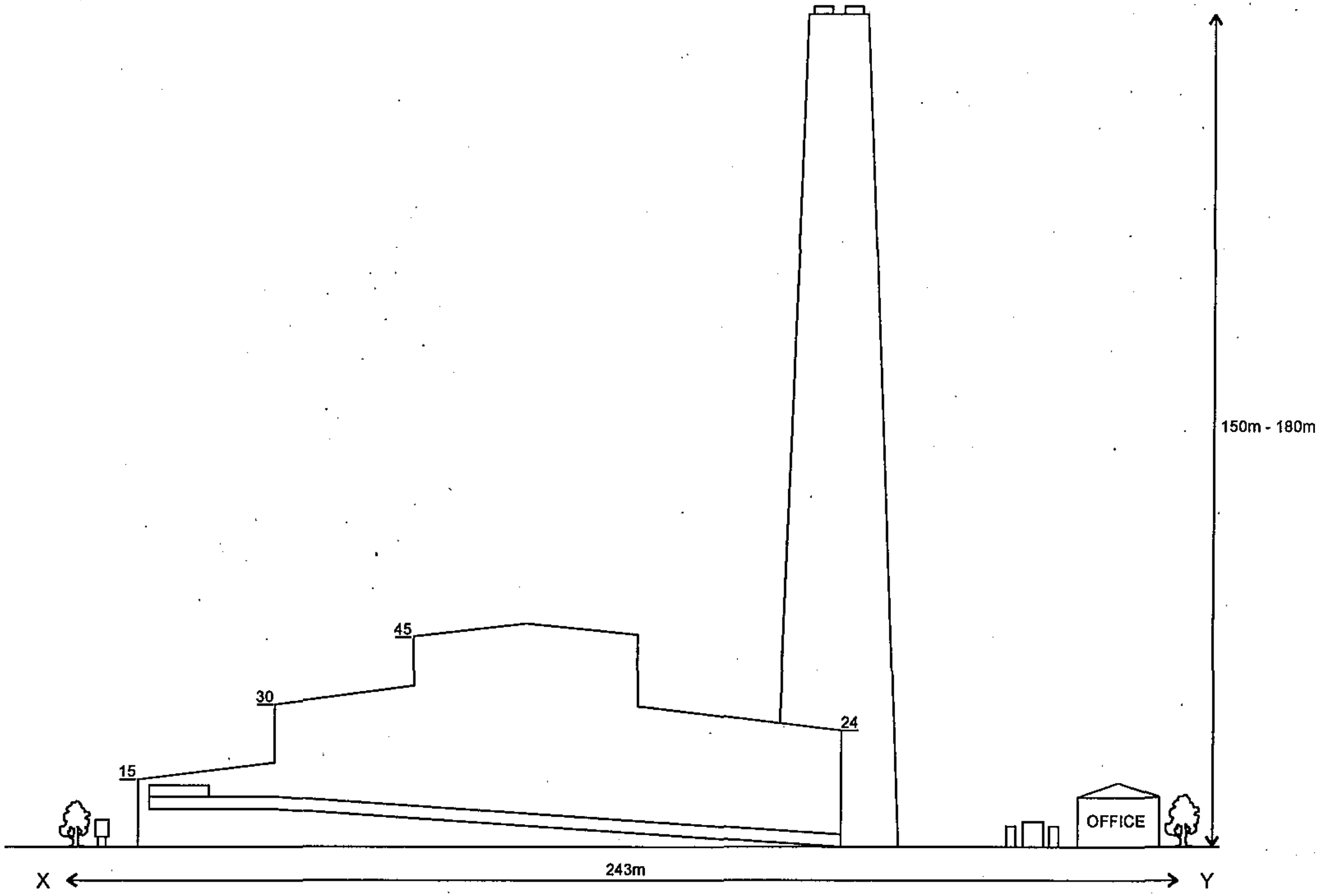

FIGURE 2.4b - 1,000,000 TPA MASS BURN PLANT, ELEVATION

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Hong Kong

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Fluidised Bed WEIF

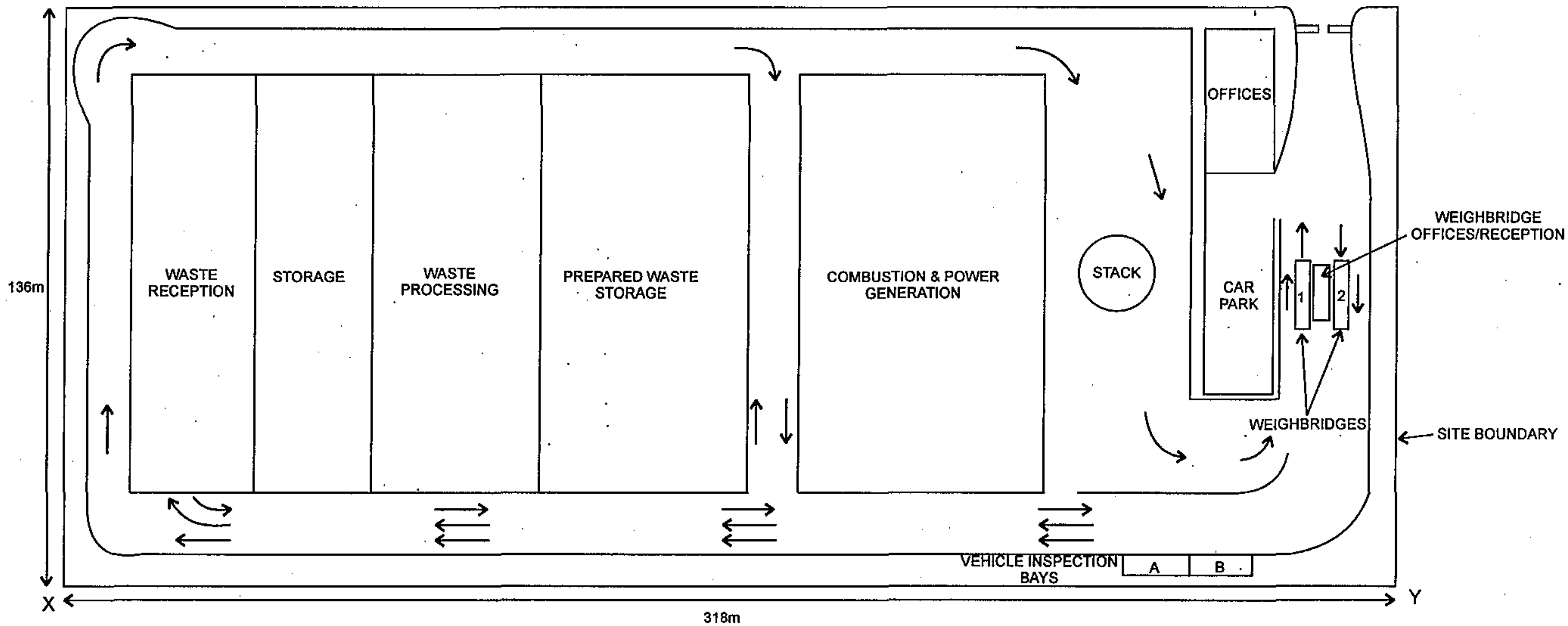
Figure 2.4c presents a notional layout for a 300,000 tpa fluidised bed incineration plant with a total site area of approximately 4.3 ha. The elevation of the plant is presented in *Figure 2.4d*. The layout is based on a capacity considerably below that required for the WEIF because, to date, no fluidised bed plants of the same magnitude are in operation. For this reason, and because of the pre-sorting required for fluidised bed WEIFs, mass burn is likely to be the preferred technology for the WEIFs.

As for the mass burn WEIF the notional layout was based on the following predictions of vehicle movements which were in turn based on experienced norms and actual observations at facilities of a similar type elsewhere in the world:

- the annual capacity of 300,000 tpa equates to 822 tonnes per day;
- waste will be delivered by road using RCVs which have a payload of 5 tonnes and therefore there will be a total of 165 deliveries per day,
- the rate of waste delivery will not be uniform and the peak hourly rate that will be realised will be 30% of the peak daily throughput, the peak rate will therefore be 50 vehicles per hour;
- there will be two weighbridges, one for incoming vehicles and the other for outgoing vehicles; and
- there will be queuing space for 11 vehicles.

The layout of the plant is similar to that of the mass burn WEIF except that a greater site area is required for plant upstream of the combustion chamber because of pre-incineration waste processing requirements.

Comparison of site areas for notional layouts of different plant types and different plant capacities is revealing. As would be expected, the typical site area for a 300,000 tpa fluidised bed WEIF is 4.3 ha and is greater than the site area for a 300,000 tpa mass burn WEIF (4.0 ha). Comparing the site areas for plants of different capacity shows there can be considerable relative space saving with increased capacity. The notional site area of the 300,000 tpa mass burn WEIF is 4.0 ha whereas the notional site area of a 1 million tpa mass burn WEIF is 5.8 ha. Therefore, if a mass burn plant is selected a smaller site area would be required than for a fluidised bed plant.



SITE AREA 4.3 Ha

FIGURE 2.4c - 300,000 TPA FLUIDISED BED INCINERATOR NOTIONAL LAYOUT

ERM-Hong Kong, Ltd
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

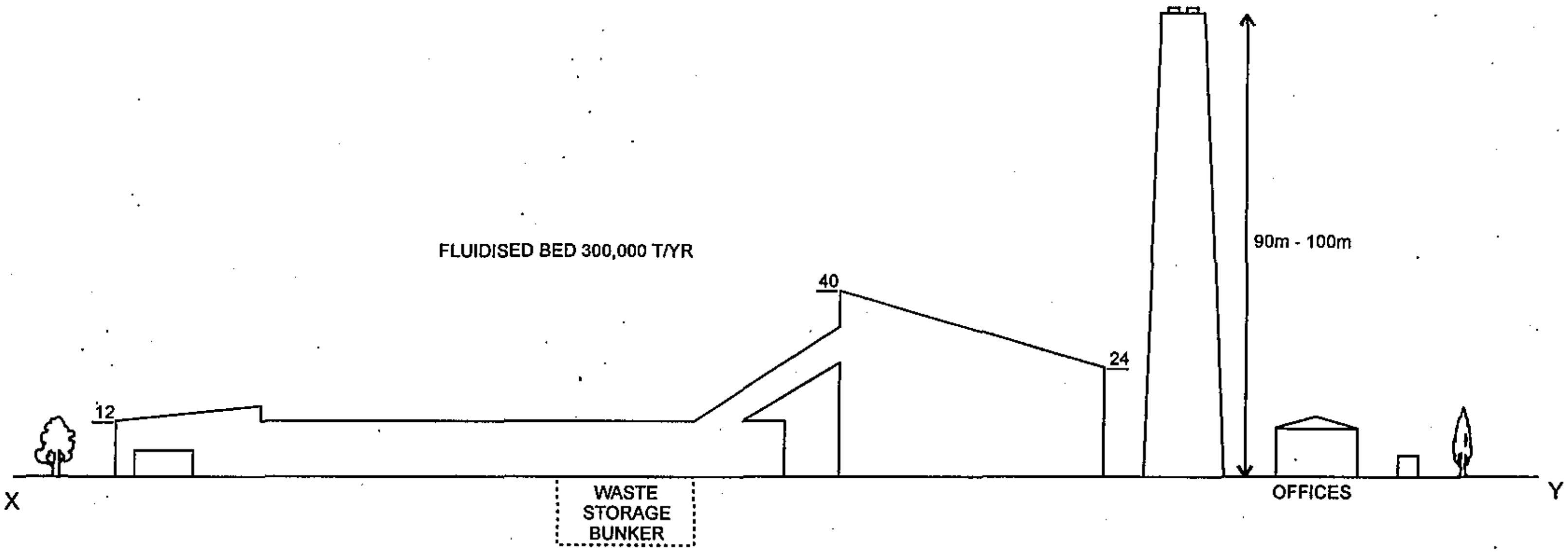


FIGURE 2.4d - 300,000 TPA FLUIDISED BED WFPG, CROSS SECTION

ERM-Hong Kong, Ltd
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

3 PHYSICAL REQUIREMENTS

3.1 SITE AREA

The following factors affect the landtake of a WEIF and hence the additional site area that would be required should the new power station be co-sited with a WEIF:

- the capacity of the plant which determines the size or number of the various components of the plant (eg how big the waste storage bunker is and how many combustion chambers and corresponding gas cleaning plants are required) and the volume of waste and incineration residues that will be transported to and from the site;
- the technology of the plant (eg fluidised bed WEIF due to its need to pre-treat the waste is likely to require a larger site area for a given waste throughput than mass burn WEIF);
- the method of transport to and from the site, marine and road delivery systems each have certain unique requirements; and
- the need or otherwise for particular facilities on the site such as emergency facilities (see *Section 4.1*) and wastewater treatment facilities (see *Sections 4.2.2 and 5.2*);

The EPD estimates that a site of 9 to 10 ha will be required for a 1 million tpa WEIF with a minimum width of 250 m for a plant with marine and road access. This is considerably larger than a previous site area estimate for a similar capacity plant without marine access of 5.8 ha. The difference is probably accounted for by facilities for the reception of containerised waste from marine vessels and the fact that the notional layout is very compact. Further details of these estimates are provided in *Sections 2.4.1* and 2.4.2. For a 2 million tpa plant a site of less than 18 to 20 ha will be required because of economics of scale.

3.2 GEOTECHNICAL

The WEIF will be a major industrial development and will require suitable foundations to support its weight. Geotechnical requirements for the WEIF are not expected to be significantly different from those for the new power station.

3.3 LOCATION

The location of the WEIF site affect the design and landtake required for the WEIF, its accessibility by road and by sea, the degree of atmospheric dispersion, and the need for significant site preparation works. Topographically an ideal site would be an existing flat area of land next to the coast.

3.3.1 *Accessibility*

Good access to the sea will be required for the delivery and removal of large volumes of waste and solid incineration residues respectively.

Access to the sea will require either a coastal site or a site that can be easily accessed from the coast. In both cases a flat area of land will be needed adjacent to the sea so that vessels serving the marine refuse transfer stations can moor and discharge containerised waste. While land excavations, dredging and reclamation could theoretically provide a suitable site where existing topography is unsuitable, cost and environmental impacts are likely to be lower if an existing relatively flat area of land on the coast can be identified.

3.3.2 *Landscaping*

The WEIF, like the new power station, will probably be visually intrusive. Process plant will be housed in several very large buildings (including a very tall stack) and will frequently be visited by marine vessels and possibly by heavy goods vehicles. In some circumstances visual impacts can be reduced by blending the developments into the surrounding topography. Two factors are likely to make it difficult to blend in the WEIF. Firstly a coastal site will be required which means the site is likely to be visible at least from the sea and secondly good atmospheric dispersion will be required which will mean the stack will have to be sufficiently high that the plume clears any nearby hills, whilst complying with current Airport Height Restrictions.

3.3.3 *Confined Air Sheds*

Location can affect the degree of atmospheric dispersion. As detailed in *Section 5.1* and presented in *Figure 5.1a* certain confined air sheds have been identified where the rate of exchange of air is low and thereby limiting dispersion. Emissions to confined air sheds are likely to result in relatively high ground level concentrations of air pollutants.

3.4 *CO-SITING WITH HEC'S NEW POWER STATION*

The Site Search for a New Power Station will include within its broad approach a requirement to provide for the potential co-siting of a WEIF within the site identified for the power station. However, whilst HEC has accepted the requirement, it is acknowledged that the primary purpose of the current site search is the identification of potential sites to accommodate a new 1800MW power station. As a consequence, the potential co-siting will be a secondary site search consideration and the potential sites for the new power station will not be excluded if they fail to meet the WEIF or co-siting requirements.

4 INFRASTRUCTURE REQUIREMENTS

4.1 INTRODUCTION

In addition to the site area, geotechnical and topographical requirements there are certain infrastructure requirements for a facility of the type envisaged. They include access for transport, and connections to communications and utilities networks. While requirements could potential be met by expansion of the existing infrastructure network, there would be high associated costs and potentially a high level of environmental impact. Hence it would be preferable to use the existing infrastructure wherever possible. Potential sites for the new power station would therefore only be suitable for co-siting if infrastructure for the WEIF already exists or if new infrastructure can easily be developed.

The infrastructural requirements of the WEIF are discussed below.

4.2 TRANSPORTATION

At 1 million tpa throughput, the WEIF will have a waste throughput comparable with the throughput of largest incineration plants in the world. It is therefore extremely important to have a good transportation system for waste delivery and export of incineration residues.

Much of the waste will probably come from marine transfer stations from which containerised waste is currently transported by marine vessel to a strategic landfill. When the WEIF comes into operation waste will probably be transported by barge from the same transfer stations to the WEIF and a hence a coastal location is considered essential. Following incineration, solid residues would be transported from the WEIF to the landfill by marine vessel.

In the document '*Information on Intended Capacity & Intended Basic Siting Requirements of Waste-to-Energy Incinerator*' the EPD state "marine access and road access need not be mutually exclusive". Sites with good road access are obviously preferred irrespective of the operation mode of the incinerators'.

The EPD has estimated a peak rate of 20 vehicles per hour visiting the facility on the assumption that all the waste to the plant is delivered in containers by road. The Waste Reduction Study[4] presented a more conservative estimate peak rate of 165 vehicles per hour but in this case it was assumed that waste would be delivered in RCVs which carry considerably less waste than vehicles carrying containerised waste. In practice it is unlikely that all of the waste will be transported by road given large volumes of waste currently planned to be handled at the marine transfer stations.

The co-siting of the WEIF with the new power station would require a reliance on marine transportation only, as all of the long- and shortlisted sites are located on outlying islands.

[4] ERM (1995) Waste Reduction Study for the Environmental Protection Department, Hong Kong Government

4.3 UTILITIES

4.3.1 *Electricity*

The WEIF will probably draw and contribute electricity to the grid. An external source of electricity is important to keep the plant running in the event of failure of the power generation unit. Electricity will be generated (unless energy is exported as hot water streams which is unlikely) during normal operations which will either be exported to the grid, or to a major industrial electricity consumer. For these reasons a site that can easily be connected to the electricity grid would be preferable. Any power station site will also have to be connected to the electricity transmission grid and therefore electricity supply is unlikely to be an issue in a co-siting decision.

4.3.2 *Water Supply and Sewerage*

The WEIF will use water for cooling, for scrubbing flue gases (if a wet or semi-dry scrubber is installed) for ash quenching, for domestic type uses such as cooking, washing and drinking and for washing vehicles. For some of the uses there is no need for the water to be potable. Water for cooling will the largest volume required and it is unlikely that this water would be provided by Water Services Department (WSD). Water will probably be extracted from the sea and this will probably also serve as a source for other uses that do not require potable water. Potable water can either be supplied by pipe or by tanker, although the former would be preferable.

At least two wastewater streams will be generated. Large volumes of cooling water will be discharged to the sea. Ash quenching water, waste leachate, scrubber residues, domestic sewage and contaminated surface water may require treatment and they will be discharged either to foul sewer or to surface waters. Standards for discharges to foul sewer are less stringent than for discharges to surface waters. Consequently, a lower level of treatment would probably be required if the site is served by foul sewers and therefore a site either near or connected to foul sewer would be preferable. Similar connections would probably be advantageous for the new power station.

5 ENVIRONMENTAL REQUIREMENTS

5.1 ATMOSPHERIC DISPERSION

5.1.1 General

The process of converting waste to energy involves the transformation of most of the waste material into gases and aerosols. Flue gas cleaning can remove a large proportion of potential pollutants but the nature of incineration inevitably means that WEIFs will produce high volumes of emissions to atmosphere. Environmental impacts associated with air emissions from the WEIFs will depend on the following factors:

- the types and amounts of pollutants emitted which in turn depend on the type of waste being incinerated, various factors related to the combustion conditions including temperature and the supply of oxygen, and the processes employed to clean the flue gases;
- stack height;
- emission velocity;
- the degree to which the resulting plume is dispersed;
- the presence and nature of sensitive receivers downwind of the plant; and
- background air quality.

The degree to which the resulting plume is dispersed, the location of sensitive receivers relative to the plant and the background air quality will all affect whether a potential site is suitable for the WEIF.

5.1.2 Factors Affecting Atmospheric Dispersion

Potential environmental impacts associated with WEIF emissions can be mitigated by ensuring good dispersion of the plume. A key consideration, therefore, in selecting a suitable site for a WEIF will be how well the plume would be dispersed at different sites. Factors influencing dispersion include:

- flue gas temperature;
- the density of the plume relative to the density of surrounding air;
- the height of the stack through which the gases are emitted;
- the topography of the area; and
- weather patterns and particularly prevailing winds.

The density of the plume will depend on the temperature at which flue gases are emitted and the ambient temperature around the stack. Neither will be strongly influenced by the location of the WEIF site.

The height of the stack will determine the level at which emissions occurs. Taller stacks tend to reduce the likelihood of the plume becoming entrained onto the ground, which reduces dispersion, and they increase the distance from the stack at which the plume first reaches ground level (and sensitive receivers). Increasing this distance also increases the amount of dispersion that the plume undergoes before reaching ground level, resulting in lower concentrations at ground level and at sensitive receivers than would be experienced with a shorter stack.

The height of the stack will be determined by the degree to which emissions are dispersed in the atmosphere and the proximity of air sensitive receivers. At certain locations impractical and costly stacks will be required to achieve sufficient dispersion between the stack and sensitive receivers in order that Air Quality Objectives (AQO) can be achieved. Consequently, sites may be limited by engineering and economic constraints on stack construction.

The topography of the area influences the manner in which air moves in the vicinity of the emissions and hence the degree of dispersion, and potentially the height of sensitive receivers relative to the emissions. Certain topographical features such as bowl shaped hills restrict the exchange of air within or around them. Areas where these occur are referred to as confined air sheds and they are associated with poor dispersion. *Figure 5.1a* shows confined air sheds in Hong Kong.

Weather patterns determine the direction and the speed that the plume from an emission is transported. In Hong Kong the prevailing winds are north easterly and therefore sites to the north east of sensitive receivers are generally not favourable locations for industries that produce air emissions.

5.1.3 *Regulations and Guidelines Relating to Atmospheric Emissions*

Regulations Relating to Atmospheric Emissions

The principal legislation relating to air quality in Hong Kong is the Air Pollution Control Ordinance (APCO) with its subsidiary Regulations. Air Quality Objectives (AQO) specified under the APCO provide standards for 7 air pollutants that the government wants to achieve within the SAR. The Ordinance also specifies processes that have the potential to cause air pollution and for which a license is required. Incineration is a specified process and a license will be required from the EPD prior to operation. The EPD has the right to refuse the licensing of the proposed WEIF should the AQO be exceeded or if the applicant cannot provide a facility capable of meeting the best practicable mean for air pollution control or if the WEIF would have an adverse effect on public health.

Co-siting of the WEIF with the proposed new power station will probably have a more severe air pollution impact locally than either facility would if they were sited separately. This is because the air pollutants from the two facilities are likely to accumulate which will result in higher pollutant concentrations. As a result, it may be considered that the AQO will be more difficult to achieve if the WEIF and new power station are co-sited.

Guidelines Relating to Atmospheric Emissions

Two sets of guidelines relating to atmospheric emissions are relevant to the siting of incineration facilities. They are *Notes on Best Practicable Means Requirements for*

Incinerators[5] and *Hong Kong Planning Standards and Guidelines*[6].

The *Notes on Best Practicable Means Requirements for Incinerators* specify the EPD's requirements for incinerator emissions which are:

(i) the relevant Air Quality Objectives (AQO) will not be threatened;

(ii) the emission of non-AQO pollutants, in particular, heavy metals and carcinogenic organic compounds, will not cause any adverse effect to human health or environment; and

(iii) no undue constraint will be incurred to existing and future development or land use.

The *Hong Kong Planning Standards and Guidelines* provide environmental guidance for major land uses based on environmental factors influencing land use planning. The guidelines relevant to atmospheric dispersion are:

- locate air-polluting industries to the west of the SAR;
- avoid locating air-polluting industries in air sheds with limited air dispersive capacity or areas where air pollution is very serious;
- provide adequate buffer areas between Specified Processes, industries giving rise to dusty, odorous and gaseous emissions and any sensitive land uses;
- make full use of godowns and amenity areas for buffering against sensitive uses.

Applying these criteria to the SAR, all of Hong Kong Island may be excluded from consideration for potential sites given the density of the population. The entire eastern half of the New Territories can also be excluded due to the general policy that air polluting industrial development should be excluded from these areas.

5.1.4 *EPD Specifications for Stack Height*

In the document *'Information on Intended Capacity & Basic Siting Requirements of Waste-to-Energy Incinerator'* the EPD state that they expect the incinerator stack will be in the order of 150 to 200 m.

5.2 *AQUEOUS DISCHARGES*

Aqueous discharges that will arise during the operation of a WEIF include cooling water, scrubber residues, waste leachates, quench tank residues, site drainage and domestic sewage. Large volumes of cooling water will be produced and will probably be discharged independently of wastewater from the other sources.

Relatively large volumes of cooling water will be required to extract heat from the

[5] Environmental Protection Department (December 1991)
[6] Environmental Protection Department (1990) Hong Kong Planning Standards and Guidelines Chapter 9, endorsed by the Land Development Policy Committee on 3.8.1990.

flue gases as part of the energy recovery process. After energy extraction the cooling water will be discharged at a higher temperature than at the intake. Discharges into a watercourse or an enclosed water body are not favourable because they have a low capacity to dissipate heat. Large open water bodies have a greater capacity to dissipate heat and therefore for a given cooling water discharge, lower temperature elevations are experience than for small enclosed water bodies. Additionally, cooling water discharges may contain some form of biocide to protect the pipe work of the plant from fouling. Impacts from the biocide are best mitigated by reducing the quantities used as far as is practicable and diluting the cooling waters in the receiving water body. The degree to which dilution will occur depends upon, among other factors, on the size of the water body. For these reasons there are considerable benefits associated with cooling water discharges in a coastal site.

Smaller volumes of wastewater will be generated from scrubbers, waste storage bunkers, surface drainage including any vehicle washing and from sanitary appliances. Scrubber residues will be contaminated with pollutants extracted from the flue gases and treatment will be required prior to discharge to sewers or to surface waters to remove residual lime slurry and particulate, and to neutralise and precipitate dissolved salts. Leachates from the waste tanks, surface drainage and domestic sewage are all likely to be moderately contaminated and they will also probably require some form of treatment prior to discharge.

Effluent quality standards for discharges are specified in the *Technical Memorandum - Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters.* Standards for discharge to sewer are less stringent than for discharge to surface waters. Consequently less treatment is required for discharges to sewer and therefore sites close to an established sewer would be preferable. The new power station will also generate various wastewater streams for which the same standards will apply.

Environmental impacts of the cooling water discharge and any of the other potential wastewaters that arise from the plant depend on the nature of the wastewater discharged, the degree to which the resulting plume is dispersed and the proximity and nature of sensitive receivers. Selection of an appropriate point to discharge will be critical part of mitigating environmental impacts. At some locations it will not be possible to mitigate the impacts to an acceptable degree because of low rates of dispersion and/or the proximity of sensitive receivers.

5.3 *POTENTIALLY HAZARDOUS INSTALLATIONS*

5.3.1 *Introduction*

The operation of various components of the WEIF and in particular the scrubbers, will require a variety of process chemicals. The nature of the chemicals and the quantity stored on the site will determine whether the WEIF is classified as a Potentially Hazardous Installation (PHI). Planning restrictions apply to the siting of PHIs to limit risks associated with the storage of hazardous chemicals. Classification of the WEIF as a PHI would therefore result in planning restrictions, and hence siting restrictions, that would not otherwise apply.

The amount and type of chemicals that will be used in the operation of the WEIF will not be known until more detailed design of the plant is conducted. The type of plant and processes that will be used will determine the type and quantity of chemicals required and hence whether the WEIF is classified as a PHI. Operations requiring chemicals that are potentially hazardous to health include gas cleaning and water treatment. In addition storage for less hazardous substances such as fuel oil may be required.

5.3.2 *The Framework for PHIs*

A PHI is an installation which stores hazardous materials in quantities equal to or greater than a specified threshold quantity, which varies with different substances. The purpose of the designation is to create a mechanism to minimize the potential risks associated with PHIs. This is achieved by controlling the siting of PHIs, by controlling land use in the vicinity of PHIs, and by requiring the PHIs to be constructed and operated to specified standards.

Planning restrictions apply to an area around the PHI which is called the Consultation Zone (CZ). The size of the CZ is determined according to the local topography, the nature of the PHI and its chemical storage capacity.

The body responsible for determining what development is acceptable within the CZ is the Coordinating Committee on Land-use Planning and Control relating to Potentially Hazardous Installations (CCPHI). The CCPHI is advised by either the EPD or the EMSD on the off-site risks associated with PHIs.

Risk Guidelines (RG) have been adopted by the CCPHI to assess the off-site risk levels of PHIs. They are expressed in terms of individual risks and societal risks. Individual risk is the predicted chance of death to an individual living or working near a PHI. Societal risk is the predicted risk to the whole population living near a PHI.

5.3.3 *Application for A New PHI*

The process for gaining planning approval for a new PHI involves a defined series of steps. Initially a site search is conducted by the Planning Department in consultation with the EPD or the EMSD. When a suitable site is identified a Hazard Assessment (HA) and a Planning Study (PS) are undertaken concurrently. The HA assess the risks posed by the PHI on the present and future population in its vicinity against the RG. In addition, the HA determines what actions can be taken to reduce risks. The PS identifies present and future developments in the CZ and advises on controls on development in the CZ to prevent exposure to unacceptable levels of risk. Following the HA and PS, an Action Plan (AP) is prepared which specifies measures to implement recommendations in the HA and PS. The AP is submitted to the CCPHI for approval.

5.3.4 *Site Requirements for A PHI*

If the WEIF is classified as PHI there will be implications for its siting. PHI sites are surrounded by CZs which extend up to 1 km depending on the nature of and quantity of chemicals stored. In order that risks are acceptable to people living and working within the CZ, there will have to be a low population density in the area. Potential PHI sites are consequently in remote areas with sparse population.

5.4 *NOISE*

Activities associated with the WEIF including traffic movement, waste handling and power generation will generate noise. The impact of this noise on the environment depends on what measures are taken to suppress it propagating from the site, reduction at source, and the proximity and nature of sensitive receivers and background noise levels.

Standards for noise levels are specified in the *Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites*. The Acceptable Noise Level (ANL) for a Noise Sensitive Receiver (NSR) depends on the character of the area within which the NSR is located and the time of day under consideration.

The WEIF will be a major industrial development and this will be reflected in its location. It is not likely to be close to urban developments and it is not likely to be close to many NSRs. However, it is expected to operate 24 hours a day, 7 days a week and 52 weeks a year. The proximity of NSRs will be a consideration in the acceptability of any site.

6 IMPLICATIONS OF CO-SITING THE NEW POWER STATION WITH A WEIF

6.1 INTRODUCTION

The previous sections of this technical paper describe the physical, infrastructure and environmental requirements of the proposed WEIF. Many of the requirements are consistent with the site requirements for the new power station proposed by HEC; for example both require a coastal site with good connections to infrastructure and with good atmospheric dispersion. There are various implications associated with co-siting the two facilities and these are discussed in this section.

6.2 PHYSICAL REQUIREMENTS

6.2.1 Site Area

As outlined in *Section 3.1*, the EPD estimates that a WEIF with a capacity of 1 million tpa will require a site of 9 to 10 hectares. As a total incineration capacity of 2 million tpa is required, the resulting site area could potentially be in the order of 18 to 20 ha. However, due to the economies of scale and because of shared facilities a smaller area would probably be required than twice the area for a 1 million tpa facility. Additional area may also be required around the site for a Consultation Zone if the WEIF is classified as a PHI as detailed in *Section 5.3.2*.

The size of the site required for the new power station will depend on the choice of fuel. Scenarios have been developed for a coal-fired power station with a site area of 80 ha and a gas-fired power station with a site area of 50 ha.

Identification of suitable sites for the WEIF and the new power station facility is difficult given the severe shortage of land in Hong Kong. Co-siting the facilities would mean that only one site would be required which may ease the pressure on land in the Hong Kong SAR and the site search processes. Alternatively however, it may be that increasing the site area so that it is sufficient for both facilities would eliminate some site options that would be suitable for one or other of the facilities on their own, thus making site identification more difficult.

6.2.2 Geotechnical

The geotechnical requirements for the new power station and the WEIF are not expected to be different. No implications of co-siting with respect to geotechnical requirements have been identified during the preparation of this report except that a larger site with suitable geology would be needed for the co-sited option than for either of the two facilities should they be sited independently.

6.2.3 Location

Locational requirements for the two sites will be similar because the same issues relating to accessibility, landscaping and confined air sheds will apply to the new power station and the WEIF.

Better access to the shared site may be necessary because the co-sited facilities would generate higher volumes of traffic than either of the facilities on its own. In addition, as a larger site area (see *Section 6.1.1*) would be required, more landscaping and/or reclamation works would be required than for either of the two separate sites. However the total amount of landscaping / reclamation for two separate sites would probably be greater than for a single site. This is because there would probably be economies associated with landscaping and reclaiming one rather than two sites.

The need for good atmospheric dispersion at the site, which is influenced by location, would be particularly acute if the plants are to be co-sited because the combined emissions will be large. Atmospheric dispersion requirements are discussed in *Section 6.4.2*.

6.3 *INFRASTRUCTURE REQUIREMENTS*

6.3.1 *Transportation*

For both facilities good transportation access is required; if the coal fired station is adopted, good access by sea will be essential. Transport links serving the WEIF will be used for staff access, delivery of waste and removal of ash. Transport links serving the new power station will be used for staff access and, if is coal fired, for delivery of coal and removal of ash.

Marine access will be required for both the WEIF and the power station. The WEIF will receive waste from the RTSs and ash may be removed by marine vessels for disposal at the strategic landfill. The coal power station option would receive coal and probably also export ash by barge. Co-siting of the two facilities may therefore require a wharf that can serve both facilities. The vessels used to transport coal are larger than those used for the transport of waste and different handling facilities are required for waste (which is containerised) and coal. As a result there may be a requirement for separate rather than shared berthing facilities. If this was not required, the shared requirement for a wharf would probably lead to savings in cost and space. In either case (separate or shared wharf facilities) there would be a common requirement for approach channels.

6.3.2 *Utilities*

Electricity

The WEIF will probably produce electricity and if so both the facilities will require a connection to the electricity distribution grid. Co-siting may allow for the potential of sharing of some of the transmission equipment and connection to the distribution grid.

Water Supply and Sewerage

Both facilities will require access to a large water body for the provision and discharge of cooling water. They will also both require a potable water supply and sewerage to collect wastewater and possibly wastewater treatment facilities to treat wastewaters.

Co-siting may allow shared use of a cooling water abstraction point and of a cooling water outfall. It would also mean that a larger amount of heat would be discharged locally (rather than from two independent discharges) which would result in the enlargement of the mixing zone. Consequently, a longer outfall may be required to meet WQOs than would have been necessary for either of the facilities at independent sites. The advantage or otherwise of co-siting will therefore depend on the relative weights of the benefit of sharing facilities and the detriment of discharging larger amounts of heat locally. Alternatively, the co-sited facilities may have independent cooling water systems, which would need to be designed so as not compromise one another's extraction and outfall locations.

Other wastewater that may be discharged by both facilities includes flue gas cleaning residues, which will be of particular concern for the WEIF and the power station if the coal fired option is adopted, ash quenching water and domestic sewage. Treatment may be required at either of the facilities prior to discharge to sewer or coastal waters. The quality of the wastewater from the two facilities will probably be very similar and therefore the methods of treating these effluents are also likely to be similar. Co-siting might allow shared use of a single treatment works. If this is the case, co-siting would probably result in cost and space savings. Similarly provision of a mains water supply and mains sewerage would probably be cheaper if the two facilities were co-sited provided that both sites would otherwise require independent connections.

6.3.3 *Constraint of Sharing*

Since the owners of the WEIF and the new power station are different, co-siting the two facilities together may only allow very limited sharing of infrastructure from security and operating points of view. Other than construction site supplies and perhaps the marine access channel, there are very few permanent facilities that can be shared. However, innovative contractual arrangements for constructing and operating the WEIF may mitigate some of these constraints.

6.4 *ENERGY TRANSFER*

6.4.1 *Introduction*

The heat energy from the burning of waste in the WEIF can be utilized for the generation of electricity or steam. The following sections outline the feasibility of transmitting these the two forms of energy to an adjacent power station.

6.4.2 *Transfer of Power by Means of Electricity*

Transmission Power Loss

The power loss during transmission of electricity is directly proportional to the resistance of the transmission line. The greater the distance the higher the resistance and hence the power loss. Co-siting the WEIF next to a power station would not minimize the transmission loss. The electricity generated by the WEIF would still have to be transmitted through the power company's long transmission lines before it can be consumed by the end users in the load centres. There is virtually no advantage in the co-siting in minimizing the transmission power loss.

Subject to site constraints, it would be more desirable for the WEIF to be sited adjacent to a switching station/substation near to the load centre in order to minimize transmission losses.

Transmission Circuits Capacity

The transfer of 100MW power from a neighbouring WEIF to a power station would have significant impact to the capacity of the outgoing transmission circuits as the scale is equivalent to an additional generating unit at the power station. The capacity of the transmission network would have to be increased correspondingly to cater for the additional power transfer to the consumers. This could possibly involve the installation of an additional circuit which would cover the distance between the new power station and the load centre. The capital cost for installation of additional facilities or reinforcement of existing facilities for transmission of the power from the WEIF would have to be apportioned between the power company and the WEIF owner.

Capital and Maintenance Cost

The capital and maintenance costs of the transmission system are directly proportional to the length of the transmission circuits. For co-siting the WEIF with the new power station, there would be no saving on the capital and O&M costs of the transmission system as either design capacity of the cable current will need to be increased or an additional circuit would be required, to transmit the power from the WEIF.

6.4.3 *Transfer of Power by Means of Steam*

The energy from the WEIF can be transformed into steam. In some countries, steam generated in this fashion is used for district heating or for use in industrial processes. It is very rare that this amount of steam to be fed to a neighbouring power station to generate electricity, since it would be more efficient and easier to control if the WEIF has it own power generating facilities.

For the following reasons, it is not considered technically feasible or cost-effective for a power station to take up the heat energy from the steam.

- Stringent requirements on the quality of steam and strict control and monitoring of the steam pressure and temperature are required for the safe and uninterrupted operation of modern large capacity steam cycle plant. This is particularly so for the APC generating units recommended for the coal firing option since the main steam will be at *supercritical* conditions. For the combined cycle (CC) units using the gas firing option, taking the WEIF steam may be possible as the steam quality and control requirements are less stringent. In this case the steam turbine of the CC unit would have to be sized to take the steam from its own waste heat boiler and the WEIF. However, this is not an efficient design configuration and the operating mode of the CC unit would be dependent or handicapped by the WEIF operation. Alternatively, a separate turbine machine could be designed to take up the WEIF steam only, but in this case there is no reason why this turbine machine should be installed in the power station and not as part of the WEIF installation.

- The WEIF steam may be fed to the auxiliary steam system of the power station for plant heating and miscellaneous use, instead of directly to the steam turbine for power generation. However, the quantity of steam required by the auxiliary steam system would be too small to take up all of the steam produced by the WEIF.

- It is much more efficient and cost effective to design and install a designated generating unit to take up the WEIF steam, which means the WEIF installation should have its own generating plant instead of relying upon the adjacent power station to take up the steam.

6.4.4 *Summary*

It is feasible that the electricity generated from the WEIF could be fed to an adjacent new power station for onward transmission and distribution to the end users. It is considered that there would be no advantage in term of minimizing the transmission power loss, unless the WEIF power feeds directly to a switching station or substation near to the load centre. On the other hand, feeding 100MW of WEIF power to a neighbouring power station has a significant impact to the design capacity of the power station transmission circuit. Reinforcement of existing systems or installing an additional circuit may need to be made, hence additional capital investment on the power plant side.

Exporting steam from the WEIF directly to the generating units of the coal fired power station is not technically feasible since there would be technical difficulties in meeting the high steam quality and pressure and temperature conditions required. It is preferable that the WEIF takes up the steam for power generation on-site.

Sharing of infrastructure between the WEIF and an adjacent power station is very limited due to different ownership and nature of operation between the two installations.

There is no definite synergy advantage for co-siting the WEIF with the new power station. It is very rare to have such co-siting arrangement in other parts of the world. Isolated exception, e.g. Senoko Incinerator installed next to the Senoko Power Station in Singapore, are mainly due to land use planning factors rather than benefits due to engineering or operational considerations.

6.5 ENVIRONMENTAL REQUIREMENTS

6.5.1 *General*

The WEIF and the new power station have the potential to cause significant environmental impacts during their construction and operation.

The principal implication of co-siting would be that impacts would be concentrated at one location. If the facilities were not co-sited their impacts would be more diffuse. This may or may not be beneficial; co-siting may increase the magnitude of impact but it will also reduce the number of locations impacted.

6.5.2 *Atmospheric Dispersion and Air Quality*

The WEIF and the new power station will both be sources of atmospheric emissions. As detailed in *Section 5.1*, the degree of impact from an emission depends on a number of factors including the pollution control technology adopted, the rate of emission, prevailing background conditions, the degree of atmospheric dispersion and the proximity of sensitive receivers.

Co-siting the facilities would result in a substantially higher local emission rate than would be experienced for either plant in isolation. However, the absolute quantity of air pollutants discharged SAR-wide will be the same whether or not the power station and the incinerator are co-sited.

There is a potential trade off between the advantages and disadvantages of co-siting with respect to air quality. A high local emission rate would potentially result in a greater local impact than two emissions of lower rates at independent locations. However co-siting would mean that just one location rather than two would be affected by the emissions and this may reduce the number of sensitive receivers impacted. If a site has high atmospheric dispersion and there are no sensitive receivers at which exceedances of AQOs are predicted for co-sited facilities, then it would be beneficial with respect to air quality to co-site the two facilities.

Alternatively if co-siting the facilities is predicted to cause exceedances of AQOs at sites where no exceedances would occur if the facilities were sited separately then co-siting would reduce the number of potential locations for the facilities.

6.5.3 *Aqueous Discharges and Water Quality*

The WEIF and the new power station will discharge large volumes of cooling water. Similar considerations to those described for atmospheric emissions (*Section 6.4.2*) apply to wastewater discharges: if the facilities are co-sited then the local rate of discharge will be higher than if the facilities are sited independently.

As is the case for the consideration of air emission implications, a high local rate of aqueous discharge would probably result in a greater local impact than two discharges of lower rates at independent locations. However, as only one location is affected for a co-sited option, it may also reduce the number of sensitive receivers affected. If a site has high dispersion and there are no sensitive receivers at which exceedances of WQOs are predicted then it would be beneficial with respect to water quality to co-site the two facilities. Alternatively if co-siting the facilities is predicted to result in exceedances of WQOs at sites where no exceedances would occur if the facilities were sited separately then co-siting would reduce the number of potential locations for the facilities.

6.6 *POTENTIALLY HAZARDOUS INSTALLATIONS*

The classification of one or other of the WEIF and the new power station as a PHI would result in the requirement for a CZ around that facility as detailed in *Section* 5.3. Developments within the CZ are limited and this may constrain how close the two facilities could be sited. Therefore classification of either facility as a PHI might result in a larger site area.

6.7 *NOISE*

Noise level are not expected to be a major issue for the siting of either facility and it is expected that mitigation measures would be able to reduce the impacts to an acceptable level for the co-sited facilities or for either of the two facilities independently.

6.8 *CONCLUSION*

On the basis of the implications described above the following factors will be used to assess the feasibility of siting a WEIF on shortlisted potential sites for the new power station:

- the site requirement for the WEIF;
- the rate of emission from the WEIF of SO_2, NOx and particulates;
- the quantity of cooling water required; and
- the quantity and quality of effluent and nature of receiving water to which the effluent will be discharged.

All depend upon the technology that is employed in the WEIF and the WEIF capacity.

7 SUMMARY AND CONCLUSIONS

7.1 GENERAL

This Technical Paper presents the preliminary site requirements for a Waste-to-Energy Incineration Facility (WEIF). The need for a WEIF along with other measures to reduce the volume of waste disposed to landfill was identified in the Waste Reduction Study. Waste-to-energy incineration substantially reduces waste volumes as well as providing the opportunity to recover energy in the waste in the form of hot water/steam or electricity. The WEIF will be a large industrial structure that has the potential of being highly polluting if its siting and operation are not carefully managed. It will require a site with particular physical, infrastructure and environmental characteristics. Few potentially suitable sites exist because of the severe shortage of land and various physical and environmental constraints that prevail in Hong Kong.

There may be benefits in the co-siting of the WEIF with the new power station proposed by HEC, on the basis that the two facilities have similar physical, infrastructure and environmental requirements. However, the study commissioned by the EPD, into the siting of the WEIF, will need to clearly identify the extent of any inferred synergistic benefits arising from the co-siting suggestion.

7.2 WEIF TECHNOLOGY

Two different options for the type of waste incinerator were considered:

- a mass burn plant; and
- a fluidised bed plant.

The difference between the two technologies is primarily the type of combustion chamber employed, although fluidised bed plants require facilities for waste processing prior to incineration whereas mass burn plants do not. Consequently, fluidised bed plants tend to need a larger site than mass burn plants of the same capacity. This is potentially disadvantageous given the extreme shortage of sites in Hong Kong. In addition, no fluidised bed incinerators have been developed for the capacity required in Hong Kong, whereas large capacity mass burn incinerators are relatively well proven.

7.3 WEIF SITE REQUIREMENTS

The Report has identified various physical, infrastructure and environmental requirements for the site. They are as follows:

- a minimum of 1 incinerator with one million tonnes per year capacity will be required. If site characteristics allow, the options of siting 2 incinerators, each with a capacity of one million tonnes per year or one incinerator with a capacity of 2 million tonnes per year will also need to be considered(7);

(7) EPD **Information on Intended Capacity & Basic Siting Requirements of Waste-to-Energy Facility**

- a million tonne per year facility will have a site area of 9 to 10 ha[8], a two million tpa facility will have a site area of less than 18 ha because of economies of scale;

- the facility will have to be coastal for the delivery of waste from marine based refuse transfer stations and to allow sufficient supply and disposal of cooling waters;

- the facility will have berthing facilities with about 200 m of seawall or equivalent with a water draft of no less than 4.5m for the reception of vessels carrying waste[9];

- the site will preferably be flat with easy access by road and/or sea;

- the facility will benefit from a site with good infrastructure including connections to the road network or navigational waterways, the electricity grid (which will be vital if electricity is to be exported from the site), water mains and sewerage;

- the site will have to be such that good atmospheric dispersion of emissions can be achieved. Location in a confined air shed will not be feasible;

- the facility will have to be close to the sea to allow extraction and discharge of cooling waters and, in the event that the facility is not connected to foul sewer, to allow the discharge of other wastewaters;

Although the site may have to be surrounded by consultation zones in which development is limited, as the WEIF may be classified as a Potentially Hazardous Installation, this will not be considered as a primary selection criterion as this may constrain the power station site search.

7.4 CO-SITING IMPLICATIONS

The co-siting the WEIF with the new power station has a number of further implications:

- it may be possible to fit the two facilities into a smaller area than would be required if the two facilities were independently sited;

- construction costs associated with site earthworks, reclamation and connections to utilities would probably be lower than if both sites were independently sited;

- there is no definite synergy advantage for co-siting the WEIF with the new power station. It is very rare to have such co-siting arrangement in other parts of the world. Isolated exception, e.g. Senoko Incinerator installed next to the Senoko Power Station in Singapore, are mainly due to land use planning factors rather than benefits due to engineering or operational considerations;

[8] EPD *Op Cit*
[9] EPD *Op Cit*

- the site may need to be associated with higher atmospheric and hydrodynamic dispersion than would be necessary for either of the facilities independently. Therefore fewer sites may be suitable for co-siting than would for either of the two facilities;
- the classification of one or either of the facilities as a PHI may limit the proximity of the two facilities and hence increase the site area required.

7.5 *INTEGRATION OF THE WEIF REQUIREMENTS WITHIN THE SITE SEARCH*

The Site Search for a New Power Station will include within its broad approach a requirement to provide for the potential co-siting a WEIF within the site identified for the power station.

Whilst HEC has accepted the requirement, it is acknowledged that the primary purpose of the current site search is the identification of potential sites to accommodate a new 1800MW power station. As a consequence, the potential co-siting will, at each stage of the Site Search, be a secondary consideration and whilst the site requirements presented in this Technical Paper will be referred to as sites are subjected to increasing scrutiny, sites will not be excluded if they fail to meet the WEIF or co-siting requirements.

It is intended, therefore, that the potential for co-siting is introduced to the Site Search process following the shortlisting of potential sites. The shortlisted sites will then be assessed in broad terms of their suitability for accommodating the additional landtake and infrastructural requirements and, where co-siting can be physically achieved, an assessment of additional environmental impact will be made.

This evaluation is reported in *Annex A*; this represents a separate output and has not be fed into the selection process for the power station.

Annex A

Evaluation of Sites

1 INTRODUCTION

1.1 THE SCOPE OF THE CO-SITING EVALUATION

The assumptions presented in the Technical Paper formed the basis of subsequent evaluation of the co-siting option during the Site Search Study; potential sites for the new power station were evaluated in terms of their suitability for co-siting with the WEIF at two stages:

- the shortlisted sites for both the gas- and coal-fired scenarios were qualitatively evaluated against landtake requirements and marine accessibility; and
- the preferred site under each scenario was assessed against the additional air and water quality impacts associated with the co-siting of the WEIF.

The findings of these evaluations were reported in the subsequent Stage 1 EIA Report.

Whilst the requirement to provide for the potential co-siting of a WEIF within the site identified for the power station has been accepted by HEC, it is acknowledged that the primary purpose of the current site search is the identification of potential sites to accommodate a new 1800MW power station. As a consequence, the potential co-siting has been a secondary site search consideration and the potential sites for the new power station have not been excluded if they have failed to meet the WEIF or co-siting requirements.

1.2 STRUCTURE OF THE ANNEX

The remainder of this Annex is organised as follows:

- *Section 2* presents the findings of the evaluation of shortlisted sites; and
- *Section 3* presents the evaluation of the preferred site.

2 THE FEASIBILITY OF CO-SITING A WEIF AND THE NEW POWER STATION

2.1 INTRODUCTION

The following sections provide a qualitative assessment on the general feasibility of WEIF co-siting with the proposed new power station at each of the shortlisted sites for each fuel options. The assessment focuses on the feasibility of providing additional land required for the WEIF adjacent to each of the shortlisted sites and feasibility of co-siting the two facilities with respect to maritime and navigation requirements.

A more detailed environmental assessment of the feasibility of the co-siting a WEIF at the preferred site(s) for the power station for the gas- and coal-fired options are discussed in *Sections* 3.2 *and* 3.3 respectively.

2.2 LANDTAKE IMPLICATIONS

To accommodate the WEIF adjacent to the proposed new power station, an additional site area of about 9 to 10ha will be required for a 1 million tpa WEIF plus standby units and power generation facilities.

The total landtake for the two facilities will be approximately 60ha and 90ha for gas and coal fired options respectively. The WEIF site should provide a minimum width of 250m. To accommodate vessels from the existing marine-based refuse transfer stations, about 300m vertical seawall length or equivalent in the form of a jetty is required.

2.3 MARINE IMPLICATIONS OF CO-SITING

2.3.1 *Introduction*

The waste transportation arrangements to and from the WEIF will be developed in the WEIF Feasibility Study to be overseen by the EPD. As all the shortlisted sites are located on the outlying islands, it is unlikely that the waste would be routinely delivered to the WEIF by road. The siting of the new power station at a coastal location will ensure that the waste would be transferred to the co-sited WEIF by marine vessels in accordance with existing transfer station operating arrangements. It is probable that the incineration residues to be disposed of at landfill would also be transferred away from the WEIF using marine vessels.

The following sections present the qualitative assessments of the suitability of co-siting a WEIF adjacent to each of the shortlisted sites for the gas or coal fired power station with respect to marine accessibility, marine traffic, and berth availability. The locations of the shortlisted sites are shown in *Figure 2.3a*.

These assessments identify the practical marine navigation features affecting the passage of refuse transfer vessels transiting through the Western Harbour en route to the shortlisted sites and any problems associated with the co-siting of the two facilities.

2.3.2 *Vessel Requirements*

It is expected that a dedicated refuse transfer vessel will make a minimum of one journey to the WEIF per day from their transhipment point, through the Western Harbour. In addition to the dedicated transfer vessel there is a range of vessels that could also be adopted for transferring waste to the WEIF, including:

- towed barge/pontoon;
- self-propelled pontoon;
- self-propelled barge; and
- container/ro-ro vessel.

The initial assessment of access and berth availability has been based on a vessel similar to the existing vessels adopted for the transport of waste from the marine-based transfer stations to the strategic landfill sites; ie:

- Length = approximately 60 - 70m;
- Beam = approximately 15 - 20m;
- Draft = approximately 3 - 5m; and
- Speed = approximately 8 knots.

It is expected that the berthing facility will operate in conditions up to the Typhoon Signal no 3, and will not be required to provide shelter to vessels during typhoons. However, the berthing facility must ensure that it provides sufficient shelter during normal operating conditions up to wind speeds associated with Typhoon Signal no 3. Significant wave heights (H_s) of up to 0.5m for the dedicated container/ro-ro vessel and H_s = 0.3m have been considered as the maximum permissible for safe operations at the berth. The significant height corresponds to the mean height of the highest 1/3 of the observed waves.

2.3.3 *Maritime Requirements*

The objective of applying maritime screening criteria to the shortlisted sites is to ensure that the selected sites are not constrained in terms by marine access, traffic, or the availability of the berth for the berthing, unloading and unberthing of the refuse transfer vessel. Although the influence of water depth will be briefly examined during this phase of the work, the focus of such examination will be to determine any requirements for a dredged navigation channel, and associated turning basin. Marine accessibility will be judged under three broad criteria.

Navigational Constraints

The key navigation issues relating to site evaluation are those of marine access, and any risks associated with the refuse transfer vessel traversing and crossing existing, or future marine traffic streams. This assessment has been conducted with respect to the MARAD (1997) study, and databases held in-house by Babtie BMT (HK) Ltd.

Metocean Conditions

The refuse transfer vessel, on transit to the sites, and during berthing will be liable to the influences of wind, waves and currents - the "Metocean" environment.

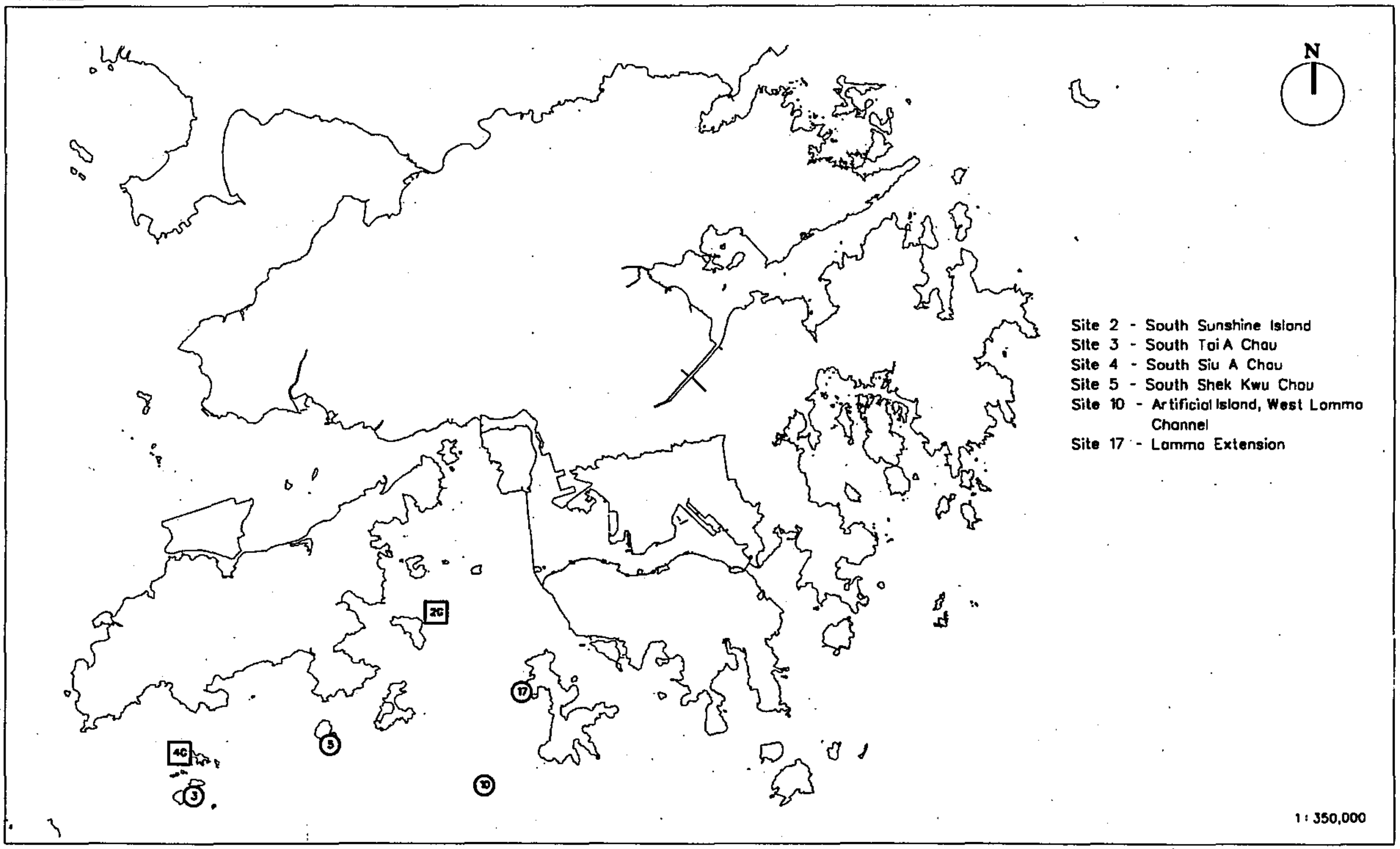


FIGURE 2.3a Short-Listed Sites for the Power Station

Date : 30 May 1997

Drawing No. /Contract/C1432/C1432_1a

Sources :

Prepared by ERM's GIS & MAPPING Group

KEY

C Gas Fired Station only

1 Gas or Coal Fired Power Station

ERM Hong Kong
6th Floor
Hecny Tower
9 Chatham Road
Tsimshatsui, Kowloon
Hong Kong

ERM

- *Winds*: The typical wind regime is dominated by the north-east monsoon between September and May, and the south-west monsoon in June to August. It is considered that the weather station data collected at Cheung Chau can be generally applied for all the shortlisted sites under consideration.

- *Waves*: The wave climate at each site requires consideration with regard to the affect on transit and berthing operations due to the variations in shelter affected by islands, shoals and the mainland land mass.

- *Currents:* Currents may be produced by the action of tides, winds and waves. While areas with high currents exist within Hong Kong waters the shortlisted sites are unlikely to be acted on by currents exceeding 1 knot.

Jetty Facilities

The refuse transfer vessel will require an area of sheltered quayside with container handling and storage facilities remote from the power station operations allowing independent operation of the delivery facilities. An upper berthing limit of 0.5m wave height has been provisionally adopted for this study.

The marine facilities for the WEIF will supplement those developed for the gas fired power station. Facilities required include a small boat harbour and quayside for operational supply craft and small workboats.

Facilities required for one Cape class bulk carrier include a large quayside with a dedicated jetty with coal stackers and conveyors, and small boat harbour for supply crafts.

The nature of the facilities required for the dedicated refuse transfer vessel will be quite different from the coal receiving jetty with stackers and conveyers used at the coal-fired terminal, but may be integrated with a small boat harbour required for the supply craft and workboats.

2.4 CO-SITING AT THE SHORTLISTED SITES FOR A GAS-FIRED POWER STATION

2.4.1 *Site 2 - Sunshine Island (Chau Kung To)*

Location

The sites for the WEIF and the new power station are located across the south and south-east edges of the Sunshine Island, with berths located for the north-eastern edge of the reclamation.

Accessibility

The approach to the north-eastern berth would be directly from the Adamasta Channel which lies along a south-west to north-east axis 1km to the south-east of the Sunshine Island. Traffic heading in a south-west direction utilises the western edge of the fairway, while traffic travelling north-east utilises the eastern side of the fairway. Minimum water depths of approximately 8m would not require the provision of a dredged approach channel for the refuse transfer vessel.

Marine Traffic

Vessels leaving the WEIF and the power station via a dredged channel along the north-west and north of the Sunshine Island, or from the north-east berth may not rejoin the Adamasta fairway directly but travel the 1.5km to the convergence zone of the Adamasta and West Lamma Channels outside the established fairway. The vessels would then enter the dense traffic streams of the Western Harbour.

Availability

The north-eastern berth site is exposed to northerly to south-easterly winds, generated from winds blowing across the sea towards Tsing Yi, a distance of some 11km, and between Hei Ling Chau and Lamma Island, a distance of 6.5km. Winds corresponding to typhoon signal no 3 (17m/sec) are most likely to be generated from an easterly direction. Consequently some form of protective structure would be required for vessels of this size, to ensure availability of the berth in seastates up to typhoon signal no 3, and for seastates below this windspeed. The current arrangement of the north-east berth would prove difficult to provide a breakwater or small boat harbour configuration sufficient to provide the require protection, with adequate access. However, if the line of the north-east edge of the reclamation was moved 100m to the north-east on the offshore breakwater, or the small boat harbour could be provided to offer adequate protection and access, without the potential restriction to navigation presently posed by the eastern tip of the island.

Summary

The access to the north-east berth will be good, marine traffic will be high and berth availability (without the development of sheltered waters) will be moderate.

2.4.2 ***Site 3- South Soko Island (Tai A Chau)***

Location

The sites for the WEIF and the new power station are located across on the northern tip of the Tai A Chau. The berth is situated on the north-west face of the reclamation.

Accessibility

Access to Tai A Chau would be from the West Lamma Channel on the north-eastern face of the reclamation. No dredging of approach channels would be required for access of the refuse transfer vessels.

Marine Traffic

The West Lamma Channel carries predominately high speed passenger ferries from Macau, with workboats and river trade the largest vessel type using this route. Fast ferries use this route predominantly at night when approximately 20 ferries en route to Hong Kong from Macau pass to the east of Shek Kwu Chau and Cheung Chau along the West Lamma Channel. This channel is also used by river trade vessels, accounting for approximately 3,500 arrivals per year, or 10 per day, which amount to approximately 4% of all river trade arrivals into Hong Kong waters.

Departures of vessels from the WEIF and the power station would require a simple entry into eastbound fairway of the West Lamma Channel. Arriving vessels would be required to leave the westbound fairway and cross the eastbound fairway. For the given frequency it is be expected that the encounter probabilities will be low during the day when we might expect encounters with a single vessel to occur.

A higher frequency would be encountered after dark, but as waste delivery trips are expected to be conducted during daylight hours the crossing of the fairway after dark is not anticipated. Projections developed in MARAD for increases in traffic streams use the year 2011 as the benchline for marine traffic. Fast ferry traffic is expected to increase by approximately 70%, each way. River trade arrivals using the West Lamma Channel adjacent to the Soko Islands are not projected to increase beyond current levels. Consequently the likely encounter rate during transit of the refuse transfer vessel across the Adamasta channel is likely to increase by approximately 60%, however the level of encounters will remain low.

Availability

The site is generally sheltered from southerly waves and swell from the South China Sea, and from wind generated winds from the north-west to the north-east wind. It is not anticipated that there will be any problems with berthing or unloading operations on the north-west flank of the reclamation, and it would be unlikely that this area would suffer from down-time problems.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be good.

2.4.3 *Site 4- North Soko Island (Siu A Chau)*

Location

The sites for the WEIF and the new power station are located on the western side of the island.

Accessibility

Access to Sui A Chau would be from the West Lamma Channel which lies directly to the north. Water depths to the west of the reclamation are very low (2.1m), however access to the berths on the north face of the reclamation will not be problematic.

Marine Traffic

The traffic constraints will be identical to those developed for the Tai A Chau site; in that the impact of the refuse transfer vessels on existing or future traffic flows would be negligible.

Availability

It is not anticipated that there will be any problems with berthing or unloading operations on the north face of the reclamation and it would be unlikely that this area would suffer from down-time problems.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be good.

2.4.4 *Site 5- Shek Kwu Chau*

Location

The sites for the WEIF and the new power station are located on the southern side of the island, close to deep water.

Accessibility

The approach to the site would be relatively simple from either the Adamasta Channel to the north or preferably from the West Lamma Channel to the south. The berths are sited on the western face of the reclamation.

Marine Traffic

The island is located between the Adamasta Channel and the West Lamma Channel which are used by a large number of high speed passenger ferries and workboats. It is recommended that access to the site is from the West Lamma Channel, therefore the traffic constraints will be identical to those developed for the Tai a Chau site; in that the impact of the refuse transfer vessels on existing or future traffic flows would be negligible.

Availability

The berth is directly exposed to the southerly and south-easterly waves and swell from the South China Sea. Provision of a protective breakwater to the south of the berth would be required to allow year-round operation of the vessel in winds up to Typhoon Signal no 3.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be poor.

2.4.5 *Site 10- Artificial Island, West of Lamma Channel*

Location

This site for the WEIF and the new power station would be an artificial island located west of Lamma Island with the berthing face preferably located on the north facing side of the island. a berth could alternatively be located on the south face of the island, however, this location would be more exposed to south and south westerly waves and swell.

Accessibility

The approach to the site would be from the north from the West Lamma Channel.

Marine Traffic

The island location can be situated so that it is well clear of the proposed West Lamma Channel. Access to the artificial island could be from the established West Lamma Channel, or in the future from the new dredged West Lamma Channel that will bring vessels up to the north-east Lantau ports. Given the likely traffic using the new West Lamma Channels would consist of large container, it is recommended that access to the site be gained from the existing West Lamma Channel. Should this be adopted the traffic constraints will be identical to those developed for the Tai a Chau site; in that the impact of the refuse transfer vessels on existing or future traffic flows would be negligible.

Availability

The berths would be sheltered from the south by the artificial island reclamation, though the approaches to the berth would be exposed. Some shelter from east and north east winds may be obtained from Lamma and Hong Kong Islands; although the island may be sufficiently distant for wind speeds to become re-established. The berth is exposed to winds from the north, with wave significant wave heights of 1.65m established over the 22km from Ma Wan during a typhoon signal no 3 wind acting from the north.

Winds corresponding to an average 5% and 50% probability of excellence will have significant wave heights of 0.65 and 0.4m suggesting that protection from direct wave action should be provided to ensure operations at all wind speeds up to typhoon signal no 3 conditions.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be poor.

2.4.6 *Site 17- Lamma Extension*

Location

This site for the WEIF and the new power station would be located on an area of new reclamation to the south of the proposed Lamma Power Station.

Accessibility

The approach to the site would be from the north from the West Lamma Channel.

Marine Traffic

Access to the Lamma extension site could be the East Lamma Channel, with a passage around the north coast of Lamma, with a return via the West Lamma Channel. This would avoid the need to cross any major shipping lanes with conventional ferry and fishing vessels the most likely vessels to be encountered during this part of the transit.

Availability

A berth situated on the southern or eastern face of the reclamation would allow easiest access to the facility, sufficiently remote from the existing jetty. a small boat harbour may be required to ensure access and availability of the berth, although the protection at this site from the predominant east and south-easterly waves is very good.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be good.

2.4.7 *Summary of Co-Siting Assessments for Gas Fired Option*

The findings of the assessments for co-siting a WEIF with the proposed gas fired power station are summarised in *Table 2.4a*. All sites can accommodate an additional landtake of 10ha for a one million tpa WEIF and are accessible to refuse transfer vessels. Sites 3 - South Soko Island (Tai a Chau), Site 4 - North Soko Island (Siu a Chau) and Site 17 - Lamma Extension are preferred from a marine traffic and berth availability viewpoint.

Table 2.4a ***Summary of the Assessments for Co-siting a WEIF with the Proposed Gas Fired Power Station***

Site	Location	Additional Landtake	Access	Marine Traffic	Berth availability*
2	Sunshine Island	10ha	West berth - poor NE berth - good	high	West berth - good NE berth - moderate
3	South Soko Island (Tai A Chau)	10ha	good	low	good
4	North Soko Island (Siu A Chau)	10ha	good	low	good
5	Shek Kwu Chau	10ha	good	low	poor
10	Artificial Island, West Lamma Channel	10ha	good	low	poor
17	Lamma Extension	10ha	good	low	good

Note: * (without the development of sheltered waters)

2.5 *CO-SITING AT THE SHORTLISTED SITES FOR A COAL-FIRED POWER STATION*

The following sections review the suitability of co-siting the WEIF with the shortlisted sites for coal fired power station with respect to marine accessibility, marine traffic, and berth availability.

2.5.1 *Site 3- South Soko Island (Tai A Chau)*

Location

The sites for the WEIF and the new power station are located across on the northern tip of the island. For the coal-fired option the reclamation takes the form of a rectangular block, with a proposed coal berth of the eastern side of the north edge.

Accessibility

Access to Tai a Chau would be from the West Lamma Channel and would be adjacent to the coal bulk carrier berth on the northern face No dredging of approach channels would be required for access of the refuse transfer vessels.

Marine Traffic

The marine traffic in the area has been discussed in *Section* 3.2. Departures vessels or workboats from the WEIF and the power station would require a simple entry into eastbound fairway of the West Lamma Channel. Arriving vessels would be required to leave the westbound fairway and cross the eastbound fairway. For the given frequency it would be expected that the encounter probabilities will be low during the day when we might expect encounters with a single vessel to occur.

A higher frequency would be encountered after dark, but as waste delivery trips are expected to be conducted during daylight hours the crossing of the fairway after dark is not anticipated. Projections developed in MARAD for increases in traffic streams use the year 2011 as the benchline for marine traffic. Fast ferry traffic is expected to increase by approximately 70%, each way. River trade arrivals using the West Lamma Channel adjacent to the Soko Islands are not projected to increase beyond current levels. Consequently the likely encounter rate during transit of the refuse transfer vessel across the Adamasta channel is likely to increase by approximately 60%, however the level of encounters will remain low.

Availability

The site is generally sheltered from southerly waves and swell from the South China Sea, and from wind generated winds from the north-west to the north-east wind. The refuse transfer vessel berthed on the northern face would be exposed to waves from the east-south-east. Waves could be generated over the sea between Tai a Chau and the Dangan Liedao Island group, a distance of approximately 35km. Average wave heights of 0.5m acting bow onto the vessel are not expected to cause a problem with berthing or unloading, however waves of Hs = 0.8m, associated with a return period of approximately 5% may limit operations. Consequently, consideration should be given to the orientation of the berth, and some shelter provided for the refuse transfer vessels against these waves.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be moderate.

2.5.2 *Site 5- Shek Kwu Chau*

Location

The sites for the WEIF and the new power station are located on the southern side of the island, close to deep water.

Accessibility

The approach to the site would be relatively simple from either the Adamasta Channel to the north or preferably from the West Lamma Channel to the south.

Marine Traffic

The island is located between the Adamasta Channel and the West Lamma Channel which are used by a large number of high speed passenger ferries and workboats. It is recommended that access to the site is from the West Lamma Channel, therefore the traffic constraints will be identical to those developed for the Tai a Chau site; in that the impact of the refuse transfer vessels on existing or future traffic flows would be negligible.

Availability

The berth is directly exposed to the southerly and south-easterly waves and swell from the South China Sea. Provision of a protective breakwater to the south of the berth would be required to allow year-round operation of the refuse transfer vessel in winds up to Typhoon Signal no 3.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be poor.

2.5.3 *Site 10- Artificial Island, West Lamma Channel*

Location

The sites for the WEIF and the new power station would be an artificial island located west of Lamma Island and south of the proposed Lamma Breakwater, with the berthing face preferably located on the north facing side of the island. a berth could alternatively be located on the south face of the island, however, this location would be more exposed to south and south-westerly waves and swell.

Accessibility

The approach to the site would be from the north from the West Lamma Channel.

Marine Traffic

The island location can be situated so that it is well clear of the proposed West Lamma Channel. Access to the island could be from the established West Lamma channel, or in the future from the new dredged West Lamma Channel that will bring vessels up to the north-east Lantau ports. Given the likely traffic using the new West Lamma Channels would consist of large container it is recommended that access to the site be gained from the existing West Lamma Channel. Should this be adopted the traffic constraints will be identical to those developed for the Tai a Chau site; in that the impact of the refuse transfer vessels on existing or future traffic flows would be negligible.

Availability

The berth for the refuse transfer vessels would be sheltered from the south by the artificial island reclamation, though the approaches to the berth would be exposed. Some shelter from east and north east winds may be obtained from Lamma and Hong Kong Islands; although the island may be sufficiently distant for wind speeds to become re-established. The berth is exposed to winds from the north, with wave significant wave heights of 1.65m established over the 22km from Ma Wan during a typhoon signal no 3 wind acting from the north.

Winds corresponding to an average 5% and 50% probability of excellence will have significant wave heights of 0.65 and 0.4m suggesting that protection from direct wave action should be provided to ensure operations at all wind speeds up to Typhoon Signal no 3 conditions.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be poor.

2.5.4 *Site 17- Lamma Extension*

Location

The sites for the WEIF and the new power station would be accommodated on an area of new reclamation to the south of the existing Lamma Power Station.

Accessibility

The approach to the site would be from the north from the West Lamma Channel.

Marine Traffic

Access to the Lamma Extension site could be the East Lamma Channel, with a passage around the north coast of Lamma, with a return via the West Lamma Channel. This would remove the need to cross any major shipping lanes with conventional ferry and fishing vessels the most likely vessels to be encountered during this part of the transit.

Availability

A berth situated on the southern or eastern face of the reclamation would allow easiest access to the WEIF, sufficiently remote from the existing jetty of the Lamma Power Station. a small boat harbour may be required to ensure access and availability of the berth, although the protection at this site from the predominant east and south-easterly waves is very good.

Summary

Access to the berths will be good, marine traffic will be low and berth availability (without the development of sheltered waters) will be good.

2.5.5 *Summary of Co-Siting Assessments for Coal Fired Option*

The findings of the assessments for the co-siting a WEIF with the proposed coal fired power station are summarised in *Table 2.5a*. All sites can accommodate an additional landtake of 10 ha a one million tpa WEIF and are accessible to refuse transfer vessels. Sites 3 - South Soko Island (Tai A Chau), Site 4 - North Soko Island (Siu A Chau) and Site 17 - Lamma Extension are preferred from a marine traffic and berth availability viewpoint.

Table 2.5a ***Summary of the Assessments for Co-siting a WEIF with the Proposed Coal Fired Power Station***

Site	Location	Additional Landtake	Access	Marine Traffic	Berth availability*
3	Tai A Chau	10ha	good	low	moderate
5	Shek Kwu Chau	10ha	good	low	poor
10	Artificial Island, West Lamma Channel	10ha	good	low	poor
17	Lamma Extension	10ha	good	low	good

Note: * (without the development of sheltered waters)

3 CO-SITING WITH THE PREFERRED SITES

3.1 INTRODUCTION

The potential for a proposed 1 million tpa capacity Waste-to-energy Incineration Facility (WEIF) to be co-sited with the new power station was addressed in the Technical Paper on the Waste-to-energy Incineration Study and the findings are summarised in *Section 3.5*. The Technical Paper addressed the requirements for co-siting and provided a preliminary definition of the components of the WEIF. Following the submission of the Technical Paper further information has been received from the EPD regarding the assumptions pertaining to the basic design of the WEIF. It should also be noted that the EPD has recently awarded a contract for the assessment of the feasibility of the WEIF proposals and that this assessment requires that four alternative sites for the WEIF are addressed, namely: Lamma Island, Ha Pak Nai, Tit Cham Chau and Tuen Mun Port.

As agreed at the Stage 1 EIA Study Management Group, this section addresses the potential for co-siting a WEIF with a new gas-fired power station at the environmentally preferred site (Site 17 - Lamma Extension). As the environmental ranking of Site 10 - Artificial Island is very close to the Lamma Extension site, we have also provided an assessment of the potential for co-siting a WEIF with the Artificial Island site. The assessments consider the environmental implications with reference to impacts to water and air quality.

3.2 CO-SITING THE PREFERRED GAS-FIRED OPTIONS WITH THE WEIF

3.2.1 *Introduction*

The air and water quality implications of co-siting the WEIF with the gas-fired new power station at the Artificial Island and Lamma Extension sites are discussed below.

3.2.2 *Air Quality Implications*

A quantitative assessment of the impacts of the proposed WEIF has been undertaken on the assumption that it is located at either Lamma Island (Site 17) (see *Figure 3.2a*) or on an artificial island in the West Lamma Channel (Site 10) (see *Figure 3.2b*). The assessment is considered to represent a worst case situation as the plumes from the new power station and the WEIF have the potential to overlap, thereby increasing the predicted ground level concentrations. The plumes from these two proposed developments also have potential to overlap with the plumes from the existing and committed units at Lamma Power Station.

The maximum predicted ground level concentrations attributable to the WEIF under the hypothetical worst case scenarios, Scenario B, and Scenario C were as follows:

	B	C
SO_2	45 ppb	35 ppb
NO_x	70 ppb	60 ppb
RSP	9 $\mu g/m^3$	7 $\mu g/m^3$

The assumptions used in making these estimates are subject to review following the findings of the EPD's feasibility study on the proposed WEIF and are summarised as follows.

- Stack height - 150m
- Stack diameter - 4.66m
- Efflux velocity - 15 m/sec
- Exit temperature - 120°C
- Pollutant emission rates:
  - particulates - 8.92 g/sec
  - NO_x - 71.39 g/sec
  - SO_2 - 44.62 g/sec

It is probable that the predicted concentrations will be reduced following the refinement of the assumptions made in this assessment. In particular, the emissions were assumed to be at the limits of the Best Practical Mean (BPM) standard, whereas modern WEIF plants are capable of performing well within this standard.

Under two of the scenarios, B and C, the plumes from the new power station and the WEIF overlap to a limited extent, although it was noted that this had no influence upon the maximum predicted ground level concentrations which were attributed principally to the emissions from the existing station. This prediction was made for both the Lamma Island and artificial island sites and is explained by the slightly different trajectories of the plume from the WEIF and those from the existing and proposed new power stations. This observation is attributable to the lower buoyancy of the plume from the WEIF and the different height of the WEIF stack relative to that of the existing and new power stations.

It is considered that co-siting the WEIF with a proposed new gas-fired power station at either the Lamma Island and artificial island sites, would not increase the maximum predicted ground level concentration. On the basis of the assumptions made, siting the WEIF adjacent to the new gas-fired power station at either of the two sites does not create any insurmountable detrimental impacts to air quality.

3.2.3 *Water Quality and Thermal Plume Implications*

For the purposes of the detailed site selection of the Stage 1 EIA, it was agreed with the EPD that assessments to water quality would be focused on impacts resulting from the discharge of cooling water. Co-siting a WEIF with the power station has implications for water quality because the operation of the WEIF generates waste heat which is discharged to the sea. Thermal impacts to water quality from a WEIF and a new power station together would therefore be expected to be greater than for a new power station alone. The increase in impacts that would result from a co-siting is largely determined by the relative magnitude of the discharges resulting from the power station and from the WEIF. Accordingly, thermal impacts from a co-sited power station and WEIF have been predicted on the bases of predicted impacts arising from the power station alone and the relative additional heat that would result from the addition of a WEIF.

Heat rejection rates for power stations options in 2012 were presented in *Annex C* of the *Stage 1 EIA Report*. The peak rate for a new gas-fired station is 1122.4 Gcal/hr. However at Site 17 - Lamma Extension there is existing station

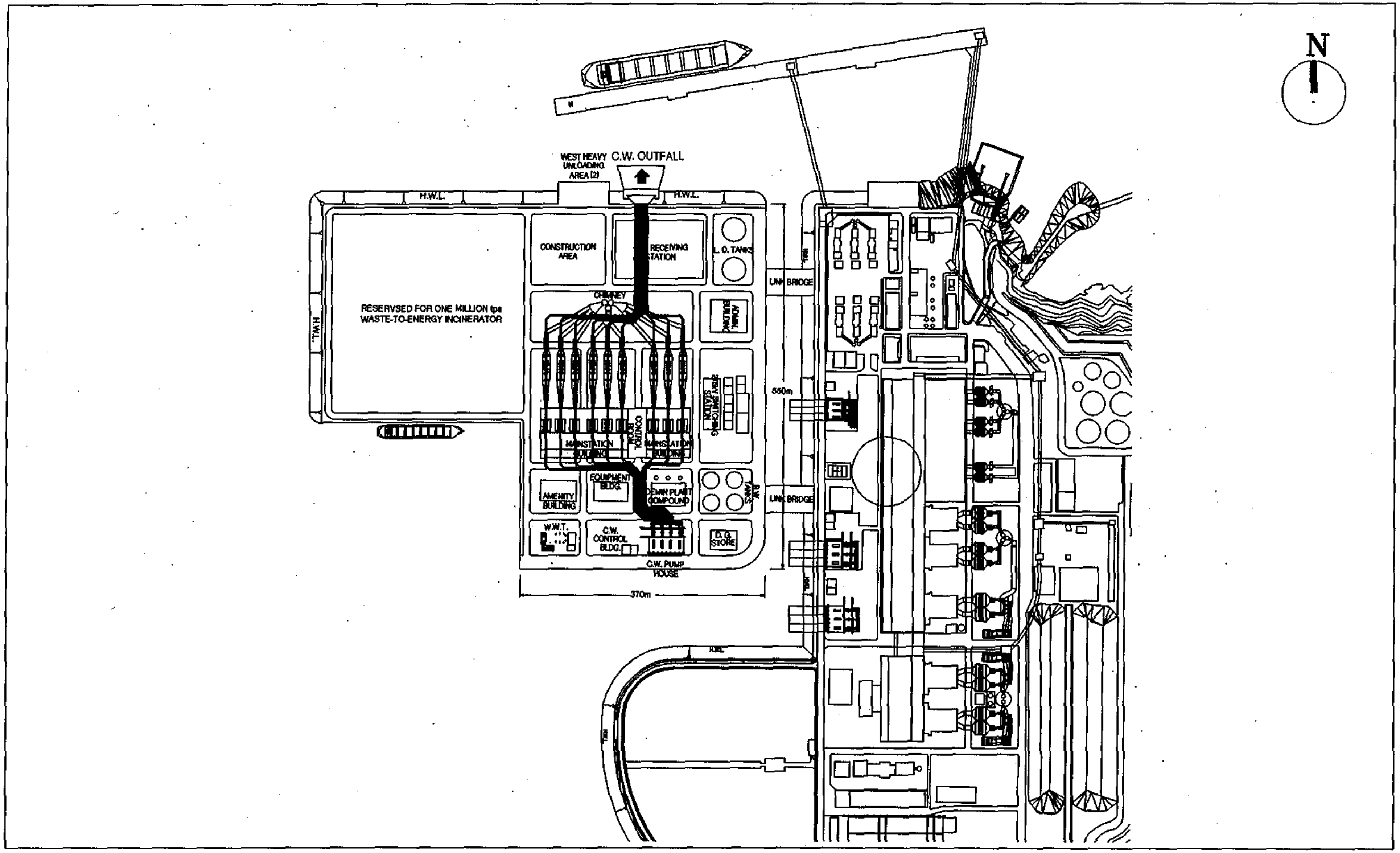


FIGURE 3.2a - COSITING WEIF WITH A GAS FIRED POWER STATION AT LAMMA EXTENSION

Date : Aug 97

Drawing No. /ermhk/c1432/stations/6.13a.dgn

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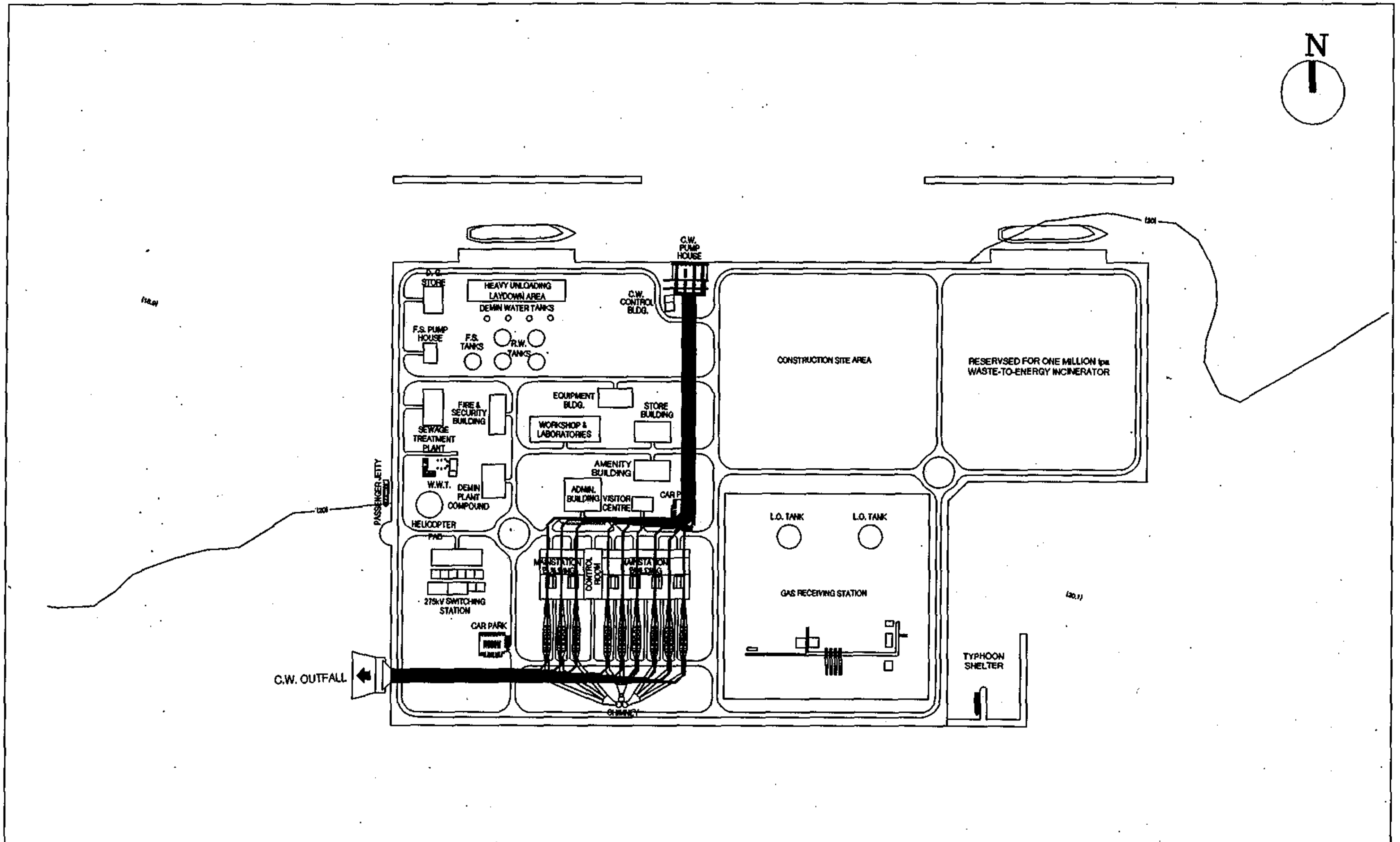

FIGURE 3.2b - COSITING WEIF WITH A GAS FIRED POWER STATION AT THE ARTIFICIAL ISLAND SITE

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which will also discharge heat and therefore for this site the peak rate is higher at 3055.4 Gcal hr^{-1}. An estimated heat rejection rate of 152,207 KJ/sec (which corresponds to approximately 130 Gcal/hr) has been provided by the EPD for the WEIF.

The combined peak heat load from a co-sited power station and WEIF would therefore be expected to be approximately 12% greater than for a gas-fired power station alone. For Site 17 - Lamma Extension, the combined peak heat load would be 4% greater. The total heat load from both facilities would be less than the heat load for a new coal fired power station. Given the acceptability of thermal impacts predicted for coal stations at all of the sites, as detailed in *Section 6.3*, co-siting a gas-fired power station with a WEIF is unlikely to result in unacceptable thermal impacts.

3.3 CO-SITING THE PREFERRED COAL-FIRED OPTIONS WITH WEIF

3.3.1 *Introduction*

The air and water quality implications of co-siting the WEIF with the coal-fired new power station at the Artificial Island and Lamma Extension sites are discussed below.

3.3.2 *Air Quality Implications*

A quantitative assessment of the impacts of the proposed WEIF has been undertaken on the assumption that it is located at either Site 17 - Lamma Extension (see *Figure 3.3a*) or on Site 10 - Artificial Island, West of Lamma Channel (see *Figure 3.3b*). The assessment is considered to represent a worst case situation as the plumes from the new power station and the WEIF have the potential to overlap, thereby increasing the predicted ground level concentrations. The plumes from these two proposed developments also have potential to overlap with the plumes from the existing and committed units at Lamma Power Station.

The maximum predicted ground level concentrations attributable to the WEIF under the hypothetical worst case scenarios, Scenario B, and Scenario C were as presented in the *Stage I EIA* and in *Section 3.2* above. The assumptions used in making these estimates are subject to review following the findings of the EPD's feasibility study on the proposed WEIF and are summarised as follows.

- Stack height - 150m
- Stack diameter - 4.66m
- Efflux velocity - 15 m/sec
- Exit temperature - 120°C
- Pollutant emission rates:
    - particulates - 8.92 g/sec
    - NO_x - 71.39 g/sec
    - SO_2 - 44.62 g/sec

It is probable that the predicted concentrations will be reduced following the refinement of the assumptions made in this assessment. In particular, the emissions were assumed to be at the limits of the BPM standard, whereas modern WEIF plants are capable of performing well within this standard.

Under the two *Scenarios B* and C, the plumes from the new power station and the WEIF overlap to a limited extent, although it was noted that this had no influence upon the maximum predicted ground level concentrations which were attributed to the emissions from the new power station and the existing station. This prediction was made for both the Site 17 - Lamma Extension and Site 10 - Artificial Island and is explained by the slightly different trajectories of the plume from the WEIF and those from the existing and proposed new power stations. This observation is attributable to the lower buoyancy of the plume from the WEIF and the lower height of the WEIF stack relative to that of the existing and new power stations.

It is considered that co-siting the WEIF with a proposed new coal-fired power station at either the Lamma Extension and Artificial Island sites, would not increase the maximum predicted ground level concentrations of RSP, NO_x and SO_2. On the basis of the assumptions made, siting the WEIF adjacent to the new coal-fired power station at either of the two sites does not create any insurmountable detrimental impacts to air quality.

3.3.3 *Water Quality and Thermal Plume Implications*

Water quality assessments for co-siting a new coal-fired power station with a WEIF have been conducted in the same way as for co-siting a new gas-fired power station with a WEIF.

Heat rejection rates for power station options in 2012 are presented in *Annex C* in of the *Stage 1 EIA Report*. The peak rates for a new coal- fired station is 1843.5 Gcal/hr. However at Site 17 - the Lamma Extension there is existing station which will also discharge heat and therefore for this site the peak rate is higher at 3879.2 Gcal/hr. An estimated heat rejection rate of 152,207 KJ/sec (which corresponds to approximately 130 Gcal/hr) has been provided by the EPD for the WEIF.

The combined peak heat load from a co-sited power station and WEIF would therefore be expected to be approximately 7% greater than for a coal- fired power station alone. For Site 17 - the Lamma Extension, the combined peak heat load would be 3% greater. Because these increases are relatively small, the additional impacts generated by co-siting a WEIF with the power station are also expected to be small. Co-siting at Site 17 - the Lamma Extension would be of more concern than co-siting at other sites because of the discharge from the existing power station and the proximity of various sensitive receivers (see *Section 6.3.7*). However, because the percentage heat load increase is very small (3%), the increase to thermal impacts would also be very small and would therefore be unlikely to be significant.

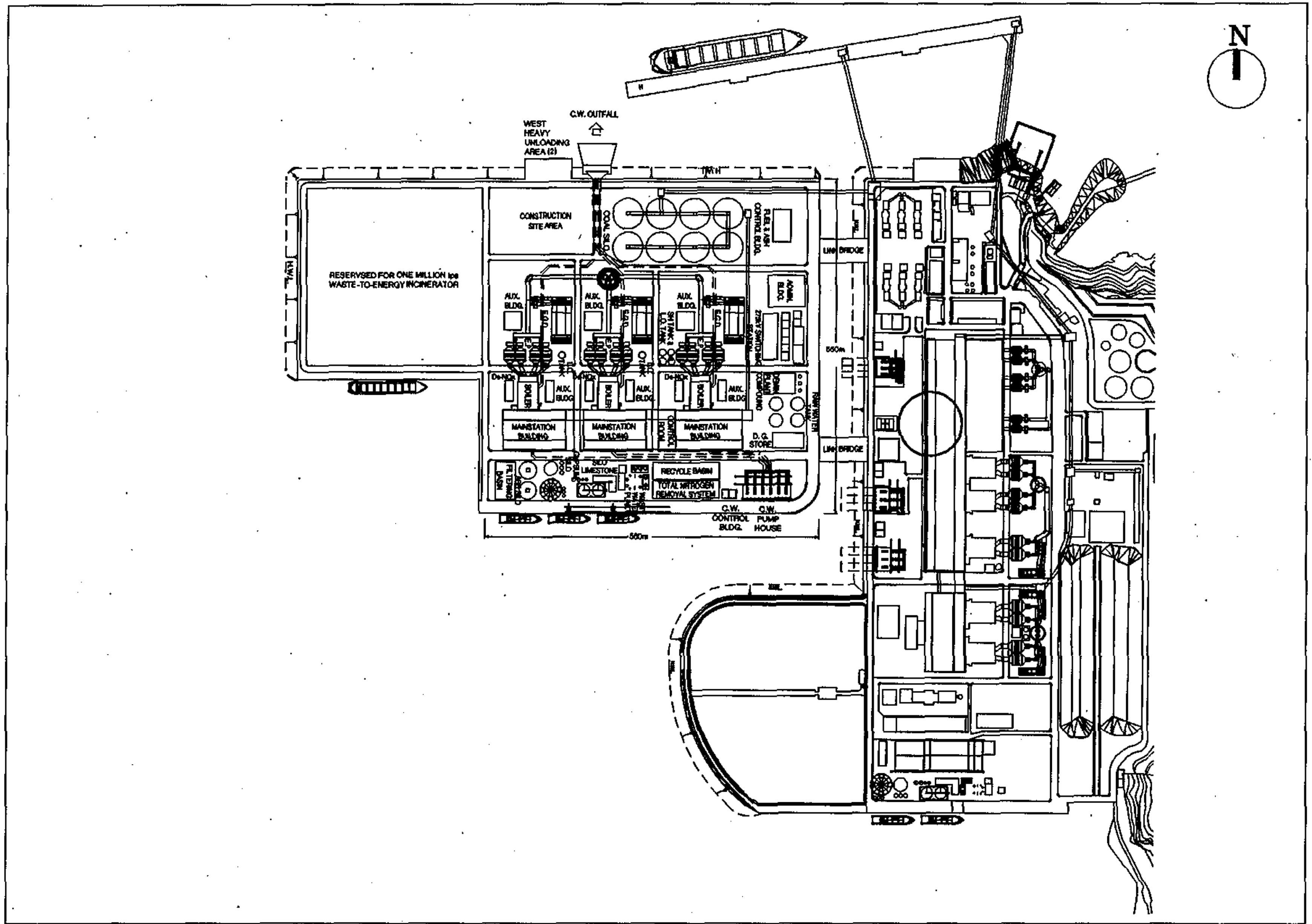

FIGURE 3.3a - COSITING WEIF WITH A COAL FIRED POWER STATION AT LAMMA EXTENSION

Date : Aug 97	Drawing No. /ermhk/c1432/stations/7.12a.dgn

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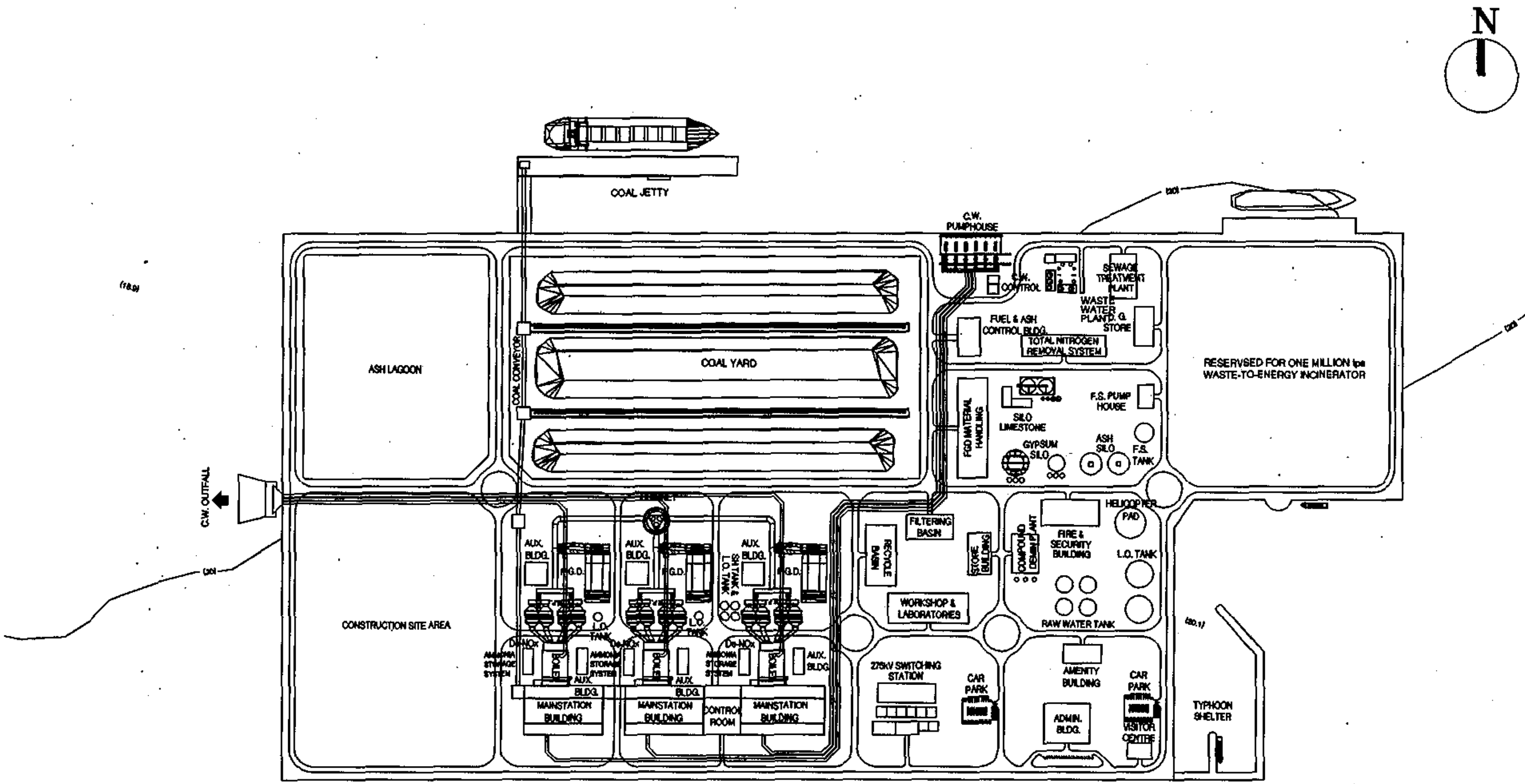

FIGURE 3.3b - COSITING WEIF WITH A COAL FIRED POWER STATION AT THE ARTIFICIAL ISLAND SITE

Date : Aug 97

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Annex B

Response to Comments

Response to Comments
HEC's Technical Paper on Waste-to-Energy Incineration Study
for the Stage 1 EIA for its Proposed New Power Station

No.	Department	Reference	Comments	Consultants' Response
1.	EPD/Wong Hon-meng/21 May 97	General Comments	The technical paper only describes broadly the site requirements of the WEIF and in sections 1.3 and 7.5 that 'the site requirements... will be referred to as sites are subjected to increasing scrutiny'. As only broad requirements are specified in the technical paper, the consultants should elaborate in details all assumptions made with regard to the WEIF (e.g. aerial and thermal emission rates from the WEIF when assessing cumulative impact during modelling assessment) as the Stage 1 EIA progresses.	Section 2 of the Paper describes the technical assumptions associated with defining the requirements for a WEIF and it is acknowledged that these are defined in general terms. The design of the WEIF is not yet at even the conceptual design stage, pending a forthcoming feasibility study to be commissioned by the EPD, and it is not considered appropriate that design details be developed as part of this study. The site requirements are based upon those outlined in the Waste Reduction Study and defined by EPD (*Information on Intended Capacity & Basic Siting Requirements of waste-to-energy Incinerator*). Further details of WEIF assumptions will be used in the Stage I EIA to the extent that they are made available by the Government's appointed consultants for the *Feasibility Study of Waste-to-energy Incineration Facilities* (Agreement No. CE 97/96) (the WEIF Feasibility Study).
2.			As it is one of the requirements of the Stage 1 EIA to consider the feasibility of siting the WEIF next to the proposed power station, the evaluation results should be reported as part of the EIA report. However, it is noted in the last line of Section 7.5, page 28 saying "This evaluation will be reported as a separate output to Government and will not be fed into the selection process for the power station.", please clarify the meaning of 'as a separate output'.	The intention is that the consideration of the feasibility of co-siting will be reported as part of the EIA report. However, if co-siting is considered feasible the additional environmental implications will be reported outside of the consideration of alternative sites . This is to ensure that the site requirements and environmental impacts associated with the new power station are not confused with those arising from the proximity of the WEIF.
3.			It is noted that the plant layout as shown in figure 2.3a and figures 2.4a to 2.4d are schematic of key processes only which do not necessarily reflect the waste disposal arrangements adopted in Hong Kong.	The designs are schematic in nature, reflecting the very preliminary nature of all design information related to the WEIF. These will be revised as information becomes available from the Government's consultants for the WEIF Feasibility Study.

No.	Department	Reference	Comments	Consultants' Response
4.			The issue of waste transportation should be considered as one of the factors affecting the choice of the site for a stand-alone waste-to-energy incinerator as well as a site for a waste-to-energy incinerator co-siting with a power station. A proper waste modelling should be set up to evaluate the advantage and disadvantage of various site locations.	Waste transportation issues will be addressed in the WEIF Feasibility Study for a stand alone incinerator. This information will be used to address the transportation issues associated with co-siting the incinerator with the new power station in the Stage 1 EIA. There will be no evaluation of the advantages and disadvantages of various site locations for the WEIF, rather a consideration of the feasibility of siting the WEIF at identified power station site options will be undertaken.
5.		Specific Comments	Paragraph 2, Section 1.1 - It is suggested that the paragraph be amended as follows to reflect the requirements of the Study Brief: 'A Waste-to-Energy Incineration Facility (WEIF) has physical, infrastructure and environmental requirements similar to those of the power station. the Study Brief for the State 1 EIA requires that the feasibility of the option to co-site the power station with a WEIF be considered, in particular related to the potential cumulative environmental impacts.'	It is our view that the current wording of Section 1 reflects the requirements of the Study Brief.
6.			Section 1.3 - It is suggested that the heading of the section be replaced by 'Potential Advantages of the Co-Siting' and the first sentence be amended as follows: 'There is a shortage of suitable sites for the power station and WEIF within the territorial boundaries of Hong Kong'.	Comments noted and text amended accordingly.
7.			Last sentence, Section 2.1.2, page 3 - For clarity, amend text as '...the introduction of waste-to-energy incineration facility'.	Comments noted and text amended accordingly.
8.			Paragraph 2, Section 4.2.2 - Could the consultants give an (rough) idea on the quantity and nature (e.g. range of temperature elevation) of cooling water arising from WEIF with handling capacity of 1M tpa and 2M tpa?	At this stage we are not in a position to make such an estimate. However, these data will be reported as they become available from the consultants appointed by the EPD to undertake the WEIF Feasibility Study.
9.			Paragraph 2, Section 4.2.2 - The consultants should briefly describe the assumptions made on the nature of effluent arising from WEIF such as the key pollutants present and the strength and load of those effluent as compared with general domestic effluent.	This level of detail would only be available from a heat and mass balance calculation for the WEIF and this is expected to be provided by the Government's consultants appointed for the WEIF Feasibility Study. As an interim measure, it could be assumed that any discharges would correspond to the limit values defined in the *Standards for Effluents Discharged into Drainage and Sewerage systems, Inland and Coastal Waters.*

No.	Department	Reference	Comments	Consultants' Response
10.			Section 5.1.2, penultimate line, page 15 - For clarity, amend text as '....emitted and the ambient temperature around the stack...'.	Comments noted and text amended accordingly.
11.			Last line, 1st paragraph, Section 5.1.3 - It should be noted that in addition to AQO exceedance, EPD may also refuse the licensing of an incinerator if - i) the applicant is not capable of providing and maintaining the best practicable means for the prevention of the emission of air pollutants; and ii) there will be adverse effect to public health.	Noted.
12.			Section 5.1.4, page 17 - The Notes on BPM Requirements for Incinerators specify that the height of the stack should be determined by modelling and no mention was made on '150 to 200 m'. The consultants should revise the statement accordingly.	The 150 to 200m range in stack heights was stipulated by Government in the information provided on siting requirements but we note that the final stack height would be the subject of assessment by modelling. This is expected to be undertaken in the WEIF Feasibility Study and the information provided for use in the Stage I EIA.
13.			Section 5.3.1 - It is acknowledged that whether the WEIF will be classified as a PHI depends on the plant/processes and the type & quantity of chemicals used, however, could the consultants provide some preliminary indication of the likelihood of a 1 million tpa mass burn incinerator would become a PHI (perhaps based on their experience of the Senoko plant)?	At this stage we consider it unlikely that the WEIF would be classified as a PHI, although the residual possibility that this would be the case and the implications for the approval and design processes warrant that this matter is raised at an early stage. Explicit consideration of this issue is a requirement of the WEIF Feasibility Study and we expect to receive further details from the Government's appointed consultants.
14.			Last line, last paragraph, Section 6.2.3 - Atmospheric dispersion requirements are not found in 'section 6.3.1' as stated. Please check and revise text as appropriate.	Text amended to make reference to Section 6.4.2.
15.			Section 6.6 - Have the consultants considered the potential cumulative road traffic noise impact if road access is provided and used a as a major mode of material/waste transportation to and from the power station and WEIF?	The waste transportation arrangements to and from the WEIF will be developed in the WEIF Feasibility Study. At this stage, we consider it unlikely that the waste would be routinely delivered to the WEIF by road. The probable location of the new power station at a coastal site will ensure that it is highly likely that the waste would be transferred to the co-sited WEIF by marine vessels in accordance with the existing Transfer Station operating arrangements. It is also probable that incineration residues to be disposed to landfill would be transferred away from the WEIF in a marine vessel.

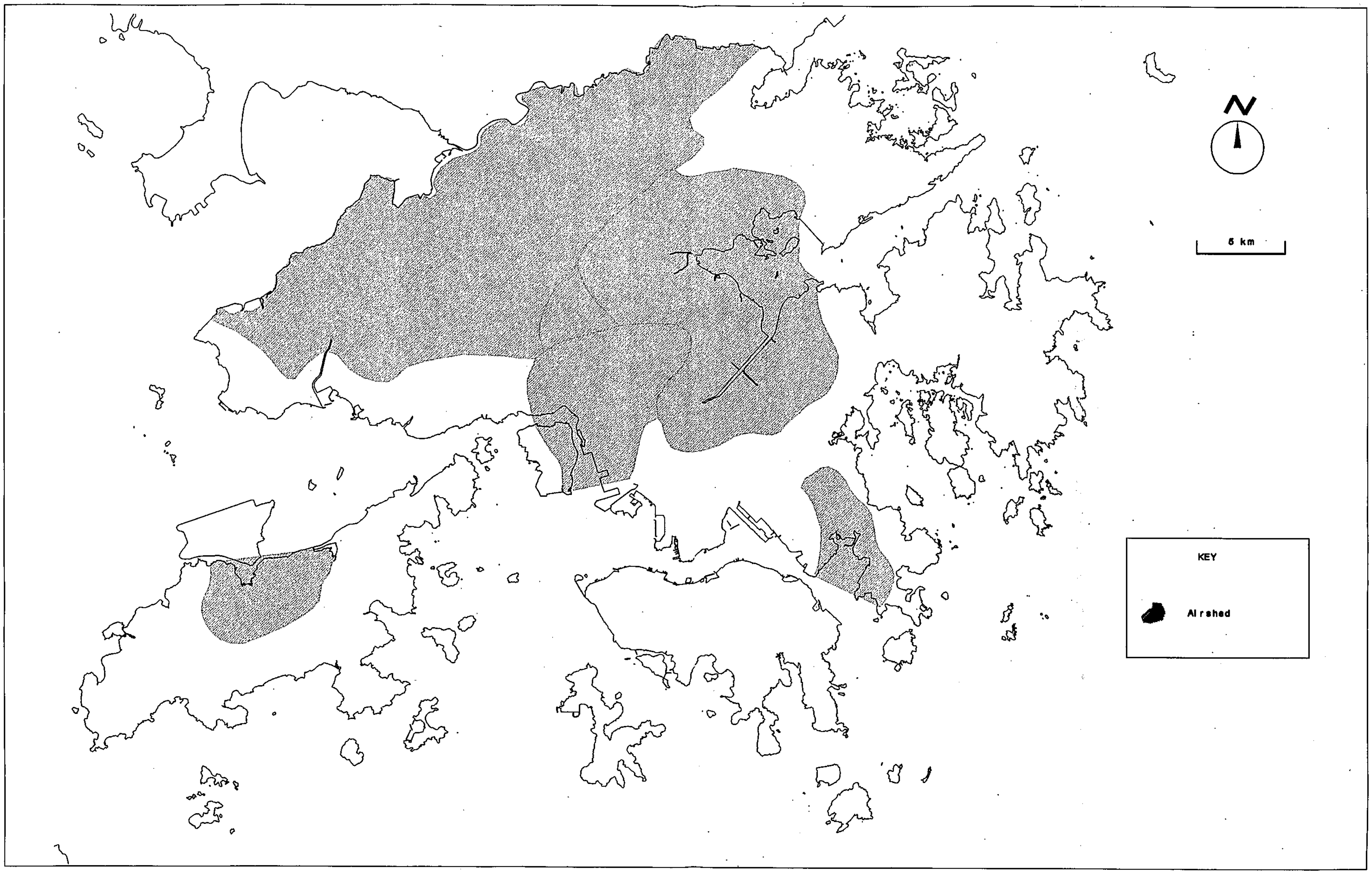
No.	Department	Reference	Comments	Consultants' Response
16.			First bullet, Section 6.7 - the point should be replaced by 'the site requirements for the WEIF'.	Noted. However, the requirements pertinent to the consideration of co-siting feasibility are limited to landtake area, transportation arrangements and the environmental elements listed in the remaining bullet points of Section 6.7.
17.			Last bullet, Section 6.7 - it should read as 'the quantity and quality of effluent and nature of receiving water to which the effluent will be discharged.'	Noted and text amended accordingly.
18.			Last paragraph, Section 6.7 - If there is inadequate information on the WEIF emissions to allow assessment of the cumulative impacts due to co-siting of the WEIF and power station, the Stage 1 EIA should either make reasonable assumptions on the WEIF emissions or, base on the characteristics of the potential sites, estimate the WEIF emission levels above which the co-siting option would likely to be environmentally unacceptable.	At this time there are insufficient details regarding the design of the WEIF to allow assumptions to be made regarding its predicted operational characteristics. More detailed information will be utilised as this becomes available from the WEIF Feasibility Study. However, so as to avoid duplication of effort, it is not considered appropriate that any shortfalls in the adequacy of information should be remedied by the New Power Station Stage 1 EIA Study team.
19.			First sentence, last paragraph, Section 7.1 - Delete 'The EPD has recognised that'.	Noted and text amended accordingly.
20.			First bullet, Section 7.3 - it should be amended as 'a minimum of 1 incinerator with one million tonnes per year capacity will be required. If site characteristics allow, the options of siting 2 incinerators, each with a capacity of one million tonnes per year or one incinerator with a capacity of 2 million tonnes per year will also need to be considered'.	Noted and text amended accordingly.
21.	PELB		In Section 6 of the technical paper, the consultants compare the physical, infrastructure and environmental requirements of a waste-to-energy incinerator against those of HEC's power station, and briefly describe the PHI and noise implications of co-siting the two facilities. I would like to know if the consultants would undertake a further comparison between co-siting the incinerator and a new power station using coal, and co-siting the incinerator and a new power station using natural gas. It could be reasonably, expected that power stations using different fuel options would be different in terms of the afore-mentioned parameters and hence would not be similarly suitable in all aspects for co-siting with the incinerator.	The consultants will give consideration to the feasibility of co-siting the WEIF with both coal and gas-fired shortlisted sites; however, it is outside the study brief to undertake the explicit comparison referred to.

No.	Department	Reference	Comments	Consultants' Response
22.	AFD		Section 1.2 - It was mentioned that one of the objectives of this technical paper was to specify 'the environmental issue which would arise as a consequence of co-siting a WEIF with HEC's proposed new power station.' However, in this technical paper, ecological aspect was not included for consideration. Please kindly explain, especially regarding the 'physical requirement' and 'environmental requirement' which may hae ecological consideration.	Whilst ecological impacts will be addressed in the Stage I EIA, they were not considered material to the discussion presented in the Technical Paper which is consistent with the scope presented in the Inception Report.
23.	EMSD		Section 2.3.2 - Apart from the Waste-to-Energy Incineration Facility (WEIF) technology elaborated in the paper, ERM should provide information relating to the electricity generation technology associated with the WEIF including the annual electricity energy (GWh) exported to the power grid as well as the generating capacity (MW) and efficiency of the plant.	This information is outside the scope of this study. It is expected to that this information may be made available by the consultants undertaking the WEIF Feasibility Study.
24.			Section 2.3.3 - Same comment for section 2.3.2.	See above.
25.			Section 2.4.1 - The design of WEIF should also depend on the financial factors relating to the capital cost, operating cost, waste reduction unit cost, etc. of the plant.	Agreed. An additional bullet point will be added to the list of factors presented in Section 2.4.1.
26.			Section 4.2.1 - Regarding the feeding of surplus electricity generated by WEIF onto the power grid, more detailed evaluations in sharing of responsibility of maintaining the system reserve margin, justification of capital investment by the power company on transmission network to cater for such additional transmission needs, effect on rate due to the revenue of leasing the transmission lines and the additional cost relating to the additional transmission needs should be required.	This is outside the scope of the study but would need to be addressed before a co-siting option could be implemented.
27.			'Electricity' sub-section, Section 6.3.2 - Same comment as for section 4.2.1.	See above.

No.	Department	Reference	Comments	Consultants' Response
28.	Planning Department		Agreeing with para 4(f) of the Study Brief, my main concern is the feasibility of siting the WEIF adjacent to the new power station. In reading the technical paper (TP), I was expecting more in-depth discussions on the advantages and disadvantages of the co-location from the technical and environmental impacts points of view. Examples of some of the items I am looking for are: i) a typical layout with the WEIF and the power station together to demonstrate possible savings in landtake;	Such layouts will be provided as part of the evaluation of shortlisted sites and will be presented in the Stage 1 EIA. However, the assessment of landtake savings will not be undertaken until detailed design is underway; this is likely to be during the detailed EIA Stage.
			ii) whether there could be any scope in reducing building bulk and height by designing the WEIF and power station together;	The level of detail requested in the comment is outside the scope of this study and would require the design processed for both the WEIF and the power station to be well advanced.
			iii) presumably, siting the WEIF near to the power grid or power station would maximize the rate of energy recovery. Can the consultants actually quantify or advise on the relationship between distance and rate of energy loss. In other words, whether the possibility exists whereby, the energy produced by the WEIF will not serve any useful function as it is too far away from the power grid;	In general, energy loss is proportional to distance of transmission. Siting of the WEIF close to the power grid or power station would therefore maximise energy recovery.
			iv) the amount of hazardous materials possibly required for the power station and a 1 million tpa capacity WEIF and compare that with PHI threshold quantity.	The status of the WEIF in relation to whether it is to be designated as a PHI will be addressed in the WEIF Feasibility Study.
29.			Notwithstanding the above, I accept the consultant's proposal in the last paragraph that assessment in terms of the suitability of shortlisted sites for accommodating the co-location of the WEIF be carried out separately. I would like to remind the consultants that in addition to assessing the environmental impact, other non-environmental considerations should also be taken into consideration; perhaps under the context of the broader Site Search Study instead of the EIA study.	Noted. At this stage, the co-siting requirement is solely related to the Stage 1 EIA, although a wide range of non-environmental information will be considered (subject to availability) in the consideration of co-siting feasibility.

No.	Department	Reference	Comments	Consultants' Response
30.			Regarding Section 5.3.2 of the TP on PHI, you may be aware that site reservation for possible PHIs in the territory only exist in Tseung Kwan O south of the SENT landfill in the future reclamation area around Tit Cham Chau. Given the complexity of procedures and technicalities involved, I would urge the consultants of both the HEC and the WEIF to make every effort to avoid the possibility of such projects becoming potential PHIs.	We agree with the comment and would like to stress that it is unlikely that the WEIF would be classified as a PHI. The Government's consultants for the WEIF Feasibility Study will be required to explicitly address this issue as part of the EPD Study Brief.
31.	CED		The consultants should consider the option of placing some or all of the incinerator facilities within underground rock caverns. This could potentially reduce the environmental problems associated with stack heights since the chimney could be constructed a vertical shaft within a mountain-side and exit at a remote high elevation site. Also, the visual impact of the facility and land requirements will be reduced.	We understand that the feasibility of locating a WEIF within a cavern will be addressed as part of the WEIF Feasibility Study.
32.	Lands Department		No comment.	Noted.
33.	FSD		No comment.	Noted.
34.	MD		No comment.	Noted.
35.	TDD		No comment.	Noted.
36.	ESB		No written response received.	Noted.
37.	BCSB		No written response received.	Noted.
38.	HyD		No written response received.	Noted.
39.	SPEL		In paragraph 2.3.1, please clarify what were the *"detrimental environmental impacts"* and *"bulky items unsuitable for the technology"*. Would that create any disposal problem?	Older incineration plants were commonly associated with having a detrimental impact on air quality due to stack emissions which were often only subject to rudimentary pollution control measures. The bulky items referred to in the text of *Section 2.3.1* are those large non-combustible items that may be found in municipal waste. This problem is mitigated in Hong Kong as the majority of wastes pass through refuse transfer stations where such items would be removed.
40.			In paragraph 2.3.3 please define *"difficult wastes"*.	Difficult waste would include materials such as sewage sludges.

No.	Department	Reference	Comments	Consultants' Response
41.			In paragraph 2.4.3, figure 2.4a layout assume waste delivered by road but my understanding is that they are delivered by sea. In addition, except for special circumstance, the wastes are delivered in containers. If 18 tonne containers are used the number of trips would be 152 delivery/day which is substantial less than the forecast traffic volume. It appears that the traffic impact and facilities for disposal of ash to landfill is not shown.	The notional layouts presented in this section of the report are based upon those initially developed for the WRS which allow for wastes to be delivered by road. It is highly probable that wastes will be delivered to a WEIF by sea via the refuse transfer stations after containerisation. Although not a major feature of the figure, the movement of vehicles from the ash handling area is indicated. This is a very minor element of the overall operation, as the volume of ash removed is very small when compared to the volume of waste delivered, and may be removed in a containerised form.
42.			In paragraph 3.1, the idea of considering a 2 million tpa plant on one site should be develop further.	Noted. This matter would best be addressed in detail by the EPD's consultants for the WEIF Feasibility Study.
43.			In paragraph 3.3.3, I don't agree with the last sentence because both facilities should have the same degree of reliance on infrastructure.	The infrastructure requirements for a coal-fired power station and a WEIF are largely similar. Requirements for a gas-fired power station would also be similar with the exception that it would not require dredged channels or deep water berth facilities for the receipt and unloading of fuel.
44.			In paragraph 4.1, although good road transport is beneficial, it is not a must.	We would agree that good road transport is beneficial, and it should be noted that this is desirable, though perhaps not essential, for the operation of the WEIF in extreme weather conditions.
45.			In paragraph 5.1.1, I would be happy to see some emission figures to assess the effect of co-sitting WEIF and HEC's power plant.	WEIF emissions would have to meet the BPM requirements as a minimum and it is anticipated they would be relatively minor relative to those from a new power station. It is anticipated that the EPD's consultants for the WEIF Feasibility Study would be able to provide further details as they become available. Please note that some interim assumptions have been developed for the regional air quality study and this is due to be issued as a Working Paper in the near future.
46.			In paragraph 5.1.2, I think height restriction for aviation purpose may apply depending on the location.	Agreed.
47.			In general, I expect the paper to give more solid figures to indicate whether any environmental control limits/standard would be exceeded if co-sitting is adopted. Because of the lack of negative statement, I would consider co-sitting is acceptable.	More detailed information on the design of the WEIF is expected to become available from the WEIF Feasibility Study. Although the amount of data available is very limited, at this stage we would not anticipate that co-siting would create unsurmountable problems for compliance with current Hong Kong Government environmental control limits/standards.



FEATURES	SOURCES	DATE	REMARK
Airshed	ERM (HK)	Mar 1995	
Country Park	WWF	May 1994	
SSSI	WWF	May 1994	
Topography	Land Dept.	Feb 1995	

Figure 5.1a Confined Air Sheds in Hong Kong

Prepared by ERM's GIS & Mapping Group

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ERM

TECHNICAL PAPER

The Hongkong Electric Company, Limited

Stage 1 EIA for a New Power Station : *Environmental Comparison of Fuels*

November 1997
DMS#60715

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CONTENTS:

1 INTRODUCTION

1.1 BACKGROUND

This Technical Paper presents the findings of the Environmental Comparison of Fuels undertaken for Hongkong Electric Company, Limited (HEC) by ERM-Hong Kong Ltd. the Technical Paper has been prepared for submittal as part of the requirements set out in the Hong Kong Government's *Study Brief for the Stage 1 EIA (or EIA of Alternative Sites and Fuels) for a New Power Station Proposed by HEC.*

The Stage 1 EIA seeks to determine the environmental feasibility of building a new power station in Hong Kong and to recommend the most environmentally preferred site for the two power generation scenarios: a coal-fired power station and one fuelled by pipeline natural gas. The Stage 1 EIA is to be overseen by the Hong Kong Government's Environmental Protection Department (EPD) and is being undertaken as an integral part of the Site Search Study that is to be conducted under a separate Study Brief. The wider Site Search Study is being overseen by the Planning Environment and Lands Bureau (PELB) of the Hong Kong Government and will incorporate the findings and recommendations of the Stage 1 EIA as well as discussions of the wider non-environmental implications of building a new power station.

1.2 THE SCOPE OF THE TECHNICAL PAPER

As part of the Stage 1 EIA, the Environmental Comparison of Fuels assesses the generic environmental implications of coal versus piped natural gas and the measures required to mitigate these environmental impacts are identified and their feasibility evaluated. This comparative assessment will provide the basis for the selection of the most environmentally preferred fuel option.

A companion document, reporting the findings of the Greenhouse Gas Study has been prepared as part of the Stage 1 EIA Study. The Greenhouse Gas Study assesses in detail the implications of contributory emissions from the proposed new power station for greenhouse gas emission targets. These documents have been produced in parallel as there is a degree of overlap between the two. The Environmental Comparison of Fuels incorporates the broad findings of the more detailed Greenhouse Gas Study.

The findings and recommendations of the Environmental Comparison of Fuels will be fed into the wider Site Search Study and will be reported as part of *Site Search Technical Report No. 2B: Comparative Fuel Study* which will recommend the overall preferred fuel option. This assessment draws on the Stage 1 EIA findings as well as the wider non environmental issues of price stability, security of supply, and market availability. *Technical Report No. 2B* will form the basis for the discussion on the choice of fuel for the new power station.

1.3 THE OBJECTIVES OF THE TECHNICAL PAPER

This Technical Paper outlines the generic environmental impacts of a 1800MW power plant fired by coal or piped natural gas. The impacts examined include atmospheric emissions, marine impacts, noise and solid waste generation, land take, visual impacts, safety hazards and transport related issues. The generic measures required to mitigate these environmental impacts will also be identified, and their practicality and effectiveness evaluated. The key issues in the selection of an appropriate fuel will include the identification of impacts that cannot be adequately mitigated either due to practical or economic impacts.

1.4 *STRUCTURE OF THE REPORT*

The remainder of this Technical Paper is structured as follows:

- *Section 2* presents general information concerning the two fuel options;
- *Section 3* provides the findings of the comparative assessment of air pollution impacts for each fuel option;
- *Section 4* provides the findings of the comparative assessment of water quality impacts for each fuel option;
- *Section 5* provides the findings of the comparative assessment of the solid waste implications of each fuel option;
- *Section 6* provides the findings of the comparative assessment of noise impacts associated with each fuel option;
- *Section 7* provides the findings of the comparative assessment of hazard and safety implications of each fuel option;
- *Section 8* provides the findings of the comparative assessment of land take implications of each fuel option;
- *Section 9* provides the findings of the comparative assessment of the visual impact associated with each fuel option;
- *Section 10* provides the findings of the comparative assessment of the transportation implications associated with each of the fuel options; and
- *Section 11* presents the overall findings of the environmental comparison of fuels.

2 *THE FUEL OPTIONS UNDER CONSIDERATION*

2.1 *INTRODUCTION*

The fuels considered in the environmental comparison were identified by the Executive Council (ExCo) of the Hong Kong Government as those that were to be investigated by the Site search for the new power station.

This section presents general information on the use of coal and pipeline gas by the power generation sector and describes the assumed technologies upon which the comparison is based.

2.2 *COAL*

As the most abundant and economical fuel in the world, coal is currently the most widely used fossil fuel for power generation. Traditionally, coal is pulverised and introduced into a furnace where direct combustion converts water to steam which in turn drives a steam turbine generator to produce electricity. Such conventional pulverised coal-firing has been demonstrated to be a proven and reliable technology for power generation.

In line with the worldwide recognition of the need to minimise the potential environmental pollution implications of coal combustion, the power generation industry has increasingly developed advanced pollution control measures to improve the environmental acceptability of coal-fired power stations. In parallel, the past two decades have seen the expenditure of considerable effort by the power sector and related industries to develop clean and efficient coal burning technologies. So-called *Clean Coal Technologies* have received widespread interest and a number of solutions with different degrees of success have emerged; some of these solutions have entered commercial operation in the past decade.

The site search for the new power station and the associated Stage 1 EIA are being undertaken on the basis of a single assumed coal burning technology: Advanced Pulverised Coal; the option of fitting De-NO_x facilities to this technology has been retained for further consideration. In a conventional pulverized coal-firing (PC) plant, coal is ground (*pulverized*) into fine particles in a coal pulveriser and is then fed to a boiler furnace where it is burnt with an excess supply of air to ensure complete combustion. The heat produced from the combustion process is utilised to convert water to steam. The steam is generated under high pressure and temperature in the boiler and is fed to drive a steam turbine which in turn drives a generator to produce electricity. Flue gas from the furnace is passed through 'scrubbing' equipment to remove certain dirty gaseous by-products before discharge via a tall chimney to the atmosphere.

Although coal itself is the cheapest of all fossil fuels, conventional PC power plants require the installation of costly environmental control facilities in order to mitigate environmental impacts and to meet modern stringent control standards; these additional costs have rendered conventional PC less competitive and has resulted in other forms of coal firing receiving more recent attention in many parts of the world. However, the current review has indicated that developments in the pulverized coal-firing technology and associated environmental mitigation measures in the past two decades have ensured that conventional PC remains one of the most reliable, cost-effective and environmentally acceptable solutions for large capacity power generation.

The environmental comparison between coal and pipeline gas has been undertaken assuming the adoption of Advanced Pulverised Coal firing plant.

2.3 *Pipeline Gas*

During the past decade, natural gas production world-wide has increased much faster than the production of oil or coal. This is largely due to the environmental benefits of gas compared with other fossil fuels used for power generation. Markets for pipeline natural gas are well developed in North America and Europe, but have been hampered in Asia by the lack of transport infrastructure. Nevertheless, natural gas in Asia is emerging as the fastest growing source of primary energy.

The use of gas for power generation has environmental merits over other fossil fuels. The stack emissions in terms of sulphur dioxide and particulates from gas-firing plant are minimal due to the minute quantity of sulphur in the fuel. There is no solid waste, such as ash and gypsum, generated during gas firing. However, one of the drawbacks of a pipeline natural gas plant is that the location of the gas field is critical to the decision on whether transportation of the gas by pipeline to the power plant site is technically feasible and economically justified.

The site search for the new power station and the associated Stage 1 EIA are being undertaken on the basis of a single assumed gas-fired technology: Combined Cycle. A combined cycle plant is one which combines the gas cycle and steam cycle for power generation. The common configuration is to have one or more gas turbines coupled with a steam turbine. Using gas or liquid distillates as the primary fuel, the gas turbines will produce electricity. The waste heat energy from the hot gas exhaust (more than 500°C) discharging from the gas turbine is passed through a heat recovery steam generator to produce steam for driving a steam turbine for secondary electricity generation.

3 ATMOSPHERIC EMISSIONS

3.1 INTRODUCTION

This section of the report will outline the air pollution impacts of a 1800MW power plant fired by either coal or piped natural gas. The measures required to mitigate these impacts will also be identified, and the practicality and effectiveness of each of the measures evaluated.

The key issue in determining the selection between coal and piped natural gas is to identify those impacts that cannot be reduced to acceptable levels through the implementation of mitigation measures, either due to practical or economic reasons.

3.2 COAL

3.2.1 *General*

The combustion of coal for electricity generation results in the production of a number of gaseous and particulate pollutants. The main pollutants are:

- Sulphur dioxide (SO_2)
- Oxides of nitrogen (NO_x)
- Particulates
- Carbon Dioxide (CO_2)

There will be lesser quantities of hydrocarbons and carbon monoxide emitted. Depending on the coal properties small amounts of chlorides and fluorides may also be emitted. The projected emissions of the main pollutants, with and without abatement, are outlined in *Table 3.2a*.

3.2.2 *Sulphur Dioxide Emissions*

Based on the worst scenario of burning coal with maximum allowable sulphur content of 1% by weight (as required by the Air Pollution Control Ordinance), the unmitigated SO_2 emission level will be around 2,000mg/Nm^3. With the adoption of APC with FGD plant of 95% removal efficiency, the SO_2 emission can be reduced to 100mg/Nm^3. The adoption of supercritical steam conditions to enhance the plant efficiency can further lower the SO_2 emission by reducing the amount of coal consumption. For a modern 1800MW coal-fired supercritical plant equipped with 95% removal efficiency FGD plant, the annual SO_2 emission is estimated to be 4,300 tonnes.

3.2.3 *NO_x Emissions*

NO_x is present in the flue gas emissions from the combustion process as nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x is formed in two ways:

- Thermal NO_x results from nitrogen in the air supplied for the combustion process which combines with oxygen at high combustion temperatures.

- Fuel NO_x results from the fuel bound nitrogen in coal which is converted to NO_x during combustion.

The formation of NO_x is sensitive to high temperature and other factors such as excess air to fuel ratio and burner design.

For the Advanced Pulverised Coal technology, the unmitigated NO_x emission level for a conventional coal-fired boiler is around 1,000mg/Nm^3. With the adoption of advanced low-NO_x combustion systems, the emission level can be reduced by more than 60% to 370mg/Nm^3 (ie 2200 kg/hr when the plant is operating at full output). This is equivalent to an annual NO_x emission of around 15,500 tonnes for a 1800MW power station.

In addition to low NO_x combustion systems, further reduction of NO_x from the flue gas is possible by installing a De-NO_x plant at the backend of the boiler. With the adoption of 65% removal efficiency De-NO_x plant, the annual NO_x emission for a 1800MW plant can be reduced to about 5,400 (1100 to 440 kg/hr at full output).

Table 3.2a ***Typical Emissions from a 1800MW Plant Burning Coal, with and without Abatement***

Pollutant	Unabated Emissions (mg/Nm^3)	Abatement Technique	Removal Efficiency	Abated Emissions (mg/Nm^3)
SO_2	≈2000	• Wet Limestone Scrubbers	90-95%	≈100
NO_x	≈1000	• Combustion Modifications (Low NO_x Burners)	15-60%	≈370[2]
Particulates	≈3000	• Electrostatic Precipitators	99%	≈30
CO_2	10.3 million tonnes/year[1]	• None		

[1]CO_2 is better presented in tonnes
[2]De-NOx technology would provide additional removal of 65% to give emission levels of 130 mg/Nm^3

3.2.4 *Particulate Emissions*

The average content of ash in coal from HEC's approved fuel suppliers is about 11%. The adoption of Advanced PC will ensure that over 80% of the ash from the combustion of coal is entrained in the flue gas as fly ash. With the adoption of electrostatic precipitator of over 99% removal efficiency together with FGD plant which can further remove the fly ash through the wet scrubbing process, the particulate emission in Advanced PC Plant can be reduced to 30mg/Nm^3. This represents an annual particulate emissions of about 1,260 tonnes for a 1800MW plant.

3.2.5 *Carbon Dioxide Emissions*

The combustion of coal will produce significant amounts of carbon dioxide as coal contains about 60 - 70% by weight of carbon.

Based on the Advanced PC technology and an average carbon content of about 65% by weight in coal, the annual CO_2 emission from a 1800MW supercritical coal-fired plant is about 10.3 million tonnes.

3.2.6 *Summary*

The effect of these emissions on ground level pollutant concentrations cannot be ascertained without more site specific data. However the main concern is whether they meet the Hong Kong Government's requirements with regard to the Air Pollution Control Ordinance (APCO) and current guidelines relating to the Best Practicable Means (BPM) requirements as set out in *Table 3.2b*.

Table 3.2b ***Emission Limits for Coal-Fired Large Combustion Plants in Hong Kong***

Pollutant	Emission Limit
Sulphur Dioxide	90% removal of the potential emissions from burning coal with a maximum allowable sulphur content of 1% by weight. Approximately equal to 200mg/Nm^3
Nitrogen oxides (as NO_2)	670 mg/Nm^3 (as NO_2 @ 6%O_2)
Particulates	50mg/Nm^3 (2-hourly average)
Carbon Dioxide	None

In addition to the combustion emissions, dust can be generated from coal and ash handling and storage. The handling and transport of limestone and gypsum of the FGD system may also lead to increased emissions of dust. Potential fugitive dust emissions can be controlled by the development, implementation and maintenance of good site management practices. These will include:

- Maximum enclosure of all coal, ash, limestone and gypsum conveyors and transfer points to prevent dust emissions;
- The surface spraying of coal upon delivery;
- Water spraying of the coal stocking yard and chemical spraying at transfer points to suppress fugitive dust;
- The installation of wind shields around the coal yard to prevent wind borne dust dispersion and to improve the visual effect of the coal yard through the use of appropriate colouring materials;
- The design of all material handling systems and procedures to minimise drop heights and thereby to reduce fugitive dust generation; and
- Planting of selected tree and scrub species to provide wind shelter.

These measures have been implemented at Lamma Power Station and proved to reduce the fugitive dust emissions from the handling of coal, ash, limestone and gypsum.

3.3 *PIPED NATURAL GAS*

3.3.1 *General*

Major air pollutants emitted from the stack of a gas-fired power plant are:

- Oxides of nitrogen (NO_x)
- Carbon Dioxide (CO_2)

As natural gas does not contain any significant amount of sulphur or solid residue, no significant amount of sulphur dioxide (SO_2) or particulates will be emitted. The emissions are presented in *Table 3.3a*.

3.3.2 *NO_x Emissions*

Similar to coal-firing, NO_x is formed due to oxidation of nitrogen in air as well as nitrogen in fuel. Although the combustion of gas has an inherent low level of NO_x, with the use of low NO_x combustion technology, emission level of less than 60mg/Nm^3 (760 kg/hr at full output) can be achieved. For a 1800MW, this represents an annual NO_x emission of 5,300 tonnes.

3.3.3 *Carbon Dioxide Emissions*

Natural gas contains about 70% by wt. of carbon which will be converted to carbon dioxide during the combustion process. With a combined cycle plant, about 5.2 million tonnes per year of CO_2 is produced from a 1800MW plant.

Table 3.3a *Typical Emissions from an 1800MW Plant Burning Gas, with and without Abatement*

Pollutant	Unabated Emissions	Abatement Technique	Abatement Efficiency	Abated Emissions (tonnes)
NO_x	≈ 150[a] mg/Nm^3	[c]Combustion Modifications (Low NO_x Burners)	15-60%	≈ 60 mg/Nm^3
[b]CO_2	5.2 million tonnes	None	n/a	n/a

[a] Low NO_x burners installed as standard. This is a generic figure taken from process experience in the EC and is not specific to this plant.
[b] CO_2 is better presented in tonnes.
[c] Low NO_x burners would be fitted as standard on the Gas-fired plant. This would bring emissions well within current standards and further abatement would not be considered.
[d] The assumed mg/Nm^3 unit is @ 15% 0_2.

The effect of these emissions on ground level pollutant concentrations cannot be ascertained without more site specific data. However the main concern is whether they meet the Hong Kong Government's requirements with regard to the APCO and current guidelines relating to the Best Practicable Means (BPM) requirements as set out in *Table 3.3b*.

Table 3.3b *Emission Limits for Gas-Fired Large Combustion Plants in Hong Kong*

Pollutant	Emission Limit
Sulphur Dioxide	10mg/m^3
Oxides of Nitrogen	90mg/m^3
Particulates	5mg/m^3
Carbon Dioxide	None

Hong Kong's emission standards for NO_x will be met through the use of suitable abatement techniques, although the precise level of emission control will be verified through reference to the equipment's specification. As with coal, no emission standards currently exist for CO_2 and no technology exists at a feasible cost to control CO_2 emissions. It should be noted, however, that a Gas-fired power station will produce nearly half the CO_2 emissions as a coal plant.

Unlike coal, there will be no associated emissions of dust. However, fugitive emissions of hydrocarbons from vents and valves of the gas receiving station are inevitable, although with regular inspection and maintenance and good site management, these emissions should be minimal.

3.4 *COMPARISON OF COAL AND PIPED NATURAL GAS*

From the above tables it becomes clear that piped natural gas is clearly the most preferable option in terms of atmospheric emissions for the following reasons:

- It produces negligible emissions of SO_2 and small quantities of particulates;
- It produces only about half of the CO_2 emissions produced by coal and contributes less to greenhouse gas emissions; and
- It produces lower NO_x emissions without the need for specific De-NO_x plant.

4 WATER QUALITY IMPACTS

4.1 INTRODUCTION

This section of the report will outline the water quality impacts of a 1800MW power plant fired by either coal or piped natural gas. The measures required to mitigate these impacts will also be identified, and the practicality and effectiveness of each of the measures evaluated. However, the majority of these impacts will be easily mitigated, albeit at some extra cost. The key issue in determining the selection between coal and piped natural gas is therefore to identify the impacts that cannot be adequately mitigated either due to practical or economic reasons.

4.2 COAL-FIRED OPTION

4.2.1 *Inventory of Impacts*

Coal fired power plants are associated with different sources of water pollution and these are outlined below.

- *Leachate from ash lagoons* There is the potential for the leaching of trace metals from the ash disposal sites. However, this can be easily controlled by use of impermeable materials when building ash lagoons.

- *Cooling water* A power plant of this size would require considerable amounts of cooling water. The quantity of cooling water required for a 1800 MW plant is about $66m^3/s$. If located on the coast the power plant will employ a once-through cooling water system, taking and discharging water directly from and into the sea. The discharge will produce a thermal plume which is likely to increase the ambient water temperature and influence the local marine ecology. However, it is believed that through proper engineering and design of the outfall and cooling water system, such as diverting the discharge point away from the sensitive receivers, lowering the discharge velocity and temperature, etc. thermal impact of the cooling water discharge on the receiving water can be controlled to an environmentally acceptable level.

- *Spillage from coastal reception facilities* Spillages of fuel and ash may occur at coastal reception facilities, although these can be avoided by good site management.

- *FGD wastewater* The use of wet FGD system will result in a waste water stream containing fly ash, chlorides, fluorides, nitrates, calcium salts and trace metals. However, the concentration of these contaminants can be substantially reduced to meet the discharge limits of Hong Kong by treatment based on metal precipitation, removal of total nitrogen by biological treatment processes, removal of suspended solid and neutralisation.

- *Plant effluents* These will mainly result from the steam cycle unit which include boiler blowdown, water treatment plant effluent, equipment drains and plant washing.

4.3 *PIPED NATURAL GAS*

4.3.1 *General*

A piped natural gas plant will require cooling water, and although the impacts resulting from the discharge of cooling water are likely to be similar to those outlined above for coal, they will have less of an impact on the marine ecosystem as less cooling water will be required.

Gas-fired power plants will produce water pollution of two main types: cooling water and plant effluents.

4.3.2 *Cooling Water Discharge*

As only one-third of the total output is generated from the condensing steam turbine in the combined cycle system, the quantity of cooling water required for a 1800MW plant is about $33m^3/sec$.

This quantity of cooling water discharge is significantly less than for a coal-fired plant, because, in a gas-fired plant, the cooling water is mainly used in the condenser of a steam turbine plant for condensing the steam back to water after passing through the steam turbine. As more power is generated by the steam turbine, more steam is passed to the condenser requiring a larger cooling water flow. As about one-third of the total power output is generated from the condensing steam turbine, the quantity of cooling water required for a 1800MW combined cycle plant is about $33m^3/sec$ taking into account the cooling water requirements for the gas turbine generators, bearing and other auxiliaries.

4.3.3 *Plant Effluents*

Some of the plant effluents are common to both power generation technologies. These include site surface drainage which is a direct discharge and various domestic effluents which will be discharged after suitable treatment.

Plant effluents mainly come from the steam cycle unit which include boiler blowdown, water treatment plant effluent, equipment drains and plant washing. These effluents will be reused as much as possible and any surplus would be discharged.

4.4 *COMPARISON OF FUEL OPTIONS*

The water pollution potential for coal fired plant is clearly greater than that for piped natural gas. However, as has been indicated throughout a number of mitigation measures exist which could effectively minimise these impacts. As long as these are adopted, water quality should not be considered as a major constraint on the use of coal.

5 SOLID WASTES

5.1 INTRODUCTION

This section of the report will outline the generic solid waste implications associated with a 1800MW power plant fired by either coal or piped natural gas. The generic measures required to mitigate these impacts will also be identified, and the practicality and effectiveness of each of the measures evaluated. However, the majority of these impacts will be easily mitigated, albeit at some extra cost. The key issue in determining the selection between coal and piped natural gas is therefore to identify the impacts that cannot be adequately mitigated either due to practical or economic reasons.

5.2 COAL-FIRED OPTION

5.2.1 *General*

Ash exists as a mineral matter in coal which results in an incombustible residue when coal is burned. The total amount of ash generated would therefore depend on the total amount of coal burned irrespective of the type of power generation technology being adopted. Another major source of solid waste is the generation of solid chemical byproduct as a result of chemical treatment for reduction of SO_2 emissions.

Pulverized fly ash (PFA) and furnace bottom ash (FBA) are produced from the burning of pulverized coal. PFA will be carried through the furnace with the flue gases while FBA will fall to the bottom of the furnace where it sinters to form a coarser material. Based on an ash content of 11% by weight, the annual production of ash from a 1800MW Advanced PC plant is about 426,000 tonnes for PFA and 47,000 tonnes for FBA. As demonstrated through the strategy adopted at HEC's existing Lamma Power Station, both PFA and FBA are in demand for use in the construction industry. Both PFA and FBA can be used in the production of cement and in the preparation of concrete and as reclamation landfill. It is anticipated that the quantity of ash generated from a 1800MW plant can be fully taken up by the local, commercial ash demand. However, fluctuations in demand cycles are such that it is considered prudent to include an ash lagoon to ensure an efficient and uninterrupted operation of the power station.

About 270,000 tonnes per year of gypsum will also be produced as by-product of the FGD plant. Similar to ash, gypsum has commercial value and can be delivered off site for use in the manufacturing of cement and plasterboard; the success of this strategy has been demonstrated in HEC's existing Lamma Power Station.

5.3 PIPED NATURAL GAS

5.3.1 *General*

As natural gas has been purified and filtered at source, there is no ash content in the gas and, as a result, no solid waste would remain after combustion of the gas using either of the compared technologies. Other solid wastes from the plant include domestic refuse, drum screen rejects and sewage sludge. the quantity of these solid wastes would be broadly similar for both technology options.

5.4 *COMPARISON OF FUELS*

Although there are large quantities of ash and gypsum generated by a coal fired plant with wet FGD system, the disposal of ash and gypsum has become a commercial enterprise with these by-products being utilised by the cement industry.

However, it should be noted that should such commercial outlets become less sustainable the disposal of these materials as wastes will constitute a higher environmental impact as compared to Gas which produces virtually no solid wastes.

6 NOISE GENERATION

6.1 INTRODUCTION

This section will outline the generic noise generation impacts of a 1800MW power plant fired by either coal or piped natural gas. The generic measures required to mitigate these impacts will also be identified, and the practicality and effectiveness of each of the measures evaluated. However, the majority of these impacts will be easily mitigated, albeit at some extra cost. The key issue in determining the selection between coal and piped natural gas is therefore to identify the impacts that cannot be adequately mitigated either due to practical or economic reasons.

6.2 COAL-FIRED OPTION

6.2.1 General

There are many sources of noise produced by coal-fired power plant most of which can be simply controlled using conventional noise control techniques and ensuring that the power plant is not located near to noise sensitive areas. As the plant is likely to be located on an island, there is unlikely to be any road transport associated with it. The noise impact from marine tankers should be minimal so long as the docking facility is located away from sensitive areas. However, coal fired plant does involve the use of mobile plant for material and waste material transport and for coal stocking operations which can produce significant amounts of noise.

FGD equipment produces noise beyond what would be expected from a plant without FGD, due to the need for additional materials handling equipment. However, this increase is unlikely to be noticeable with conventional noise control technology and suitable siting. Such noise is more difficult to mitigate but can be made more acceptable by distancing it from nearby sensitive locations.

6.3 PIPED NATURAL GAS

6.3.1 General

Like a coal-fired plant, there are many sources of noise produced by piped natural gas fired power plant, most of which can be simply controlled by using conventional noise control techniques and ensuring that the power plant is not located near noise sensitive locations. Noise generated from the transport of piped natural gas is largely insignificant.

The power plant is the main source of potential noise and is common to both fuels. The noise potential exists through intermittent jet noise produced when high pressure steam is vented to the atmosphere; this would be mitigated through the incorporation of silencers in the plant and equipment design.

6.4 *COMPARISON OF FUELS*

It is difficult to make generic comparisons between the noise levels from coal and a pipeline natural gas-fired plant. Noise disturbance is very site specific and the definition of noise very subjective. Coal fired plant can be noisier than gas-firing plant due to "uncontrollable" noise sources such as noise produced from coal stocking and transport from the storage site to the power plant. Overall, however, provided that the power plant is located away from noise sensitive locations, noise can be controlled to acceptable levels, probably at a cost that is relatively low when compared to other project costs. Due to this, noise considerations are unlikely to be a major factor in fuel selection providing siting and design decisions take noise levels into account. With the installation of adequate mitigation measures, it can be concluded that the noise impact for the two power generating technologies using different fuels would be broadly the same.

7 *SAFETY ISSUES*

7.1 *INTRODUCTION*

This section concentrates on the potential for major hazards which could have serious implications for members of the local community, the plant and plant workers and the surrounding environment. Although such hazards are only likely to occur very infrequently their implications still need to be identified and evaluated and taken into account in site and fuel selection.

7.2 *RISKS ASSOCIATED WITH COAL*

Coal is a relatively safe fuel and generally presents no major concerns with respect to the potential for major incidents. Stockpiles of coal have been known to catch fire but these have tended to be small and controllable both on- and off-site. However, it is assumed that the coal will be pulverised into coal dust prior to combustion and this can present an explosion hazard. However, in properly designed and operated plant the risk is likely to be minimal.

There will be on-site ammonia storage for the De-No_x facilities. However, the total storage capacity will be less than 100 tonnes, the level at which the government considers that a facility should be classed as a potentially hazardous installation (PHI).

7.3 *RISKS ASSOCIATED WITH PIPELINE NATURAL GAS*

The most significant impacts from the pipeline will be those occurring as a result of pipeline failure. Such failures can arise from corrosion and mechanical defects, and result in gas leakage. Such releases normally disperse harmlessly downwind with little or no impact, but are potentially hazardous in busy shipping areas where vessels can act as ignition sources. Pipeline failures can be minimised in several ways:

- design, construction and installation in accordance with accepted standards;
- identification of failure modes and employment of mitigation measures, for example emergency shutdown valves and cathodic protection systems; and
- inspection, testing, maintenance and cleaning.

7.4 *COMPARISON OF FUELS*

In comparing the potential hazards and operational safety of Gas and coal, it becomes obvious that, while coal is virtually risk free, Gas poses greater risks. With Gas there is the potential for major incidents resulting in fires and/or explosions which could produce multiple fatalities and massive property damage both on- and off-site. To minimise these risks the power station plant, the *Hong Kong Risk Guidelines* will be followed and a detailed risk assessment will be carried out should Gas be chosen as the preferred fuel option. Site selection will therefore play an important role in minimising the risks of gas, but further analysis in this area is beyond the scope of this report. Overall, however, gas has an exemplary track record and so long as the design codes and codes of practice are met, and the appropriate operational procedures carried out, gas would not present an unacceptable risk to the people and environment of Hong Kong.

8 LAND TAKE

8.1 INTRODUCTION

This section outlines the broad land take requires of a 1800MW power plant fired by either coal or piped natural gas.

8.2 COAL-FIRED OPTIONS

Assessment of land requirements of existing coal fired power plants indicates that approximately 60ha of land will be required for an 1800MW power plant. Also, a considerable amount of land (about 20ha for one lagoon) will be required for ash lagooning. However, this will largely be reclamation from the sea.

One of the proposals by HEC is to build an artificial island to accommodate the power plant. This would obviously avoid any land take form within the Hong Kong SAR, which has very severe land restrictions.

8.3 PIPED NATURAL GAS

The land requirements for a Gas-fired plant are likely to be less than that for coal; in total an area of 50ha will be required. This includes the additional land requirements for the on-site gas receiving station.

8.4 COMPARISON OF FUELS

A coal fired plant will require more land than a Gas-fired plant due to the relatively high land requirements associated with coal handling and storage. Also, the requirement for FGD equipment and gypsum handling and storage facilities for a coal fired plant necessitates the need for more land. However, clearly more site specific data is needed to evaluate exactly how much land would be required.

9 VISUAL IMPACTS

9.1 INTRODUCTION

This section of the report outlines the visual impacts of a 1800MW power plant fired by either coal or piped natural gas. The main visual impacts that will need to be considered when comparing the two fuel options are:

- the number and height of stacks present; and
- the visibility of the plumes.

It is considered that there will be little difference in the visual impact of other buildings and activities associated with the two fuel options. There will be no need for cooling towers as the power station is to be located on the coast.

9.2 COAL

The stack is likely to be between 200 and 250 metres high and, depending in the terrain, could be visible over 10km away. Apart from at start-up, plume visibility should not be significant. However, the use of FGD could increase plume visibility due to the higher water vapour content of the flue gases, which condense on entering the atmosphere.

9.3 PIPED NATURAL GAS

A Gas-fired power plants have a lower physical profile than coal fired plant, the stack height would be in the region of 100 m due to the lower emissions and increased thermal buoyancy. Also, the plume is likely to be less visible due to the absence of particulates.

9.4 COMPARISON OF FUELS

Overall coal will have a slightly higher visual impact than the pipeline natural gas option. However, in both cases, the visual impact is not thought to be very significant.

10 TRANSPORT RELATED ISSUES

10.1 INTRODUCTION

This section of the report will outline the generic transportation related issues associated with a 1800MW power plant fired by either coal or piped natural gas.

10.2 COAL

Coal will be imported into Hong Kong from outside in bulk carriers of 60,000 to 150,000 tonne capacity. It is assumed that the power plant will be located on a coastal site away from major built up areas and is therefore unlikely to cause any significant land based movement or disturbance to the local population.

The ash produced by the power plant may need to be transported away from the site for cement production or reclamation. The gypsum and by-products of FGD systems may require the marine transport of gypsum to disposal sites or the transport of gypsum to cement plants or other possible markets. Overall, however, transport related issues are likely to be insignificant.

10.3 PIPED NATURAL GAS

During pipeline construction, impacts may occur mainly as a result of construction vessels. However, construction is relatively short-lived and the impact on shipping activities in the vicinity is unlikely to be significant.

The most significant impacts from the pipeline will be those occurring as a result of pipeline failure. Such failures can arise from corrosion and mechanical defects, and result in gas leakage. Such releases normally disperse harmlessly downwind with little or no impact, but are potentially hazardous in busy shipping areas where vessels can act as ignition sources. Pipeline failures can be minimised in several ways.

Design, construction and installation in accordance with accepted standards.
Identification of failure modes and employment of mitigation measures, for example emergency shutdown valves and cathodic protection systems.
Inspection, testing, maintenance and cleaning.

10.4 COMPARISON OF FUEL OPTIONS

Only the coal option is likely to result in significant amounts of marine transport but both options are unlikely to generate significant road transport. However, the use of coal will result in more shipments having to be made every year and imposing a higher risk in terms of marine transport.

11 SUMMARY AND CONCLUSIONS

11.1 SUMMARY OF FINDINGS

A summary of the key environmental aspects associated with the selection of fuels is presented in *Table 11.1a*. *Table 11.1b* presents a comparison of the quantifiable environmental impacts associated with each of the fuels.

The overall conclusions of the comparison indicate that the key selection issues relate to atmospheric emissions, liquid and solid by-products.

Table 11.1a Summary Table of the Environmental Impacts of a Coal and a Gas-Fired Power Plant

Impact	Likely Influence on Fuel Selection	Comments
Atmospheric Emissions	High	Gas is the most preferable option as it produces no emissions of SO_2 or particulates, and lower emissions of NO_x and CO_2. However, high efficiency abatement techniques for coal fired plant could mitigate these impacts.
Liquid Effluent and Marine Impacts	High	The water pollution potential of a coal fired plant is greater than that of an Gas fired plant. Again, mitigation measures should be able to reduce these impacts.
Solid By-products	High	Large quantities of ash and gypsum will be produced. In comparison Gas produces no solid wastes.
Noise Generation	Low	Unlikely to present any major problems as long as the power plant is located away from noise sensitive areas. Coal fired plant is likely to produce slightly more noise than Gas.
Hazards	Low	While coal is virtually risk free, gas has potential hazards. However, Gas has an exemplary track record and as long as codes of practice are met and the appropriate operational procedures carried out, the Gas hazard should be kept to a minimum.
Land Take	Medium	Land take requirements are 50ha for gas versus 80ha for coal.
Visual Impacts	Low	Unlikely to be a deciding factor although a Gas plant will have less of a visual impact.
Transport Related Issues	Medium	The use of coal will require more sea transport, both of coal and wastes such as ash and gypsum.

As can been seen from the information presented in this Technical Paper and summarised in *Table 11.1a* and *Table 11.1b*, the environmental comparison of the two fuels has indicated a preference for pipeline natural gas over coal as the choice of fuel for the new power station.

Table 11.1b ***Summary Table of Environmental Comparison of Fuels***

Environmental Issues	**Gas Option**			**Coal Option**		
Atmospheric Emissions	*Unabated Emissions*	*Abated Emissions*	*BPM Requirements*	*Unabated Emissions*	*Abated Emissions*	*BPM Requirements*
SO_2	No SO^2 would be produced	n/a	10mg/m^3	2000 mg/Nm^3	100 mg/Nm^3	200mg/Nm^3
NO_x	150mg/Nm^3	60 mg/Nm^3	90mg/m^3	1000 mg/Nm^3	370mg/Nm^3 [(a)] 130mg/Nm^3 [(b)]	670mg/Nm^3
Particulates	No particulates would be produced	n/a	5mg/m^3	3000 mg/Nm^3	30 mg/Nm^3	50mg/Nm^3 (2 hr average)
CO_2	5.2 million tonnes/yr	n/a	none	10.3 million tonnes/yr	n/a	none
Solid Wastes	No solid wastes would be produced	n/a	-	426,000 tonnes/yr of PFA 47,000 tonnes/yr of FBA 270,000 tonnes/yr of gypsum	n/a	-
Water Quality	Quantity of cooling water required is 33m^3/sec^1	n/a	-	Quantity of cooling water required is 66m^3/sec^1	n/a	-
Visual impacts	Stack height 100m	n/a	-	Stack height 150-250m	n/a	-

(a) *Without De-No$_x$*
(b) *With De-No$_x$*

11.2 *WIDER IMPLICATIONS OF FUEL CHOICE*

In addition to the largely local environmental impacts presented in this Technical Paper, the Stage 1 EIA Study Team also reviewed the findings of the Pearl River Delta Air Quality Assessment and the Greenhouse Gas Study to determine the regional and sub-regional implications of fuel choice. The findings of the two studies are summarised below:

- *Pearl River Delta Air Quality Assessment* provided a broad evaluation of the potential regional impacts of atmospheric emissions from the proposed new power station and concluded that additional emissions of nitrogen oxides would contribute insignificantly to regional surface O_3 and NO_2 concentrations irrespective of whether the new power station burns coal or gas. Furthermore, the study concluded that were coal to be selected as the preferred fuel the Advanced Pulverised Coal with De-NO_X technology option is not significantly different, in terms of effects on regional O_3 and NO_2 concentrations, from the without De-NO_x simulation. Similarly, the results of the assessment of future acid deposition indicated only minor contributions irrespective of the fuel selected.

- *Greenhouse Gas Study* concluded that whilst there were significant differences in the levels of CO_2 emitted by a coal-fired power station versus one fired by gas, even under the gas-fired scenario Hong Kong's 2012 CO_2 emissions exceed 1990 emissions by 9.6 million tonnes. The Study concluded that the reduction to be gained by selecting gas over coal does not appear to be sufficient to ensure Hong Kong SAR's conformance the Rio Summit's call to peg Greenhouse Gas emissions at 1990 levels.

In conclusion, it can be seen that at the Pearl River Delta region level the selection of fuel has a largely neutral effect.

The Greenhouse Gas Study indicates that, whilst fuel selection is not a critical issue in Hong Kong's ability to meet the Rio Summit's policy proposal, there is a strong preference for gas-fired power generation over coal-fired in terms of the absolute levels of Greenhouse Gas emissions. The Greenhouse Gas study has largely confirmed the conclusions of the local environmental impacts comparison of fuels which has indicated a preference for pipeline natural gas over coal as the environmentally preferred choice of fuel for the new power station.

Annex A

Responses to Comments

C1432/RTC/63876
27th June 1997

Response to Comments: Technical Paper on the Environmental Comparison of Fuels.

No.	Department	Reference	Comments	Consultants' Response
1.	EPD	General	Section 1.2, last para, page 1, section 3.4, page 9 and table 11.0a, page 25 - While we agree in general with the conclusion that piped natural gas is the much better fuel option than coal. HEC should quantify and present clearly the emissions, in the form of comparative table, how much better is the gas option in terms of minimising the air quality impact.	Noted. This information has already been presented in the Technical Paper on Technology Review.
			In addition, HEC should in recommending the most environmental friendly choice of fuel, take into full consideration ALL relevant environmental factors including those covered in the other relevant studies on Greenhouse Gas, Power Generation Technology, Regional Air Quality, etc. and NOT just based on the findings in this "Comparative Fuel Study". This is to ensure that ALL environmental factors are compared and taken into proper consideration in the recommendation. As stated in the report, the TR No. 2B will recommend the overall preferred fuel option in the wider Site Search Study, which draws on the findings of the Stage 1 EIA. As the Stage 1 EIA is not yet complete (e.g. the assessment of the regional air quality impacts is still outstanding), HEC should not draw on only the findings of this comparative fuel study in recommending most environmental friendly choice of fuel to the Site Search Study.	Noted. The programme of Study deliverables was agreed as part of the Stage 1 EIA Inception Report. The agreed programme was to deliver the Environmental Comparison of Fuels before the outcome of the Regional Air Quality; the Greenhouse Gas Study has been reported under separate cover.
2.			Section 1.1, 2nd para, page 1 - As we have commented before, the EIA study should recommend the most <u>environmental friendly</u> choice of site, fuel, power generation technology and design for the proposed new power station and not just selecting the preferred site for each fuel option. In particular, for the assessment, HEC should focus on the actual performance/emission levels achievable with the individual options to reflect the basic environmental advantages of the two different fuel so that the best option can be identified. HEC should not simply base the comparison on the respective "Best Practicable Means" requirements.	The comparison is based on a wide range of factors. The emission levels achievable are presented in Section 3. The comparison has two primary objectives: Firstly to assess whether the two fuels are environmentally acceptable. This has been undertaken through reference to current Government requirements. The second objective is the identification of the environmentally preferred fuel; this has been achieved through a comparison of likely environmental impact associated with each of the fuels.

No.	Department	Reference	Comments	Consultants' Response
3.			Section 2.2, 3rd para, page 3 - As APC with De-NO_x and IGCC have been identified as the two most environmental friendly coal generation technologies, the assessment should not be based assuming APC (without De-NO_x) as the "singly assumed coal-burning technology". It should include the two technology options for comparison to provide information on the trade-off with the fuel options.	The Steering Group Meeting held on 16th June endorsed Technical Report No. 1; this document identified the preferred technology for the site search and associated Stage 1 EIA is APC without De-NOx. APC with De-NOx has been retained as an option for further consideration. Other technologies have been excluded from further consideration. The reductions achieved by the De-NOx plant are presented in Section 3.2.3.
4.		Specific	Section 2.1, line 2, page 3 - Amend as "...Executive Council (ExCo) of.......".	Noted and amended accordingly.
5.			Section 3.1, line 4, page 5 - Since there are other impacts which are yet to be determined and some of which may not be easily mitigated, it is premature to conclude that "the majority of these impacts will be easily mitigated, albeit at some extra cost". HEC should delete or revise the sentence accordingly.	Noted. The sentence is considered deleted from the Technical Paper.
6.			Section 3.1, last sentence, page 5 - See comments in 2. above and revise the text accordingly.	Please refer to the response given to item 2 above.
7.			Section 3.2.5, page 6 & Section 3.3.3, page 8 - On all estimated of CO_2 emission presented for all the fuel and technology options, HEC should provide detailed calculations and assumptions, particularly on the loading factors assumed. HEC should also refer to our comments on the technical paper on Greenhouse Gas Study and revise accordingly ensuring consistency amongst the papers.	The estimate emissions are presented for the preferred technology only. please refer to the Technical Paper on the Greenhouse Gas Study for further details.
8.			Table 3.2a, page 6 - See comments in 3 above and revise the table accordingly.	Please refer to the response provide to item 3. Please note that the footnote to the table will be revised to include reference to the performance of De-NOx plant in providing additional removal of 65% of NOx emission to give an emission level of about 130 mg/Nm^3.
9.			Section 3.2.6, 2nd line, page 7 and section 3.3.3, 2nd para, page 8 - See comments in 2 above and revise the text accordingly.	Please refer to the response provided to item 2 above.
10.			Section 3.2.6, 4th line, page 7 and Section 3.3.3, 2nd para, page 8 - "Air Quality Ordinance" should read as "Air Pollution Control Ordinance" and "Best Practical Means" as "Best Practicable Means".	Noted and amended accordingly.

No.	Department	Reference	Comments	Consultants' Response
11.			Table 3.2b, page 7 - "Nitrogen Dioxide" should read "Nitrogen oxides (as NO_2)" and "Particulate" as "Particulates".	Noted and amended accordingly.
12.			Section 3.2.6, 2nd para., page 7 - Amend as "In addition ..... emissions, dust can be ....".	Noted and amended accordingly.
13.			Section 3.3.1, page 8 - As PNG contains trace amount of sulphur, for clarity, amend the text as "As natural gas does not contain any significant amount of sulphur ....., no significant amount of sulphur dioxide...".	Noted and amended accordingly.
14.			Section 3.3.3, 2nd last para., page 8 - HEC should explain and justify on the statement "NOx emission .... (although this needs to be verified)". Does it imply that the NOx emission cannot meet Hong Kong's emission standards?	Hong Kong's emission standards for NOx emissions will be met by using suitable abatement techniques, although the precise level of emission control will be verified through reference to the equipment's specification.
15.			Table 3.3b, page 8 - For clarity and consistency, amend "Particulate matter" as "Particulates".	Noted and amended accordingly.
16.			Section 7, page 17 and table 11.0a, page 25 - As gas is not expected to present an unacceptable risk as mentioned in section 7, its influence on fuel selection should not be significant and should be ranked "low" under Hazards in table 11.0a.	The intention was to illustrate the comparative difference between the risks associated with gas and those associated with coal. However, the comment is noted and it is agreed that the absolute risk associated with gas are low. the text is amended accordingly.
17.			Section 7.2 - I suggest that the health hazards to the people working or living near the new power station should also be assessed in this section.	It is not considered within the scope of the Stage 1 EIA to consider the epidemiological implications of project development.
18.	PELB		Sections 2.2 and 2.3 - HEC has compared the fuel options assuming the adoption of an APC coal-firing plant and a Combined Cycle gas-fired plant. However, according to the Inception report for the Stage 1 EIA study, the Comparative Fuel Study should assess the environmental implications of coal versus pipeline natural gas rather than the two power technology options recommended in the Power Generation Technology Review. To meet the study requirement, HEC should first state in each section what the impacts common to all the power generation technologies under each fuel option are, and then point out the specific characteristics of each power generation technology in respect of the environmental impact being assessed.	Please refer to the response provided in relation to item 3 above.

No.	Department	Reference	Comments	Consultants' Response
19.			On section 2.3, it would be enlightening if the source of potential gas supply in Asia could be identified.	Agreed. The availability of gas is addressed in Technical Report No. 2B which was submitted to the Steering Group of the Site Search on 20th June 1997.
20.			On section 3.1, I do not agree that "*the majority of these [environmental] impacts will be easily mitigated, albeit at some extra cost*". The impact of greenhouse gas emissions, in particular the emission of carbon dioxide during power generation still remains a major source of greenhouse gas emission in Hong Kong and I am not aware of any cost-effective means of removing other than minimising its production as far as possible.	Please refer to the response provided in relation to item 5 above.
21.			On section 3.3.3, the amount of CO_2 emission is quoted as 5.2 million tonne per annum but the figure quoted in table 3.3a is 4.4 million tonne. In fact, the emission quoted in the "Technology" paper is 5.2 million tonne. Please explain the difference.	The correct figure is 5.2 million tonnes and the text is amended accordingly.
22.			Could HEC please explain what the "fugitive emissions of Hydrocarbons" quoted in section 3.3.3 and advise me what are their environmental impacts.	Fugitive emissions of hydrocarbons from the vents and valves of the gas receiving station are inevitable. As indicated in the text the impacts associated with these emissions will be minimal with regular inspection and maintenance.
23.			Section 3.3.3 - I believe that the "regular inspection and maintenance and good site management" referred in the last sentence should be different from those required for a coal-fired plant. The consultants should give more details on these.	Coal-fired and gas-fired power stations both require "regular inspection and maintenance and good site management". Although these are determined by the technical requirements of different plant used in coal and gas firing, this is not a key consideration in the environmental comparison of fuels.
24.			Section 3.4 - It is true that piped natural gas produces lower NOx emissions, but based on the findings presented in the previous reports (TR1 and Power Generation Technology Review), should there be an opportunity that the coal-fired option would produce even lower NOx emissions than piped natural gas if the former incorporates the de-NOx facilities?	Agreed. The last bullet point is amended to read: • It produces lower NOx emissions without the need for specific De-NOx plant.
25.			On section 4.2.1, shouldn't there be plant effluent that needs to be treated as well.	These are acknowledged in Section 4.3.3.

No.	Department	Reference	Comments	Consultants' Response
26.			Could HEC please explain why less cooling water is required for gas-fired plant.	The cooling water is mainly used in the condenser of a steam turbine plant for condensing the steam back to water after passing through the steam turbine. As more power is generated by the steam turbine, more steam is passed to the condenser requiring a larger cooling water flow. As about one-third of the total power output in the combined cycle plant will be generated from the condensing steam turbine, the quantity of cooling water required will be less than that of the coal-fire steam plant in which all the power output is from the steam turbine.
27.			On section 5.2.1, I understand that the use of FBA in cement production was still in the development stage in Hong Kong, please clarify what other usage for FBA for which the consultant considered that future demand will be greater than the supply of FBA. In addition, even if the ash lagoon is considered as reclamation, the formed site will have limited usage as any development requiring piled foundation would be unacceptable as it would damage the leakage prevention layer of the lagoon.	It has been confirmed by the cement companies that FBA can be used for cement/concrete production. Please note that some of the FBA from CLP is also taken up by the cement industry. Please note that the ash lagoon is for contingency storage of ash only. Facilities will be provided for harvesting of the ash for use as a filling material for infrastructure projects in the Hong Kong. It should also be noted that rinsed ash is considered suitable for reclamation.
28.			On section 7.2, please explain why the risks and hazards of marine movement of large coal containing vessels is not considered. As Hong Kong is one of the world's most busiest port, marine traffic safety should be considered.	This is not considered a key concern; the marine issues associated with coal delivery is given greater scrutiny during the evaluation of specific site options.
29.			On section 8.4, I do not agree that land requirement for different fuel is site specific. The consultants should have an idea of the possible facilities layout for both coal-fired and gas-fired plant. Therefore, the amount of land required should be quite independent of the site condition since any possible reclamation is still part of the land requirement. The report should be able to advise without doubt that gas-fired plant requires less land.	The report does advise that gas-fired plant requires less land (see 1st sentence of Section 8.4). The land area requirements for each type of plant are clearly stated in Section 8; the ratio of existing land to reclamation will be determined by site specific conditions.
30.			On section 9.1, coal-fired plant would have high visual impact arising from coal storage yard which is absent in gas-fired plant.	It is acknowledged that the two types of plant have different elements (coal storage yards versus gas receiving station for example). However, visual impact is not considered a key differential between the two options.

No.	Department	Reference	Comments	Consultants' Response
31.			On section 9.3, please explain why more stacks are required for gas-fired plant since I would assume that the number of stacks is related to the number of units installed and could be made the same for both fuel options.	We can now confirm that the intended layout for the gas fired station will not have an additional stack.
32.			On section 10.2, more marine traffic would result from delivery of coal and shipments of PFA, FBA and gypsum arising from a coal-fired plant. Such level of traffic is avoided if gas-fired plant is adopted.	Noted. please note the response provided to item 28.
33.			On section 11, the report should present the fuel options in the form of comparative tables showing which option is better.	The preference for gas over coal is clearly stated; a summary table is included.
34.	AFD		As regards the discussion on "Land Take" in Chapter 8, while the concept of building an artificial island may avoid land take in area that has land use restrictions but it seems that such concept has no consideration on its environmental acceptability. Perhaps, the consultant may wish to indicate in broad terms what would be considered as a suitable site for such artificial island that would not cause adverse environmental impacts.	This site specific discussion will be provided at a later stage in the Stage 1 EIA.
35.			It is noted that the land requirement for gas-fired plant would be less in comparison to that for coal fired plant. Would there be any suggestion on the ideal siting for each of such plants from environmental point of view?	The environmental implications of siting the power station will be addressed during the site selection process and will be reported at a later stage in the Stage 1 EIA.
36.	MD		Page 17, Para. 7.3, line 4 - I have concerns over the statement of "potentially hazardous in busy shipping areas where vessels can act as ignition sources" because some of the potential sites for the proposed new power station may be closed to busy shipping areas. Could the consultants elaborate this in better details and if necessary, suggest mitigation measures.	The potential hazardous is referenced; if this potential is considered significant at any of the identified shortlisted sites, further analysis may be necessary.
37.			Page 23, para. 10.2, sub-paragraph 2 - Viewing the large quantity of materials required to be moved, I would presume that the term "transport" described herein meant marine transport as described in Para. 10.4.	Agreed.
38.			Page 25, Table 11.0a, last item, Transport Related Issues - based on the above comment, the term "transport" under the column of 'Comments' is suggested to read "sea transport".	Agreed.

No.	Department	Reference	Comments	Consultants' Response
39.	Plan Dept		No comment.	Noted
40.	EMSD		No comment.	Noted
41.	Lands Dept		No comment.	Noted
42.	TDD		No comment.	Noted
43.	HyD		No comment.	Noted
44.	BCSB		No written response received.	Noted
45.	ESB		No written response received.	Noted
46.	TD		No written response received.	Noted
47.	CED		No written response received.	Noted
48.	FSD		No written response received.	Noted