ENERGY AND NUTRIENTS IN THE HUMAN ECOLOGY OF HONG KONG

by Ken Newcombe

being a thesis submitted for the degree of Doctor of Philosophy at the Australian National University, Canberra.

February, 1976
The contents of this thesis, except as described in the acknowledgements and where credit is indicated by reference, are entirely my own work.

[Signature]
If we have a correct theory but merely prate about it, pigeonhole it and do not put it into practice, then that theory, however good, is of no significance.

ACKNOWLEDGEMENTS

I bear a lasting debt to my supervisor, Professor Stephen Boyden, whose wisdom and foresight and dedication to research into problems facing mankind have provided me with great inspiration throughout the period of our association. His guidance over recent years has made a rich contribution to my own education.

I am most appreciative, too, of the advice and support given by Jetse Kalma, Alan Aston, Roger Gifford, Eben Hipsley and Margaret Corden in regard to various parts of the research I have undertaken.

I have particularly valued the impressive contribution of my fellow research scholar, Sheelagh Millar, to the Hong Kong Human Ecology Programme. Without her efforts important parts of my research could not have been undertaken. I am also thankful for her advice during the long period of field work in Hong Kong and during the writing up period in Australia.

My sincere thanks go to Andy Tse whose company and ever joyful and resourceful approach to computer programming, data presentation, drawing and other forms of research assistance have always been highly valued. The occasional research assistance provided by Anita Ko, Marion Christie and the expert advice of Johanny Kung in regard to computer programming are much appreciated.

Research has been made pleasant and worthwhile because of the company and support given by all of the staff of the Urban Biology Group at the ANU and the Centre of Asian Studies at the University of Hong Kong.

I am especially grateful for the sophisticated typing skills of the secretary of the Hong Kong Programme, Susan Andrew.

Finally, it almost goes without saying that I am deeply indebted to Marte and Mouss to whom this thesis is dedicated.
ABSTRACT

The input-output and end-use of extrasomatic energy use is reported for 1971. Trends in Hong Kong's energy use are examined over a period of 17 years in relation to the rapidly changing urban setting and alternative sources of energy which may be adopted in the future. Forty per cent of Hong Kong's energy input is lost in conversion processes, the end-use of energy is inefficient and potential for conservation and recycling is considerable. Upto 15% of total energy use could be supplied by direct solar irradiation and bioconversion of organic wastes generated in Hong Kong. From a sector end-use analysis of energy use it is clear that Hong Kong is moving towards more energy intensive industry and more energy expensive transport. Also, new commercial and residential buildings are heavily reliant on energy-use to remain fit for human use.

An analysis of spatial and temporal patterns of energy use show a range of intensity of energy use from $0.02 \times 10^8$ MJ/km$^2$ in rural areas to $109.46 \times 10^8$ MJ/km$^2$ in heavy industrial/residential areas. Energy consumption is 26% higher in summer than in winter. Artificial heat generation over all Hong Kong is 1.7% of mid-summer and 2.3% of mid-winter incoming solar radiation; but reaches
double incoming solar radiation over 24 hour periods in some parts of the urban area.

It is demonstrated, through a study of energy use in the Hong Kong food system, that the energetic efficiency of food production in the Hong Kong region has decreased by 10 to 250 times in the past 40 years. The energy input-output ratio for all Hong Kong crop production in 1971 was 0.8:1; but where high technology production modes were practiced the ratio was 7.6:1. It is estimated that 40-50% of the energy invested in the Hong Kong food system could be conserved without a decline in crop production.

A nutrient balance is established for the Hong Kong ecosystem. Losses of nutrients in human food are up to 20% of total input for important nutrients. The flow of phosphorus in the Hong Kong food system is examined in detail. Here it is shown that about 3,600 tonnes of phosphorus are lost from the Hong Kong food system each year. From a study of the land-based forage area demand, the average Hong Kong resident is shown to consume a diet which requires only half the land area to produce as the average Sydney resident.

The nutrient balance data is presented in terms of apparent consumption of human food and is compared with the socio-economic distribution...
of nutrients in the Hong Kong community. For most important nutrients apparent consumption is at the level of western populations. However, both the intake of calcium and somatic energy are found to be deficient in comparison with recommended intake, particularly for low socio-economic groups. The likelihood of biological and cultural adaptation to these apparent dietary deficiencies is discussed.

Finally the interaction between energy use and individual health and well-being is examined. Data presented supports the conclusion that happiness and life-enjoyment improves with increases in individual energy use. Evidence is also presented to show how energy use degrades the physicochemical environment of Hong Kong leading, potentially, to an increase in human maladjustment.
### TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title page</td>
<td>I</td>
</tr>
<tr>
<td>Statement</td>
<td>II</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>III</td>
</tr>
<tr>
<td>Abstract</td>
<td>IV</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td><strong>CHAPTER I</strong></td>
<td></td>
</tr>
<tr>
<td>A brief history of energy use and of concepts of energy</td>
<td>6</td>
</tr>
<tr>
<td>and entropy</td>
<td></td>
</tr>
<tr>
<td>Perspectives in the use of energy by mankind</td>
<td>9</td>
</tr>
<tr>
<td>The emergence of ideas about energy</td>
<td>18</td>
</tr>
<tr>
<td>The laws of thermodynamics</td>
<td>20</td>
</tr>
<tr>
<td>The entropy law</td>
<td>21</td>
</tr>
<tr>
<td>Entropy and life-systems</td>
<td>23</td>
</tr>
<tr>
<td>Recognition of the wider utility of thermodynamic laws</td>
<td>25</td>
</tr>
<tr>
<td>Energy theory of cultural evolution</td>
<td>30</td>
</tr>
<tr>
<td>Lotka's laws</td>
<td>41</td>
</tr>
<tr>
<td>Energy flow analysis as a tool in the study of plant and</td>
<td>42</td>
</tr>
<tr>
<td>animal ecology</td>
<td></td>
</tr>
<tr>
<td>Energy accounting, entropy and economic theory</td>
<td>44</td>
</tr>
<tr>
<td>Thermodynamics and economics</td>
<td>47</td>
</tr>
<tr>
<td>Enabling and disabling philosophies</td>
<td>54</td>
</tr>
<tr>
<td>Energy and the human ecology of urban settlements</td>
<td>62</td>
</tr>
<tr>
<td>Conclusion</td>
<td>63</td>
</tr>
<tr>
<td>Bibliography</td>
<td>65</td>
</tr>
<tr>
<td><strong>CHAPTER II</strong></td>
<td></td>
</tr>
<tr>
<td>Energy use in Hong Kong: Part I, an overview</td>
<td>77</td>
</tr>
<tr>
<td>Introduction</td>
<td>77</td>
</tr>
<tr>
<td>Explanatory notes</td>
<td>78</td>
</tr>
</tbody>
</table>
CHAPTER VII

Apparent consumption and socio-economic distribution of nutrients in Hong Kong 272
  Introduction 272
  The setting 274
  Methodology 274
  Apparent consumption 278
  Comparative data 279
  Dietary adequacy of available nutrients 280
  Calcium 281
  Apparent consumption compared with household intake 286
  Socio-economic variation in nutrient intake 288
  General discussion 292
  References 298
  Tables and figures 305

CHAPTER VIII

Energy use, health and well-being in urban centres; the case of Hong Kong 321
  The case of Hong Kong 331
  Methodology 331
  Individual energy use and well-being 338
  The proximate environment and well-being 341
  Potential impact on health of general changes in life conditions in Hong Kong 344
  General discussion 346
  References 353
  Tables and figures 358

CONCLUDING REMARKS

  Introduction 368
  The city as an ecosystem 369
  Economic and ecologic approaches to ecosystem management 375
  The human component 377
  References 380
INTRODUCTION
INTRODUCTION

The research presented in this thesis forms part of the system ecology section of the Hong Kong Human Ecology Programme. This programme was initiated during 1972 by Professor S.V. Boyden, Head of the Urban Biology Group* at the Australian National University. Field work for the research programme began in Hong Kong in October 1973, and was based at the Centre of Asian Studies, University of Hong Kong, and carried out with the co-operation of the Chinese University of Hong Kong and the Hong Kong Colonial Government. During the course of research the Hong Kong programme was adopted by UNESCO, and is now part of the Man and the Biosphere Programme, Project 11.

One of the major aims of the Hong Kong programme is to gain greater understanding of the interplay between cultural and natural processes in the urban environment. The characteristics of air, water, nutrient and energy flow are all significantly modified by the processes of culture in any environment of which modern man is an important constituent. A knowledge of the ways in which the cultural processes of mankind modify natural systems is of the greatest importance to an understanding of mankind's responsibility to his environment, as well as contributing to wise management of the greatly changed human environment of urban settlements.

*Formerly in the Human Biology Department of the John Curtin School of Medical Research, now it is renamed the Human Ecology Group and is part of the Centre for Resource and Environmental Studies.
Although the two approaches to human ecology adopted in the Hong Kong Programme, namely system ecology and population ecology, are distinct, in accordance with the Hippocratic axiom that patterns of health and disease are ultimately a function of the quality of the environment, information gathered in the one area is clearly pertinent to that gathered in the other. A major orientation of the Hong Kong programme, then, is to examine the nature of the relationships which exist between features of the urban system as a whole and the health and well-being of its human constituents.

An important theoretical consideration, which forms part of the conceptual framework of the Hong Kong programme, is the principle of phylogenetic maladjustment. This principle is a corollary to the Darwinian theory of evolution, according to which species become, through natural selection, increasingly well adapted in their genetically determined characteristics to the conditions of life in the environment in which they are evolving. It follows from this fact that if the environmental conditions deviate significantly from those prevailing in the evolutionary environment, the likelihood is that individuals will be less well suited in their biological characteristics to the new conditions, and consequently some physiological and behavioural signs of maladjustment may be anticipated. There is an important difference between the human species and other animals in regard to the application of this principle, that is, that mankind has the advantage of an additional set of adaptive
processes which can render individuals and populations better able to cope with the new conditions, namely, the processes of cultural adaptation.

The main emphasis of research in the system ecology section of the Hong Kong programme is on the flow and end-use of energy in the Hong Kong ecosystem. Energy flows and forms are part of every transaction which takes place in an ecosystem, and they assume particular importance in any setting of which modern man is a part. Therefore energy analysis represents an ideal entry point to the study of human ecology. In association with the study of somatic energy\(^1\) flow, the flow of major nutrients in the Hong Kong ecosystem and aspects of the nutrition of the Hong Kong population have been examined. Finally, there is discussion of the interaction between energy, a major component of the urban system and the population ecology of \textit{Homo sapiens} of Hong Kong. Here the principles of phylogenetic maladjustment and cultural adaptation are examined.

With the exception of the first chapter, each chapter has been prepared as a paper; chapters 2 and 3 are actually published, chapter 5 is in press, and chapters 4 and 7 have already been submitted to journals. The first chapter deals with the history of mankind's use of energy and the emergence of his thinking about energy. The second

\(^1\) Somatic energy: "that energy which is utilised, through the metabolic processes, within a living organism".

Extrasomatic energy: "that energy which flows through or is utilised by a human community and which is not utilised through metabolic processes with a living organism". In this research 'extrasomatic energy' only includes fuels in current use.
and third chapters deal with the flow of extrasomatic energy through the Hong Kong ecosystem, and follows energy through its various end-uses in the major sectors of economic activity. The fourth chapter describes in detail the spatial and temporal distribution of energy in Hong Kong, discussing results in relation to urban planning concepts and urban climate. The fifth chapter examines energy flow in the Hong Kong food system, indicating the energetics of modern agriculture and the energy and resource constraints being created by current trends in agricultural production in Hong Kong and other parts of the far east. This last chapter, together with chapter six, which describes nutrient flow in the Hong Kong ecosystem, compares the integrative, conservation-orientated nature of traditional agricultural ecosystems with the disrupted pattern of nutrient flow in contemporary urban settlements.

Chapter seven is an examination of nutrient flow in the Hong Kong food system in more detail, making particular reference to human nutrition. Data supporting the general findings presented in chapter 6 and showing the socio-economic distribution of nutrients amongst the Hong Kong population are presented.

Chapter eight presents an examination of the theory, and supporting data, on the interaction between aspects of the total Hong Kong ecosystem, specifically of energy-use and its pollutant byproducts, with individual health and well-being.

The final section of concluding remarks draws together many of the major findings of the research presented
in the context of ecosystem concepts of management of an urban settlement, but particularly related to the urban settlement of Hong Kong.

Other papers prepared and published during the course of the Hong Kong programme, are included in an appendix pocket because, on occasions, reference is made to them in the thesis.
CHAPTER I

A BRIEF HISTORY OF CONCEPTS OF ENERGY AND THE USE OF ENERGY BY HUMANKIND
INTRODUCTION

The recent history of mankind has been one of ever-increasing consumption of extrasomatic energy. Recent cultural evolution has been marked by rapid changes in the kinds of skills and technology that have been used to harness the dynamic and static sources of energy. Indeed, it is now commonplace to find reference to the transition of human societies from the hunter-gatherer phase to the western-industrial phase as initiated, or promoted by a stepwise increase in energy conversion, beginning with a total reliance on the somatic energy obtained from wild plants and animals for human muscle power, and leading ultimately to the sophisticated technology used to harness the energy of the atom in societies with a per capita energy-use two orders of magnitude higher than those of the Paleolithic Age. (Cook, 1971; Singer, 1971).

Nevertheless, despite the undoubted significance of the role that energy conversion has played in the history of mankind, the conscious recognition of a concept of 'energy', or the formulation of a coherent theory of energetics, is no more than a century old.

* Somatic energy: "that energy which is utilised, through the metabolic processes, within a living organism".

Extrasomatic energy: "that energy which flows through or is utilised by a human community and which is not utilised through metabolic processes with a living organism". In this research 'extrasomatic' energy only includes fuels in current use.
Furthermore, as we will show, the utility of energy theories, which are critically important to an understanding of the operations of, and limitations to human civilisation, was appreciated only by a small group of physicists and chemists until the beginning of the 20th century. Even until the 1960's, the wider implications of the thermodynamic laws established in the middle of the 19th century remained isolated from, or were ignored by, policy makers, economists and administrators who dealt with the day to day management of public life.

It is only now, in the 1970's that the advent of a global energy crisis has done for theories and concepts of energy what widespread pollution did for concepts of environment and ecology a decade ago, that is facilitate public discussion, in this case on the implications of maintaining or expanding a 20th century high-energy life style.

However, the discussion generated by scientists elaborating concepts of energy-use, energy conservation, alternative energy sources and so on through the public media, does little to emphasise the importance of the laws of thermodynamics.

Very frequently the impression is given by economists that free energy can be created by man. Moreover, the fact that every process requires free energy, and inevitably degrades low entropy to high
entropy, is somehow forgotten, or simply not understood. This kind of thinking is particularly prevalent amongst economists whose business it is to establish the feasibility of harvesting new sources of energy. For example, it may seem feasible in dollar terms to mine oil shales but the energy spent in the process could prove to be greater than that retrieved. Certainly it may prove more attractive to spend the same amount of money harvesting another energy source where the return of energy per unit of energy expended is greater. In this regard energetic analyses, indicating what is energetically possible, as opposed to what seems financially attractive, are particularly important.

This chapter presents a brief analysis of the history of man's use of energy, particularly extrasomatic energy, and relates the development of concepts of energy and theories of energetics. We are most concerned with the use of energy analysis as a tool in the management of the urban-industrial environment, a setting which will soon constitute home for the majority of the world's population. Before examining early thinking about energy and the origins and impact of thermodynamic theory, it is appropriate to outline the patterns of the relationship with extrasomatic energy man has cultivated over the ages.
Perspectives in the use of energy by mankind

The first life forms of about 3,000 million years ago derived their energy from complex molecules in the primordial environment, and as these became depleted only those life forms survived that could synthesise their own complex molecules from more simple ones.

At this time we can imagine the beginning of photosynthesis, perhaps the most important event in evolution. In photosynthesis, chlorophyll molecules absorb photons of light from the sun, becoming activated and leading to the production of carbohydrates from carbon dioxide and water. Carbohydrates are the source of energy for practically all living cells. For every molecule of carbon fixed into a carbohydrate, a molecule of oxygen is released. Eventually an oxygen rich atmosphere was formed allowing the formation of aerobic respiration and ultimately facilitating the evolution of animals. With the exception of the chemosynthetic bacteria, all present life owes its existence to the processes of photosynthesis.

Green plants flourished sufficiently to provide not only food for the animal kingdom of 1,000 million years ago, but also the accumulation of vast stores of organic matter that constitute the fossil fuels of today.

The emergence of early mankind, probably some 4 million years ago, also meant the beginning of human
culture. The evolution of culture signalled a major departure from patterns of energy consumption characteristic of the rest of the animal kingdom, for, through cultural processes, *Homo sapiens* was able to capture and convert more energy than was required for his metabolic processes. Although for millions of years hominids only used cultural processes to increase the efficiency with which they used somatic energy, i.e. by using tools such as bones, shaped sticks and so on, once they learnt to utilise extrasomatic energy, it was, in comparison to geological time, a fleeting moment before man's energy conversion significantly modified the global environment.

The change which added extrasomatic energy use to somatic energy use for mankind came with the discovery of fire. There is evidence that *Homo erectus* used fire in Africa 500,000 years ago, during the pre-Chellean age, and that fire appears to have warmed the sites of human occupation from 350,000 years ago in the far east, 250,000 years ago in Europe and 100,000 years ago in West Asia (Oakley, 1956). The time when *Homo sapiens* learnt to renew fire is not known with any certainty, although the first evidence that he could actually rekindle it is as late as 6000 BC. It is said that even the Tasmanian aborigines of the 18th century did not possess fire-making skills; instead they carried glowing coals with them wherever they went and had to obtain fire from a neighbouring group if they lost their own (Bonwick, 1870).
The acquisition of fire did not initially substitute for human muscle power in major work efforts. The main purposes for which fire was used initially were to ward off predators, to provide warmth and to cook food. Acheulean people also used fire to drive game towards hunters, and eventually upper Paleolithic societies employed fire to hollow dugout canoes and perform other such work which directly replaced human labour. It is estimated that the amount of energy consumed through the use of fire by hunter-gatherers of the Paleolithic Age was about 10 MJ per capita per day, in other words about the same as their somatic energy consumption.

Throughout the Paleolithic Age improvements in technology added to the efficiency with which man utilised his muscle power, further tipping the balance of ecosystem control in his favour. For example, the invention of the bow and arrow during the upper paleolithic age dramatically improved man's efficiency of energy use in hunting (Derry and Williams, 1960).

Some suggest that the next major step in energy use was the domestication of the dog (Steinhart and Steinhart, 1974). Throughout the period 35,000 BC to 7,000 BC hunters spread over the earth in search of game. During this period, and some time before 13,000 BC, domesticated dogs and wolves became constant companions of man, extending his hunting range, improving his hunting performance and even
providing him with a source of traction in the cold northern lands. However, the next change in energy use most commonly acclaimed, was the domestication of plants and animals, sometimes referred to as the 'agricultural revolution'. The domestication of plants and animals must have spanned several thousand years, for a number of discoveries and observations were needed, as well as a significant change in lifestyle away from the long lasting hunter-gatherer tradition. Signs of agriculture, for example, the remnants of sickles, occur from the fertile crescent as early as 7,000 BC.

The advantages mankind is supposed to have earned through the processes of cultivation included greater control over energy flow in the biosphere, by manipulating a larger portion of the flow of solar energy to suit his needs. Perhaps of great significance is that cultivation in the more fertile parts of the globe, for example the Nile Delta, created circumstances whereby an individual could regularly produce far more food than he or his family could consume. Whereas there is considerable evidence that hunter gatherers needed to spend little time to collect their food requirements, this does not seem to have facilitated the development of structures whereby sections of the community could be permanently isolated from the processes of food production. However amongst agriculturalists elite groups could,
by invoking superstition, by coercion or by other means, direct surplus labour into non-productive tasks such as the modification of the physical environment to fit preconceived spiritual, or other notions. A classical example of this phenomena is the construction of the pyramids where, for generations, more than a hundred thousand men laboured at the direction of the pharoahs (Henry, 1873).

It has been estimated that early agriculturalists, utilising fire and the somatic energy of domestic animals, controlled the flow of about 50 MJ per capita per day, and that by the 15th century, with increased technological efficiency, and the use of wind and water power, European agricultural communities used about 100 MJ per capita per day (Cook, 1971).

Technology was always very important in the utilisation of energy, for, although the amount of energy available to man did not change very greatly for thousands of years after the advent of agriculture, the work that could be performed with that energy increased along with the efficiency of his tools and his technology. An example of this kind of change is the beginning of metallurgy around 3000 BC (Derry and Williams, 1960).

By accident or design, men learned that the heating of particular ores caused liquid metal to flow which could be readily formed and moulded. Furnaces were designed which developed temperatures of more than 1200°C to extract metals from ore bodies. Metal
implements were in many ways superior to those made of wood or stone. For example, a knife or axe made of metal could be more finely honed, allowing a greater concentration of force at the cutting edge, and increasing the efficiency with which muscle power could be used.

Water and wind power came into use comparatively late. Waterwheels were definitely in use in Greece in 300 BC, and windmills were in use in the 7th century AD in Europe. Of course, the dugout canoes of the late Paleolithic Age converted water power into transport energy for Homo sapiens, though the amounts of energy involved were likely to have been very small in comparison to his total energy use. The development of the sailing ship placed a major energy converter at mankind's disposal. Sailing vessels of the middle ages returned about 240 man-days for every man-day of somatic energy expended (Cottrell, 1955). The energy trapped in this manner, though not great in comparison to the total energy consumption of that period, activated a 'trigger' mechanism disseminating dominant cultures throughout the globe, thereby contributing to many changes in the course of human history.

The next great increase in mankind's use of energy came with the Industrial Revolution, which began in England in the 18th century. However, the Industrial Revolution neither precipitated the discovery of fossil fuels, nor was it initially powered by them.
Water works, such as those at Versailles in 1600, which produced 56 KW of power, and windmills, such as those which provided the power to drain and maintain submerged lands in the Netherlands, plus firewood, fueled the factories of the early Industrial Revolution (Steinhart and Steinhart, 1975).

It was not that the various fossil fuels were unknown in the 18th century; oil wells had been drilled in the Ionian sea in 300 BC; the Chinese tapped natural gas in 1000 BC, and coal was used by the Greeks, and the Chinese of about 100 AD, and was burnt in an English monastery in 852 AD (Egerton, 1951, Cottrell, 1955, and Steinhart and Steinhart, 1974). However, it was not until all forests within reach of the factories of the industrialising countries had been felled for fuel that people turned, reluctantly, to the use of coal and, later, to other fossil fuels (Luten, 1971). During the peak years of the Industrial Revolution in England, between 1850 to 1870, per capita energy consumption rose to about 290 MJ per day (Cook, 1971).

Once again, the technology which developed during the early stages of the fossil fuel era, led to a rapid growth in the utilisation of the newly appreciated energy forms. The internal combustion engine, pioneered by Huygens in 1673, embodied in effective form by Otto in 1876 and produced commercially by Daimler in 1883, brought about a rapid increase in the consumption of petroleum products early in the 20th century (Usher, 1954).
The principles of electricity discovered by Coulomb, Ørsted, Faraday and others during the late 18th century and early 19th century, were well enough understood by the 1880's that electricity could begin to provide a major form of power. In 1891, a hydro-electric system was installed at Niagara Falls. Electric power plants were installed in England and Germany during the decade 1890-1900. Between 1880 and 1905, electricity consumption in the United States increased by 414% (Emery, 1973), and throughout this century, in most of the developed world, electricity consumption has doubled, on average, every 10 years (MacDonald, 1972).

In our own era there is promise (or threat) of widespread use of nuclear power, marking a fourth (see p. 33) stage in the history of energy-use by mankind. Energy use has now reached 1000 MJ/capita per day in the United States, and 500 MJ/capita/day in Australia (United Nations, 1973).

Probably the two most important features of the recent history of mankind's energy use are, firstly, the magnitude of total energy being converted and secondly, the rate of growth in global energy consumption. As we have seen, for literally hundreds of thousands of years, the human species' consumption of extrasomatic energy remained parallel with its
somatic energy use, i.e. about 10 MJ/day. Levels of energy consumption of this order are still found in some contemporary groups, such as the nomadic peoples of the Sahelian desert (Moumoumi, 1973) and the neolithic tribesman of New Guinea (Hipsley, 1965). Surprisingly, it is also the level of direct energy consumption, for general domestic purposes, of the majority of the population in the urban settlement of Hong Kong (Newcombe, in preparation).

Maintained over such long periods, this basic level of energy consumption meant that growth in total energy consumption was always roughly parallel to growth in population. However, during the Industrial Revolution this relationship between energy use and population growth was disrupted because of the ease with which man could exploit fossil fuels. Currently world energy consumption is growing at a rate double that of population growth, the latter doubling every 30 years and the former every 14 years (United Nations, 1969, SCEP, 1970).

The current level of humankind's energy conversion even rivals that of photosynthesis. The figures speak for themselves: annual net photosynthesis over land is estimated at 0.58Q (Leith, 1964) and mankind's global energy consumption is 0.23Q, roughly 40% of continental photosynthesis (1Q = 1.06 x 10^{21} J). Of course, gross photosynthesis, over all of the world,
is about ten times higher than the figure given for net photosynthesis over land (Odum, 1971).

Another way of looking at the magnitude of human species' energy use is to compare present and projected power densities with net solar radiation at the surface of the earth. The global average power density in the early 1970's was roughly $0.016\, \text{W/m}^2$ (at the rate of $8 \times 10^9 \text{kw}$ over $5 \times 10^{14} \text{m}^2$), or less than $10^{-4}$ of global average solar irradiation. However, it has been estimated that, if we continue to increase the use of energy at the current rate, within 200 years the power density of mankind's activities will be equal to total solar irradiance (Weinberg, 1975). Already some parts of large urban settlements have power densities exceeding solar radiation for extended periods of the year (see Kalma and Newcombe, 1975).

It is without question that the human species' use of energy has become exceedingly important, not only to its own welfare, but also to the survival of the biosphere. On the other hand, our appreciation of the 'thing' that is energy, and of concepts related to energy use, has not grown at anything like our dependence on its consumption.

The emergence of ideas about energy

For all intents and purposes, the use of the word energy to describe that elusive quality of widely varied materials which, when processed in certain ways,
perform work for man, arose during the period of discovery and documentation of the laws of thermodynamics, the 1840's and 1850's. For a considerable period thereafter the word 'force' was readily interchanged with 'energy', causing considerable confusion (for example, see Mayer, 1842 and Spencer, 1860).

However, despite the lack of a unifying concept of 'energy' there was considerable discussion of energy-related phenomena prior to the 19th century. In accordance with the division of the elements proposed by the philosophers of ancient Greece into earth, air, fire and water, heat was apparently regarded as a separate, though weightless, substance. The Greek philosophers believed that when an object was hammered, a substance which they called 'caloric' came to the surface. This concept of heat stood even until the time of Lavoisier, who identified the nature of chemical combustion in the late 18th century. His list of simple substances in Traite Elementaire de Chemie, 1789, included 'caloric' (Encyclopaedia Britannica, 1969). Even though Lavoisier's discovery has proved basic to the science of nutrition in particular, and to other important aspects of contemporary energetics (e.g. energy accounting), it was not until the 19th century that the general characteristics of energy were recognised.
Apart from the discoveries leading to the enunciation of the laws of thermodynamics, perhaps the most important insight came from Sir John Herschel, who according to Herbert Spencer (1860, p. 204) was the first to recognise the sun as the ultimate source of all energy used by man. In his book 'Outlines of Astronomy' of 1833, Herschel recorded '... the sun's rays are the ultimate source of almost every motion which takes place on the surface of the earth' (cited by White, 1954, p. 4). Spencer (1860) reiterated and further developed this concept. Nevertheless, it was the discovery of the laws of thermodynamics which led to truly comprehensive understanding of the nature of energy.

The laws of thermodynamics

According to Cajori (1929), the science of thermodynamics had its origin in attempts to calculate the amount of work which could be achieved by a steam engine. In his 'Refleions sur la puissance matrice de fur' (1824) Carnot discussed the work efficiency of steam engines and cyclic operations whereby a working substance could, after a series of changes, be brought back to its initial condition. He showed that heat may be taken from a condenser and restored to its source by the expenditure of an equal quantity of work. Carnot believed in the theory of 'caloric' although
he came later to recognise the law of conservation of energy (Cajori, 1929).

Mayer, in 1842, first stated the principle that the energy of the world is constant, and later, in 1850, Clausius stated the laws in their present form: (First law) "The energy of the world or cosmos, is constant". (Second law) "The entropy of the world, or cosmos, tends, or strives, toward a maximum" (cited by White, 1959, as a translation of Clausius's work by Gibbs, 1874). Joule and Helmholtz also shared in the discovery of the principles of thermodynamics, and with Thompson and Rankine were successful in developing thermodynamics as a new science (Cajori, 1929).

Of the two major laws of thermodynamics, the second, the entropy law, has created the most controversy, is the least well understood, and is, arguably, of the greatest importance to the wider socio-cultural affairs of human communities. Therefore, its general implications deserve more careful delineation, particularly in regard to biological, life-sustaining processes.

The entropy law

There is no easy way of defining entropy, as reference to the dictionary definition of the term will show, to wit: 'a measure of the unavailable energy in a closed thermodynamic system so related to the state of the system that a change in the measure varies with change in the ratio of the increment of heat taken in
to the absolute temperature at which it is absorbed' (Webster's Seventh New Collegiate Dictionary). This definition does not readily provide the reader with the relatively simple concept that is useful to the discussion of entropy in this paper. Entropy is most usefully discussed in relation to the concepts of 'free' and 'bound' energy. This concept and the nature of entropy become clear if we look at the process of burning a piece of coal in order to do some mechanical work. Before combustion begins, the chemical energy of the coal is 'free', that is, available to us to do work. As it is burnt, the free energy loses this quality, bit by bit as the particular work is performed. Ultimately the coal changes to ashes, yet as the first law of thermodynamics states, there is no loss of energy. Instead, the energy in the coal dissipates into the whole system, where it is 'bound' energy, that is, unavailable to us for the performance of the same mechanical work again. Entropy can now, more instructively, be defined as an index of the relative amount of bound energy in an isolated structure or, more precisely, of how evenly the energy is distributed in such a structure. In other words, 'high' entropy means a structure in which most or all energy is bound, and low entropy, a structure in which the opposite is true. (Georgescu-Roegen, 1971, p. 5).
A useful point to remember throughout this discussion about entropy and energy is that it is not energy which is in short supply in the world, but low entropy, and that any process of energy conversion necessarily decreases the stock of low entropy.

Entropy also has a statistical definition arising from the investigations of Boltzmann and Gibbs, who established the exact quantitative expression

\[ \text{entropy} = k \log D \]

when \( k \) is the Boltzmann constant \((3.2983 \times 10^{-24} \text{ cal/}^\circ\text{C})\) and \( D \) a quantitative measure of the atomistic disorder of the body in question (Schrödinger, 1944). Here the entropy law introduces the concept of 'order' and 'disorder' in so far as it states that any process in the universe involves an increase in disorder. If this is so, how is it that life, which can only be sustained by maintaining highly ordered structures, can co-exist with the entropy law?

**Entropy and life-systems**

The most widely accepted interpretation of the relationship between life and entropy is that provided by Schrodinger (1944, p. 76): 'a living organism continually increases its entropy - or, as you may say, produces positive entropy - and thus tends to approach the dangerous state of maximum entropy. It can only keep aloof from it, i.e. alive, by continually
drawing from its environment negative entropy.'

This interpretation, though widely cited, has caused some confusion. For example, White (1959, p. 33-34) cites Schrödinger's discussion on entropy and life, but is led to conclude that life systems are part of a 'tiny sector of the cosmos .... (where) ... we find a movement in a direction opposite to that specified by the law of entropy'. Clearly it is not consistent with the second law of thermodynamics to suggest that the law holds for one part of the universe and not another. Life systems do not create low entropy from high, instead it may be claimed that they hasten the degradation from low entropy to high entropy (see Adams, 1975, p. 122). If life systems were believed to be capable of creating low entropy from high, then it would be possible to hold that man could create low entropy. This would be a serious delusion for man is now one of the main agents in the global process of degrading low entropy.

An important aspect of the entropy law is that it, more than any other physical law, depends on human perspective to retain validity. The concept of order-entropy must be related to the peculiarly human interpretation. As with the energy in coal, it is more value to us as the chemical energy of coal than as the heat energy derived from its combustion. However, at the molecular level, the nonanthropomorphic mind
would simply perceive the same energy moving from one place to another. It is the economic value which adheres to states of low and high entropy, or, as we will discuss later, it is the degree of entropy which influences economic value (see Energy accounting, entropy and economic theory).

Recognition of the wider utility of thermodynamic laws

Joseph Henry, an American physicist, is attributed the first suggestion that the various stages in human history can be described in terms of increasing control over extrasomatic sources of energy (White, 1954, p. 4). Henry (1873, p. 644) said in part 'It is this substitution of the energies of nature for the power of human muscle that, as we have said, has abolished slavery and elevated humanity to a higher plane than was ever dreamed of by the wisest sages of ancient times'.

It is not surprising that a physicist should first see the wider implications of thermodynamics for, after all, physicists developed thermodynamic theory and it is likely that understanding of thermodynamics was confined to a small circle of physicists and chemists for most of the 19th century.

Nevertheless, it would be misleading to suggest that a good grasp of thermodynamics is essential to an understanding of the importance of energy to man and his socio-cultural affairs. Perhaps the reverse is true; that it is necessary to have an understanding of the
importance of energy to man before seeing the real utility of taking a thermodynamic perspective of human ecology.

The importance of energy to human society was emphasised frequently in the latter half of the nineteenth century. Spencer (1860, p. 202) wrote that 'whatever takes place in a society results either from the undirected physical energies around, from these energies as directed by men, or from the energies of men themselves.' In 1886, Ludwig Boltzmann deduced from the entropy law the basic principle that the struggle for existence is a struggle for free energy (cited by White, 1954, p. 4). There is no doubt, however, that the greatest impetus to the energy theory of cultural evolution was provided by the controversial theory of energetics developed by Wilhelm Ostwald (1907), later supported by Frederick Soddy (1912).

Ostwald lamented that the inertia which prevailed in physics of the last half of the 19th century had retarded any full recognition of the importance of the law of conservation of energy. In his view, the laws of thermodynamics had not been given the practical recognition they deserved as a means by which to unify the natural sciences. At the turn of the century, the idea that matter was real, and energy was only thought, was prevalent. Ostwald forcefully propounded the monistic philosophy which reduces all things to forms of and flows of energy, and that they are explicable in terms of the laws of thermodynamics. It is easy
to see the attraction that Ostwald and his followers must have felt towards thermodynamics as a unifying concept explaining all events in the universe. As a philosophy of science it has arguable legitimacy even now, but this theoretical perspective does not have a practical manifestation, for while all things are reducable to energy forms and flows, not all things are equally well, if at all, describable in energetic terms.

The opposing school of thought to Ostwald perceived the weakness of his monism. However, it took the other extreme, which was to dispute that matter was in fact energy. They summarised their position in these terms, 'his methods are mistaken, his main conclusions untenable and his philosophy deficient' (Carus, 1907, p. 540).

From our viewpoint, the most interesting position that Ostwald took on energetic theory was on the relationship between energy and culture. As we intend to show, his general line of argument was accepted and more widely propounded by others decades afterwards. Briefly, Ostwald surmised that culture exists through the fact that man possesses much more extensive control over his environment than animals and that the progress of culture is characterised by the increase in man's dominion over the world. Having defined all events as transformations of energy 'their control becomes
directly dependent upon the control of the relations of energy and the history of civilisation becomes the history of man's advancing control over energy' (1907, p. 511).

Soddy (1912, p. 11) followed Ostwald's general position on the importance of energy laws by asserting that 'they necessarily come first in order, in the fundamental sense described, in the whole record of human experience, and they control, in the last resort, the rise or fall of political systems, the freedom or bondage of nations, the movements of commerce and industry, the origin of wealth and poverty, and the general physical welfare of the race'. Both Soddy and Ostwald alluded to a likely scheme of events in the evolution of man whereby primitive races were first to have utilised fire and wind in addition to human muscle power, and that apart from the increased efficiency of technology to utilise these sources of energy, the next major cultural change resulted from the exploitation of the energy of coal. Other prominent physicists to describe the relationship between energy and cultural systems include Millikan (1939, as cited by White, 1954, p. 7) and Schrodinger (1935) whose interpretation of the co-existence of the entropy law and life-systems we have already utilised.

Prominent anthropologists of the late 19th century also began to relate energy to cultural change (e.g. Morgan, 1877 and Tylor, 1881). They did
not discuss energy in terms of thermodynamic theory, probably because the facts spoke for themselves and any thermodynamic perspective would have brought unnecessary complication. The events these anthropologists regarded as significant included the domestication of animals and the cultivation of cereals (Morgan, 1877, p. 39), and particularly the substitution of human labour with water power and fossil fuels (Tylor, 1881, 204, 215). It is interesting, as an aside, to note that even at that time a switch to what we now term alternative sources of energy was envisaged, in so far as it was predicted that fossil fuels would be exhausted and we would have to turn to 'tide force or sun's heat to labour for us' (Tylor, 1881, p. 204-5).

Similarly, early in the 20th century the energy theme occurs in anthropological texts (e.g. Wissler, 1923, McCurdy, 1924). Again energy use is seen as an indication of the level of civilisation 'the degree of civilisation of any epoch, people, or group of peoples, is measured by ability to utilise energy for human advancement or needs' (McCurdy, 1924, p. 134).

These writers, and others (e.g. Scott, 1933, p. 28-9, Carver, 1935, p. 288) merely hint at the importance energy has assumed in the affairs of man. The first comprehensive theory relating energy to cultural
change was advanced by Leslie White, and represents the integration of all previous thinking on energetics.

Energy theory of cultural evolution

Leslie White first formulated the energy theory of cultural evolution in 1943. He quite explicitly accredits the elements of his theoretical work to earlier anthropologists such as Tylor and Morgan and particularly to earlier physicists and chemists such as Ostwald and Soddy. White's theoretical perspective deserves elaboration here, for more recently there has been considerable attention paid to the fundamental issues which he raises (e.g. Shawcross, 1972, Adams, 1975, Bayliss-Smith, 1975).

White (1954, p. 2) described culture as an extrasomatic mechanism for capturing energy, harnessing it, and putting it to work in the service of the human species. He saw the purpose of culture as serving the needs of man. Those needs he stated as lying in two broad categories, those satisfied from within the organism alone and those satisfied by drawing upon the resources of the external world. This latter category of needs included such things as tools and weapons for the provision of defense, food and shelter. The former set of needs are only satisfiable following the provision of the latter. In that sense the whole cultural and social structure depends upon the material, mechanical means with
which man articulates himself on the earth. By regarding the nature of the human organism and habitat as constants, White sees any cultural situation as resolving into the amount of energy per caput per unit of time harnessed and put to work, the technological means by which this energy is expended, and the human needs-serving product that occurs from the expenditure of energy.

So far there are two points which deserve comment. Firstly, White's definition of culture does not account for cultural changes which can occur without any increase in energy expenditure but merely through a redirection of existing energies and involving the enhancement of existing skill, for example in the fine arts. Secondly, it is arguable that some aspects of cultural evolution, which by White's definition advances with increased energy consumption, actually makes it more difficult for man to satisfy needs, to wit, pollution, noise and so on, as features of a high-energy society, are not compatible with human health.

Returning to the theory, White constructed a formula expressing the relationship between energy and technology as follows:

\[ E \times T = P \]

where \( E \) represents the amount of energy expended per capita per time, \( T \) the technological means
of its expenditure, and $P$ the magnitude of the product per unit time. The technological means may be 0 to 100% efficient having recognised its inherent limitations. From manipulations of the above formula and in consideration of the factors outlined here, White stated the law of cultural evolution as 'culture develops when the amount of energy harnessed by man per capita per year is increased; or as the efficiency of technological means of putting energy to work is increased; or, as both factors are simultaneously increased' (1943, p. 338).

To White the particular interdependence of social structure, ideology or philosophy and technology added emphasis to the importance of energy in cultural development. He saw social systems and idea systems as functions of technological systems even though capable of conditioning technology to some extent. He was at pains to stress that it was the energy which drove the technology that was important and not the technology that used the energy. In his most sophisticated exposition of the role of energy in culture he recorded that 'no amounts of addition to, or improvement of, mechanical means advance culture beyond a certain point, so long as the energy factor remains unchanged. Culture would retrogress, even if its tools and machines were perfect - and precisely because they were perfect - if the amount of energy harnessed
per capita per year were diminished' (1959, p. 56-7).
With due reverence to White's important theoretical constructs, it seems quite likely that if the tools and machines which convert energy were lost, no amount of energy would, by itself, advance culture either.

White applied these laws, so deduced, to the prehistory of mankind as it was then understood. He describes three stages, and suggests the arrival of a fourth, in man's stepwise increase in control over energy flows and forms. The first is the human-energy era where cultural systems were activated solely by the energy of the human organism. Included in this time was man's use of fire, wind and water as sources of energy, but he regarded them all as being infinitesimal besides the somatic energy of human muscles. The second stage he depicts as the beginning of agriculture, the domestication of plants and animals he supposes to have occurred around 7,000 to 10,000 years ago. His third stage began in the 18th century with the exploitation of fossil fuels, initially coal, and the construction of the industrial revolution. White spoke of a possible fourth stage, the potential nuclear age, with barely disguised awe.

During the 16-year period that White published and expounded the energy theory of cultural evolution similar positions were taken by Clark (1946, p. 29) who considered the low cultural status of savage societies as best illustrated by the amount of energy at their disposal, and by Cottrell (1955) who provided a lengthy
documentation of the history of mankind in terms of the technological capacity for energy conversion. Cottrell was the first to discuss in detail the impact of increasing magnitudes and changing forms of energy on the physical design and geographical distribution of human settlements. He reckoned that change in a society could usually only be brought about by the adoption of a new energy converter, for example, the utilisation of solar panels or wind generators in our own era. (Cottrell, 1955, p. 30-31, p. 172). The likelihood of the adoption of such an energy converter, he claimed, was largely dependent on a society's current ability to produce an energy surplus. In other words, once having obtained the means to generate an energy surplus, it was more likely changes would be accepted whereby that surplus was increased. Energy flow would reinforce the means which initiated the flow and a kind of positive feedback would be started. There is nothing so far in the history of western civilisation to refute Cottrell's theory.

One can only agree with Cottrell that a change in energy converters is likely to bring about a change in society; but he does not suggest, as we do, that societal change can also occur without changing energy converters. To use an energy-related example, a redistribution of converters throughout society, such as permanent reduction in private cars and an increase in buses and bicycles, would certainly make for considerable change in the structure of urban society and the compatibility of the
environment with human health and well-being.

Generally Cottrell's explanation of the social impact of increased energy consumption and his description of man's employment of each new means of harnessing the dynamic and static sources of energy supports White's general contentions. Cottrell was the first person to coin the terms 'high-energy society' and 'low-energy society' which have crept into common usage in discussion of the many energy scenarios for our future.

Not unnaturally, White's theories attracted considerable controversy as he was quick to recognise (1954, p. 7-8). Nevertheless, energetic theories of cultural change were attributed some importance by anthropologists and prehistorians during the early 1960's, for example, in the collection of papers edited by Sahlins and Service (1960) and in the later work of Childe (1963, p. 33). Gideon Sjoberg (1965a and b) was impressed with the role of energy as an instrument of change in pre-industrial cities. In his words 'none of the advances in the feudal world was as revolutionary as the momentous shift to dependence upon inanimate providers of energy' (1965a, p. 197). However, these authors do not aggrandise the role of energy in the sense that White does, and, in effect, only fleeting attention was given to the energy theory of cultural evolution until Rappoport's (1968) pioneering study of the energetics of environment-culture interaction in the
Tsembaga tribesman of New Guinea. Since then ecological energetics has developed a special role in the new ecological studies in cultural anthropology. Recent research in this area include Kemp's (1971) analysis of energy flow in the hunter-gatherer society of the South Baffin Island eskimos and Brooke-Thomas's (1974) analysis of energy flow and energy strategies in an essentially neolithic community of Peruvian Indians.

Energy flow analysis has also flourished in the area of nutrition, food production and agricultural economics. Work carried out by at least two groups of people prominent in establishing the field, Durnin and Passmore at the University of Edinburgh and Poleman and associates at Cornell University, is expansive. A somatic energy cost for almost all activities has now been recorded, particularly amongst neolithic peoples and cultivators in third world countries, and the technology applied to this kind of analysis has become very sophisticated (see Poleman, 1974). Some of the applications of this work are useful. For example, it is possible to examine the impact of technological change on the level of physical activity, or alternatively to structure a labour using rather than labour saving agricultural system to cater for more full employment. However, apart from the nutritional questions which can be examined such as the contribution of decreased physical activity to obesity (see Passmore, 1962), it is difficult to see how this very clever approach to agricultural
economics questions is any more useful than information that is already available from simple observation and common sense.

However, energy flow, or more precisely, somatic-energy budget analyses have served to question some common preconceptions in anthropology and prehistory, for example, the view that hunter-gatherers literally lived from day to day, frequently on the borderline of starvation, having to devote all their time to food gathering. Certainly studies on such groups as the Eskimos have biased our thinking in that direction (for example the description of frequent starvation in Weyer, 1962). Yet the work-effort studies by Lee (1969) on the Kalahari bushmen and supporting evidence provided by Sahlins (1968, 1972) indicate that even under the harshest conditions, at the most 2 to 3 days work were required to obtain an adequate diet for a full week.

Perhaps the most significant work to arise out of the research of Leslie White in recent times is the enunciation of a theory of social power related to the control and distribution of energy flows and forms by Richard Adams (1975). Adams' work is intriguing and is of particular relevance to the present day where we are faced with the momentous choice of either a much higher energy future or a relatively low energy future.

Adams (1975, p. 120-21) proposes that social
power derives from, and is directly dependent on, energy forms and flows. He presents the argument that 'as more energetic processes and forms enter a society, control over them becomes disproportionately concentrated in the hands of a few, so that fewer independent decisions are responsible for greater releases of energy'. Clearly the current concern over the exhaustion of easily gained, simply utilised energy sources should revitalise discussion on the energetic theories of socio-cultural behaviour. Controversial positions such as that arrived at by Adams deserve, indeed demand, further and in-depth examination. However, as Adams laments, 'nearly thirty years after White's article, professional disinterest in the subject is still evident' (1975, xiii).

The apparent failure of White's work to stimulate other research workers to further examine the role of energy in human society does not reflect upon the value of a thermodynamic perspective, for many of the contemporary writers we have discussed find this perspective rewarding. Rather there has been distraction from White's central theme through the weakness of some of the more peripheral elements in his overall scheme. We have already criticised his definition of culture as restrictive and found his treatment of culture change, as only arising through changes in energy use, wanting. Another Shawcross
1972, whose own work has extended the application of thermodynamics into prehistorical research, has also noted particular criticisms that can be made of White's work. Shawcross (1972, p. 585-6) criticises the uncompromising rigidity of the stage by stage picture of energy presented by White, such that the hunter-gatherer era lasted 990,000 years and the neolithic for only 10,000 years, because it denies the fact that cultural change is a continuum for many of the cultural phenomena which facilitated the agricultural revolution must have been developed over many thousands of years during the hunter-gatherer phase.

He points out that White disregarded the real importance of wind power, which Cottrell (1955, p. 49) claims to have altered the scale of trade in the time of the Romans. White suggests that wind added infinitesimally to the power of muscle during the hunter-gatherer phase, but does not suggest a significant role for wind power in the neolithic period and later (1954, p. 3).

A particularly important criticism arises from the ethnographic studies of Lee (1968), Sahlins (1972) and others, which question the advantage, in work-effort terms, of cultivation over the hunter-gatherer phase in human evolution. If food was provided with the same, or even less energy through the hunter-gatherer mode, then it was not so much the
increased control of energy flow which led to the dominance of agriculture, but entirely different factors, probably related to the social structure which could develop during a sedentary, as opposed to a nomadic existence. This is not to suggest that agriculture gave rise to sedentary modes of existence, for settlements have been discovered where no traces of domestic foods can be found (e.g. Van Loon, 1968), but that agriculture is associated with a sedentary pattern of life rather than a nomadic one (see Jacobs, 1969).

These criticisms do not negate the fundamental theme of White's theory, i.e. that an evolutionary perspective is the most appropriate when dealing with culture change and that changes in energy consumption following the advent of culture have been an exceedingly important part of cultural evolution. Whether progress in culture, and indeed civilisation, can continue to be equated with ever-increasing energy consumption is a question we will discuss at a later stage.

During the same period that White was developing his energy theory of cultural evolution, Alfred Lotka was applying thermodynamics to the theory of biotic evolution. Lotka's research ranged from economic (1921) to biological applications of thermodynamic theory (1922, 1925, 1944, 1945) and his thinking is still widely respected in many
fields including, particularly, anthropology and ecology.

Lotka's laws

Lotka took up and expanded Boltzman's principle, derived from the second law of thermodynamics, that life is a struggle for free energy. According to Lotka (1922, p. 148-9) 'natural selection tends to make the energy flux through the system a maximum, so far as compatible with the constraints to which the system is subject'. Given the almost infinite number of organisms possible such that the material for selection is not limited, then evolution, in these circumstances, proceeds in such direction as to make the total energy flux through the system a maximum 'compatible with the constraints'.

Lotka also perceived that when the available supply of energy is limited, the advantage will go to that organism which is most economical or efficient in utilising that energy for maintenance purposes. Though Lotka has in mind particularly plant and animal communities, the inference for contemporary human societies is ominous. We will refer to Lotka's thoughts in later discussion, but it is a fitting introduction to an overview of energetics in biology.
Energy flow analysis as a tool in the study of plant and animal ecology

As early as 1887 Forbes had pioneered the concept of food networks linking organisms together. His research provided the basis for the later enunciation of concepts of 'trophic level', 'ecological niche' and 'pyramid of numbers' (Theineman, 1926; Elton, 1927), which together with Forbes' research provided the framework to which Lotka (1922, 1925) applied the laws of thermodynamics. This marriage of ecological and thermodynamic concepts led naturally to the study of energy budgets and energy productivity in plant and animal communities. Juday (1940), in his study of the energy productivity of an inland lake ecosystem, and Lindeman (1942), with his development of the trophic-dynamic concept of ecosystem structure, were the first people responsible for this vital integration. The elements of Lindeman's thesis of energetic relationships between trophic levels still stands, although the precision with which he described and defined energy at each trophic level has been questioned recently by Slobodkin (1968a). Apart from Macfayden's (1949) re-examination of the concept of ecosystem productivity, research into the energetics of plant and animal communities was infrequent until the work of Eugene and Howard Odum confirmed its utility in ecological research (Odum, 1956, 1957, 1959). The Odums and others (1960, 1962, 1963) developed the energy flow concept and, through their research, formulated the
two broad principles which apply to all organisms, including man, in all ecosystems: a) the one-way flow of energy, and (b) the circulation of materials.

Following the groundrules laid down by the Odums, research into plant and animal community energetics flourished. Richman (1958) and Slobodkin (e.g. 1959, 1962) studied Daphnia populations; Englemann (e.g. 1961, 1968) soil arthropods; Whittaker et al (e.g. 1966, 1967) particular tree species; Goldman (e.g. 1960, 1968) aquatic primary productivity in lake ecosystems; Golley (e.g. 1960, 1968) energetics of old field communities and secondary productivity in terrestrial communities and Weigert (1965, 1967) researched secondary productivity in grasslands.

Odum (1968) has described Lotka's (1925) contribution of the relevance of the laws of thermodynamics to ecological theory as a milestone. A second milestone must surely be the development of the energy flow diagram concept by the Odums themselves. Not only has the concept facilitated the simple expression of fundamental concepts in ecological theory (e.g. Phillipson, 1966) and the development of system ecology (Watt, 1966), but it has enabled a new appreciation of fundamental global problems such as world food production (Odum, 1967). The point in outlining here the history of the application of energetics in biology is to show that this approach has provided theoretical constructs and groundrules which can
be successfully applied to the study of energy flow in human communities. Howard Odum's 1971 publication 'Environment, Power and Society' exemplifies the important contribution of ecological energetics to the wider description of socio-cultural affairs. This work opens up entirely new vistas for the application of energetics, such as in the analysis of religious and political systems. However, the usefulness of some of this energetic analysis is yet to be verified.

Two important and interlinked areas which Howard Odum has emphasised (1971, p. 113-138, 176-205, 1973), and in which energetics has proven most useful, are food production and economics, joined together particularly by the new discipline of energy accounting.

**Energy accounting, entropy and economic theory**

We have previously referred to Lavoisier's formidable discovery of the principles of chemical combustion (p. 19) and the importance of his research to the science of nutrition. In a sense Lavoisier's work was the beginning, albeit unnoticed, of the now flourishing business of energy accounting. Lavoisier foresaw this wider application, though perhaps not the contemporary deployment, of his research when he said 'Even the work of an artist or a plumber can now be expressed and measured in the same units as the work of a horse or an earthquake' (Kleiber, 1961, p. 310).
The modern applications of energy accounting are equally rewarding. H.T. Odum (1967, 1971) perceived that, at least energetically, the marvel of high yield agriculture was a deception, in so far as higher yields were only achievable at the cost of enormous extrasomatic energy subsidy, or as he graphically portrayed the situation, 'our potatoes are made partly out of oil' (1971, p. 115). To facilitate research to examine Odum's contention, Gerald Leach and Malcolm Slesser established a set of energy equivalents for the network of inputs common to contemporary western agriculture. They established direct and indirect energy subsidies for fertiliser and machinery production and the provision of transport and other services (Leach and Slesser, 1973). This work provided the foundations not only for later work on the energetics of food production by Leach (1973) and Slesser (1974), but with the additional support of work by Berry and Fels (1973), for the first major analysis of the energetics of modern cereal crop production (Pimentel et al, 1973). Studies on the energetic efficiency of food systems have become commonplace in the last two years. In our own work we have covered the major contributions and methodology of the Hong Kong food system (Newcombe, 1976a, and Leach (1975) has recently completed a comprehensive review of the research and findings in this field. A major result
of the food system studies has been the development of systems of accounting for energy costs of all forms of services and materials provisions, including the critical energy costs of harvesting energy itself. This work, pioneered by Leach and Slesser in the U.K. and Stephen Berry, Margaret Fels and Hiro Makino in the U.S. has also been approached from an econometric perspective, using Leontief's (1966) input-output models to examine energy subsidy in the input-output matrices of a national economy (e.g. Herendeen, 1973 and Wright, 1974, 1975). The field has been expanded considerably through the work of Peter Chapman at the Open University in the U.K. (1974a, 1974b, 1975). International groundrules for the science of energy accounting have recently been produced (IFIAS, 1975), mostly at the initiative of Malcolm Slesser.

The importance of energy accounting cannot be underestimated for it represents a means by which the implications of thermodynamic theory can be exactingly applied to societal processes. In particular, energy accounting has demystified the process of economic growth represented as the ever-increasing expansion of material production, by providing an analytical tool to quantify the amount and source of low entropy required to maintain or expand the material standard of living to which the industrialised west, epitomised by North America, has become accustomed.

The methodology of energy accounting also
provides an empirical base for the theoretical energetics approach of economist Nicholas Georgescu-Roegen, whose recent works could possibly revolutionise economic theory.

**Thermodynamics and economics**

In the view of Georgescu-Roegen, Carnot was the first econometrician, since his work on steam engines was aimed at finding the greatest amount of mechanised work that could be obtained for a given input of free energy. Physicists again were the first to speculate about the wider role of thermodynamics in understanding economics. Helm (1887) wrote that money constituted the economic equivalent of low entropy, and Winiarski, (1900, p. 265) though a sociologist, discussed social systems in terms of the first and second law of thermodynamics using differential equations and strictly adhered to the language of physics. It was his opinion that the price of a commodity represented nothing more than conversion coefficients of biological energy.

Ostwald and Soddy, of whom we have already spoken, were also interested in the relationship between energy and money. Ostwald believed that money bore a certain resemblance to energy though it was not identified with it (1907, p. 155), and Soddy (1926) extended his general philosophy of economics and energetics into a major work on wealth and poverty. Lotka (1921), following on from the work of Helm and
Ostwald, pursued the nature of the economic conversion of energy. He raised the point that, as opposed to thermodynamic conversion factors, there is no law regulating the ratio of the energy released to the energy applied in a market place transaction; for example, between pushing a button on a drink dispenser and the energy contained in the beverage so obtained. The energy conversion in economic matters was through trigger action, yet he asserted that through application of calculus it could be shown that there were fairly definite economic interconversion factors for different forms of energy purchased on the open market, and applied to specific uses.

Georgescu-Roegen's work derives much from this earlier reasoning, but his re-assertion that important relationships exist between thermodynamics and economics, in that 'thermodynamics is largely a physics of economic value' (1971, p. 276) is more pertinent now than was Lotka's reasoning to the 1920's, for there is no question that traditional economic theory has been found deficient to operate a global economy in times of energy and resource crises (see Schumacher, 1973).

Georgescu-Roegen's thesis is that there is a strong link between the economic process and thermodynamic principles, i.e. that 'thermodynamics
is largely a physics of economic value (1971, p. 276). His conceptualisation of the relationship between entropy and economics presents much of critical importance to the future of mankind. It is well worth spelling out the basic tenents of his proposals and the way in which they contradict conventional economic thinking. He sees the first important connection between low entropy and economic value as arising from the obvious fact that all of the absolute necessities for life are purely biological, and biological life feeds on low entropy. Certainly, regardless of the technological genius of 20th century western man, he has not been able to change the basic condition of life. Georgescu-Roegen claims that it is also demonstrable that all of our economic life feeds on low entropy, and it may be taken as fact that low entropy is a necessary condition for a thing to be useful. It follows that if a thing is useful it will also have economic value. Value adheres because of the thermodynamic maxim that low entropy is decreasing continuously and irrevocably and that a given amount of low entropy can be used by us only once.

There are two major schools of thought amongst resource strategists regarding the availability of key resources during, say, the next 100 years. One school of thought is that in the near future a number of key mineral resources will be mined out in which case the
ocean does not hold untold minerals which might provide us with our requirements for hundreds of years to come (Cloud, 1969, 1973). The other school of thought is that there are no resource shortages; even if land held reserves of key minerals are exhausted, the bottom of the ocean is littered with agglomerations of every element (Kahn, 1975). The essential difference between these two schools of thought, as we see it, is not that the minerals do not exist, on earth, but that they are unavailable in a thermodynamic sense.

It is here that Georgescu-Roegen's perspective is most valuable. His thermodynamic interpretation of the formation of a copper sheet serves to illustrate the fact that beyond a certain point resources can only be won at a greater cost in low entropy than they themselves represent. When that point is reached they must be considered 'unavailable'. Georgescu-Roegen explains that in the process of forming a copper sheet from the original ore body we have 'used up irrevocably a greater amount of low entropy than the difference between the entropy of the finished product and that of the copper ore' (1971, p. 279). In the process of consumption of the finished product, the copper molecules would disperse, much in the same manner as most minerals are dispersed.
in the ocean or, upon consumption, on land. But to gather together widely dispersed mineral bodies, or molecules, into a highly ordered form to be useful to man 'would require such a long time, that the entire low entropy of our environment would suffice to keep alive the numberless generations of Maxwell's * demons needed for the completion of the project.' (1971, p. 280).

In essence, the difference in thinking about resource availability is a difference between conventional economic reasoning and economics with a thermodynamic perspective. Conventional economics sees the economic system as closed, i.e. mostly circular, thereby ignoring the continuous inflow of low entropy from the environment, whereas economists who take a thermodynamic perspective (Georgescu-Roegen, 1971, p. 281) would view the economic process as unidirectional, always transforming low entropy into high entropy, i.e. into irrevocable waste or pollution. In that sense the process parallels what is going on all the time in the natural environment automatically, only in the economy, man is deliberately sorting, rather than merely shuffling, and the result is a faster transformation of low entropy to high entropy.

*Maxwell (1921): Maxwell's demon is imagined to be able to selectively allow only certain molecules to pass from one side of a wall dividing a sealed container to the other, creating a difference in temperature between the two compartments, i.e. unbinding bound energy to defeat the entropy law.
relative to natural processes.

There is little doubt that Georgescu-Roegen's basic thesis will have increasing impact on economic thought and practice. The positions taken by economists who adhere to his thinking are well illustrated by Herman Daly (1973) in discussing growth in electric power production in the United States. The attitude taken by people who promote the idea of continual growth in energy consumption is summarised by Daly from the Congressional Record (Simpson, 1971, Holifield, 1971). The promoters of growth suggest that it is necessary to continue to increase the level of energy consumption so as to extend the standard of living, to clean up pollution and recycle waste, to maintain an acceptable level of employment through increased work of power production and in production processes using power, and to produce military devices to ensure world peace.

Daly's rejoinders to these positions are as follows. While economists have recognised that the costs of growth in GNP beyond a certain level are not worth paying they seem unprepared to recognise also that the costs of growth in energy consumption beyond a certain point are not worth paying. Therefore, the phenomenon of continued growth in energy consumption is implicit in all their arguments. It is logical that the more pollution there is, the more energy will be required to clear it up. Since what is scarce in the world is low entropy, not energy, the more energy
we use, even to clean up, the more rapidly we use the stocks of low entropy and the more rapidly we degrade the total environment. Cleaning up is part of, not a cancellation of, the environmental cost of production growth and at some point the degradation cost of energy needed for cleaning up will be greater than the cost of the pollution it cleans up. In regard to employment allegedly created by increased energy consumption Daly argues that energy is a substitute for human labour as well as a complement to it. Continued growth in energy consumption will give rise to higher productivity per worker, but also to less employment. This situation could only be alleviated if total output were growing faster than the rate at which energy is becoming a substitute for labour, hence adhering to the total growth phenomenon implied throughout. Finally, military defence is itself growth-orientated in so far as strength remains balanced only if one side achieves the capacity of the other. In fact both sides grow continually while sparring for an acknowledged point of balance. The more input to defense the less to the civilian economy and the greater input per unit output of civilian productivity rather than vice versa. Hence an ultimate levelling off of energy use is harder to achieve.

Throughout the course of recent history
there have been both optimistic and pessimistic viewpoints expressed about the advantages of high compared with low energy consumption, relatively speaking. In that regard, a most interesting feature of the perceived role of energy in human affairs is what could be seen as the shift from an enabling to a disabling view of energy-use.

Enabling and disabling philosophies

It could be inferred that the people who predicted the exhaustion of fossil fuels, first late in the 18th century (Williams, 1789, cited by Jevons, 1865), again at the end of the 19th century (Jevons, 1865), and in the mid-20th century (Furnas, 1941), were implying a disabling potential for higher energy consumption in so far as, once having established a dependency on large fossil fuel subsidy, any sudden drop in supply would certainly be, at least initially, disruptive. Nevertheless, we only imply their concurrence and it is clear that the mainstream of energy theorists has generally viewed increasing energy consumption as highly desirable and essential for the progress of civilisation. Soddy (1912), for example, spoke of the prospect of atomic energy in glowing terms ... 'with reference to the newly revealed stores of atomic energy in matter, and to the time so lightly pictured in our imaginations, when it may raise the race to the loftiest pinnacle of its
White (1943, 1949) suggested that the degree of civilisation could be measured in terms of the level of energy consumption and Cottrell (1955) depicted increased energy conversion as adding to man's dominion over the earth and thereby to his own well-being. White's only apprehension was with the advent of atomic warfare. Writing shortly after the bombing of Hiroshima and Nagasaki he said 'the new nuclear technology however threatens to destroy civilisation itself' (1949, p. 389).

Another thought pattern of the 'energy as enabling' school holds that increased energy consumption is invariably related to increases in standard of living. This thinking is quite explicit in the work of Scott (1933, p. 18) and Hartley (1951, p. 113). Ruheman (1946, p. 110) cites a well known Indian scientist, Professor Saha, who proposed that the standard of life in a country could be measured by the amount of power produced per inhabitant. It is commonplace amongst contemporary energy scientists to relate energy consumption directly with 'standard of living' (Perrin, 1973, Sorenson, 1975).

The dominant viewpoint amongst politicians dealing with energy matters is exemplified by Chet Holifield of the Joint Committee on Atomic Energy in the American Congress. His viewpoint is that '... the doubling factor (for energy consumption) every decade
for the next thirty years is basic to our standard of living, now and in the future' (1971, cited by Daly, 1973).

The general rule, that proponents of the energy theory of cultural evolution attribute to energy an ameliorating role, does not apply to Alfred Lotka. Consistently, from his earliest formulation of his thermodynamic laws of natural selection and evolution, he added a reservation, that both natural selection and evolution tend towards, or proceed in the direction of increased energy flow through the system compatible with the constraints. Writing in 1922 he did not expatiate on what constituted constraints, but in 1945 he spelled out that there were two sides to increased energy consumption in the sense that 'the same ingenious contrivances that extend our view, that speed our travel and multiply our strength in beneficial pursuits, are equally potent to destroy' (1945, p. 189). He also foresaw the economic problems associated with using extrasomatic energy to replace human labour in producing essential life support goods, and then having, for the sake of employment, to deploy the displaced labour in the production of luxury goods, such that when luxury production was suppressed, widespread unemployment would result.

Although writers such as Odum (1971), Georgescu-Roegen (1971) and Daley (1973) have discussed problems associated with high-energy societies, it
seems that no philosophical attack has been made on higher-energy societies per se, reflecting an 'energy as disabling' school of thought, until 1973. At that time both Ivan Illich (1974) and members of the Urban Biology Group at the Australian National University (see Newcombe, 1975a) forwarded hypotheses which suggested that above a certain per capita energy consumption the social and physical milieu of every human environment would begin to deteriorate.

We have suggested that there is no necessary relationship between a growth in the social indicators of the material standard of living promoted by increased energy use, and human well-being. On the one hand there is no doubt that movements in public health policy which provided for greater sanitation, programmes to immunise against disease, enhanced child care and so on, have added much to the quality of human life, and to the extent that these measures consume additional extrasomatic energy, an index of increased energy-use related to human well-being has some validity. On the other hand, the implication that numbers of motor vehicles, television sets, refrigerators, amount of road space, numbers of hospital beds and so on, all increasing with increased energy use, are valid measures of human well-being is clearly suspect. For example, the only biosocial index of the impact of changed life conditions caused
by increased energy use *per se* which has been measured to date, is the number of suicides. Here it has been revealed that there is a positive correlation between amount of energy-use and numbers of suicides (Mazur and Rosa, 1974).

Other social indicators which superficially appear to represent increases in the quality of human life, such as numbers of doctors, nurses and hospital beds, could also mean that maladjustment in higher energy societies is such that more people require health-care facilities more of the time. This certainly applies to road traffic accidents when standard of living is deemed to increase if energy use in transport increases; but also if hospital facilities increase to cope with larger numbers of road traffic accident victims (see Cliff, 1975).

In other words, the much vaunted standard of living index which western politicians and econometricians are willing to provide as an illustration of the greater quality of life in the developed world, and which is greatly enhanced by increasing energy use, is no indication of the biosocial state of individuals, which may even deteriorate as energy use increases. In the course of the Hong Kong Human Ecology Programme we have developed this concept further, giving particular attention to the changed life conditions of the urban environment compared with the evolutionary environment of *Homo sapiens*. 
I have presented a preliminary discussion on this topic elsewhere (Newcombe, 1975b).

Following Illich's proposal that there is a defineable optimum limit to energy consumption, his colleagues at the Centre for Intercultural Documentation (Cuernavaca, Mexico) have continued to develop this concept. Jean Robert, an associate of Illich, has circulated a document entitled the 'Energy-hedonistic illusion' (personal communication, 1975) which seeks to associate the lust for gold in the Middle Ages, seen then as a source of well-being, thereby creating the so-called 'chrysohedonistic illusion', with the lust for energy to act as a slave for man in our own era. In this manner Robert provokes discussion on the relative value of our life experience with and without high energy consumption. His assertion is that when man allows his technology to grow beyond a certain limit, the structure of his life, and his daily life experience, are dehumanised.

This new perspective of the disabling potential of energy use must represent a significant turning point in theory, and ultimately, in the practical regard for energy extraction, conversion and utilisation processes. Recent thoroughgoing criticism of the question for a nuclear-electric future embodies this changed perspective and reappraises the wisdom of
adopting a high-energy future (Lovins, 1975(a), 1975(b)).

It should be clear that I am not suggesting that all energy expenditure is likely to have a disabling effect on our capacity to maintain a healthy environment or on an individual's capacity to achieve optimum well-being. Our own philosophy, which is that there is an upper limit which will vary depending on the particular physical and cultural setting, clearly accepts the value of a certain amount of energy consumption. Earlier writers had little opportunity to perceive maladjustment relating to energy use, with the exception of atomic warfare. They lived in an age of burgeoning materialism, so radically different from recent history, and so spectacular that the biosocial impact of increased energy consumption was obscured. Widespread pollution did not begin to become obvious until the 1950's, and the particular demon, the motor car, looked upon as an ideal, was the focal point of urban planning and a sociological tool towards increased equality.

Energy use is a two-edged sword and we must be careful to deploy it when and where a long-term contribution to human well-being is assured. John Holdren (1975) recently summarised this approach: 'the relation of energy to well-being is two-sided. Through its productive application in economic
technological systems, energy fosters well-being; but the environmental and social effects of mobilising and using energy can undermine well-being by means of direct damage to health, property, and human values, and by disrupting indispensable public service functions of natural systems. The higher the level of energy use already attained, the more likely it is that the economic-technological benefits of an additional unit of energy will be outweighed by the social and environmental costs'.

Each new energy form can introduce a whole new social dimension, a fundamental shift in the basic technology employed to perform work and a steady erosion of skills, techniques and values associated with the matrix of energy forms and energy strategies being foregone. Scott (1933, p. 19) was amongst the first to recognise the value of the average quantity of energy per capita as an index of social change, and Shawcross (1972, p. 588) showed an appreciation that problems could arise in an era solely because of the amount of energy converted per unit time. Using the example of the Egyptian pyramids, he postulated that the fundamental difference was not the magnitude of energy converted, but rather the increased velocity of conversion.

These kinds of differences in life conditions lead me to speculate that, ultimately because of
energy use per se, it is more difficult for individuals to achieve optimum health and well-being in high-energy societies than in low-energy societies. It is appropriate, then, for us to examine our hypotheses regarding energy-use and human well-being in the energy intensive environment formed by most contemporary urban settlements. The urban settlement of Hong Kong provided an appropriate energy-intensive environment for such a study.

Energy and the human ecology of urban settlements

To our knowledge, the Hong Kong Human Ecology Programme is unique, in so far as it represents the only attempt at an integrative, multidisciplinary analysis of the human ecology of a contemporary urban settlement.

In the system ecology section of the Hong Kong Programme, we have virtually regarded the urban settlement as a giant organic entity, a system within a wider environment, in the same manner as a plant or animal is part of its wider natural environment. In line with the thermodynamic concepts outlined in this paper we have examined the sources of low entropy, such as energy and nutrients, upon which the urban settlement feeds. We have also examined the economy with which low entropy is converted into high entropy, either directly or through useful work, and the means by which hitherto unexploited sources of low entropy might be exploited. Particularly in regard to energy, we have examined the potential for shifting
back to using more of the recurrent sources of low entropy and less of the low entropy in the capital stocks of fossil fuels. The results of this work are either published (Newcombe, 1975c and d) or in preparation. We have also sought to understand the environmental degradation caused by high entropy generation in the urban environment (Kalma and Newcombe, 1975, Newcombe, 1976, Kalma et al 1976).

Conclusion

In all respects the theory and application of energetics has provided a valuable tool with which to decipher and integrate knowledge to enable a greater understanding of the man-environment interaction in the complex urban setting.

The bulk of applied energetics has its origins well within the last decade, but the theoretical foundations were laid in the middle of the last century.

Although the utility of energy theories to the study of human affairs was as great the day they were proposed as they are now, few people were motivated to put theory to work until the certainty of energy crisis forced our hand. Almost a century ago Tylor (1881, p. 272) wrote 'Perhaps the best means of realising what coal is to us, will be to consider that of three Englishmen now one at least one may be reckoned to live by coal, inasmuch as without it the population would have been so much less'. It is paradoxical
that only now, long after the theoretical foundations have been laid, when our dependence on extrasomatic energy is almost absolute, we should become serious about the study of energy-use in human communities.
BIBLIOGRAPHY


Emery, F.E., 1973. An industrialised society -
  Australia. UNESCO - MAB Programme, Symposium, Adelaide
  (in press).


Englemann, M.D., 1961. The role of soil arthropods in the
  energetics of an old field community. Ecol. Monographs, 31:
  221-238.

Englemann, M.D., 1968. The role of soil arthropods in

Forbes, C.A., 1887. The lake as a microcosm. Republished

  p. 425.

Georgescu-Roegen, N., 1971. The entropy law and the economic

Gibbs, J.W., 1874. On the equilibrium of heterogenous
  substances. Transactions of the Connecticut Academy of
  Arts and Sciences, 3: 108.


Golley, F.B., 1968. Secondary productivity in terrestrial

Goldman, C.R., 1960. Primary productivity and limiting

  Zoologist, 8: 31-42.


Herschel, J., 1833. Outlines of astronomy. Philadelphia


darstellung der Pflanzendecke auf der Erde. Geographisches


Lotka, A.J., 1921. Note on the economic conversion factors
of energy. Proceedings of the National Academy of Science,
Vol. 7: 192-197.

Proceedings of the National Academy of Science, Vol. 8: 147-151.


Lotka, A.J., 1925. The elements of physical biology.
Baltimore.

Science and Society, 8: 161-171.

Human Biology, 17: 167-194.

Lovins, A.B., 1975. World energy strategies. Ballinger,
Cambridge, Mass.

Mass.

Sci. Am. 224: 164-175.

MacDonald, G.J., 1972. Energy and the environment. In:
Schurr, S.H., (ed.) Energy, economic growth and the
pp. 100-109.


CHAPTER II

ENERGY USE IN HONG KONG, PART I: AN OVERVIEW
ENERGY USE IN HONG KONG: PART I, AN OVERVIEW

KEN NEWCOMBE
Urban Biology Group, John Curtin School of Medical Research, Australian National University, Canberra, A.C.T. (Australia)
(Received February 10th, 1975)

ABSTRACT

The input, output and end-use of extrasomatic energy in Hong Kong is reported for 1971. A detailed end-use of the major fuels is included, emphasising their use in power generation. Trends in Hong Kong's energy-use are examined over a period of 17 years in relation to the rapidly changing urban setting and the energy forms which may be adopted in the future.

The conservation of energy is examined in regard to Hong Kong's total dependence on external sources of energy.

An ecological strategy is advanced for Hong Kong as a settlement with a continued reliance on high energy consumption. The study provides a data base which facilitates the elucidation of principles concerned with the relationships between energy-use and human well-being.

INTRODUCTION

The work presented in this paper is part of a study of the ecology of Hong Kong.*

The study takes a multi-disciplinary approach and is based on the view that a proper understanding of the human situation requires that both natural and cultural components of these systems are taken into account, and especially the dynamic interactions between them.

For organisational convenience the programme is considered as consisting of two aspects, namely system ecology and population ecology, as in the conventional approach to the study of ecology in biological science. The work presented in this paper on patterns of energy flow and usage in Hong Kong is included in the system ecology part of the study.

*This study known as the Hong Kong Human Ecology Programme is co-ordinated by the Urban Biology Group at the Australian National University and field work is based in the Centre of Asian Studies, University of Hong Kong and Chinese University of Hong Kong and has been assisted by the Hong Kong Government. Details of the programme can be obtained from the Director, Dr S.V. Boyden.
Hong Kong offers an advantage over other urban settlements in that it is a metropolis with an international political boundary which allows quantification of the interchange between Hong Kong and the surrounding regional and global networks of supply of energy and materials which enable it to survive. It also offers the unique opportunity to study the human condition in the highest physical densities that the species has experienced and therefore to examine what, if any, adaptive role has been played by the deployment of particular forms of energy in particular ways.

Throughout this study of energy use in Hong Kong it has been found useful to describe energy as either somatic or extrasomatic.* Only extrasomatic energy is discussed in the present paper in which the term ‘energy’ henceforth denotes extrasomatic energy.

This paper is concerned with an overview of energy use in Hong Kong. A more detailed description of energy use in the various economic sectors of consumption is presented in an associated paper, (Newcombe, 1975).

EXPLANATORY NOTES

Hong Kong had a population of 3,939,000, including 78,000 boat people, in 1971. The population is growing at about 2.2% per annum. The land area of Hong Kong is 1,046 km². There are 253 islands, the larger ones being Hong Kong Island, Lantau Island, Lamma Island and Cheung Chau Island. The sea area of Hong Kong is 1,823 km². (For additional detail see Fig.1).

Data gathering in the present study has proceeded in an environment where sources of information are either highly compartmentalised or specialised. Government energy statistics mostly relate to trade, dutiable goods and local production. During late 1973 and early 1974, the ‘oil crisis’ period, a Department of Oil Supplies was set up to examine energy use in greater detail. This Department has since been dissolved. Useful data was obtained through its activities but since its research objectives were limited and quite different from those of our study, the data compatibility was not high.

Most of the relevant data was obtained through contact with government departments carrying out energy related or energy intensive functions, oil companies, private industry and commerce and through field observations. It is hoped that the error in estimations will be no greater than 10%. In many cases 100% accuracy was obtainable where energy use was a matter of record; however, many areas were open to careful assumption and estimation with cross checking. Wherever necessary, footnotes recall precise sources of information when tabulated information is presented.

The units of energy used are joules. (Most commonly ‘megajoules x 10⁸’ or

---

*Somatic energy: “that energy which is utilised, through the metabolic processes, within a living organism”. Extrasomatic energy: “that energy which flows through or is utilised by a human community and which is not utilised through metabolic processes with a living organism”. In this research ‘extrasomatic energy’ only includes fuels in current use.
MJ x 10^8 is the magnitude necessary to conveniently describe the local energy system.) For converting from one unit to another the following values were used:

1 MJ = 10^6 J = 947.82 BTU = 238.85 kcal = 0.2778 kWh.

A list of conversion factors applicable in the region has also been compiled (see Appendix I).

Local terminology for fuels has been adopted. To avoid confusion, motor spirit or mogas is gasoline for motorised vehicles, ‘avturb’ is aviation turbine fuel, ‘avgas’ is aviation gasoline. The ‘gas oils, diesel fuels and distillate fuels’ are a range of middle weight fuels. Diesel fuel is locally designated as ‘medium’ and ‘heavy’ and is more viscous than gasoil.

Gasoils are designated ‘automotive gasoil’ (A.G.O.) when used for road vehicles and ‘industrial gasoil’ (I.G.O.) when used for industrial, commercial purposes and for marine transport. This compartmentalisation has been convenient for preliminary analysis of end-use. These fuels are lumped together and the category will be referred to as ‘gasoils and diesel fuels’. Town gas and electricity are generated from fuel oils and gasoils. Fuel oils and gasoils will be referred to, in this paper, as ‘primary energy’. This distinction recognises
the unusual feature in Hong Kong of generating electricity and town gas solely from already refined fuels.

Classification of local industrial and commercial activities has been adhered to, but has sometimes created difficulty. For instance, it is difficult to separate basic metal products from glass manufacture, ceramics and so on. Similarly, textiles includes manufacture of wearing apparel. Such cases are clearly referred to in the text or are otherwise made obvious.

GLOBAL AND REGIONAL PERSPECTIVE

Hong Kong is a member of the Far East region according to United Nations (1971) classification (see Table I). Within the region it has the second highest per capita energy consumption after Japan. Hong Kong's per capita consumption is three times greater than that of the so-called developing countries and half that of the world as a whole. Hong Kong is experiencing a rapid growth in energy consumption. The annual growth rate over the 17-year period, 1954—1971 was 4.6%, and over the 7-year period, 1964—1971 was 8.9% per annum. According to United Nations (1973) data, the world consumption of energy was increasing at 3.4% per annum, the United States consumption at 2.7% and Australia at 2.5% per annum during the same period. Within the region Hong Kong's growth parallels that of Korea and Japan, each with 9% increase per annum, and it is significantly greater than the regional average annual increase in energy consumption of 6.5%.

Hong Kong is totally dependent on outside sources of energy for its needs. As a non-producer it must bargain for energy on the world market. Fig.2 shows the major sources of energy for Hong Kong in 1971. The major suppliers of energy were the Middle East countries of Bahrain, Kuwait, Iran and Saudi Arabia together contributing nearly half of the total requirements. Singapore supplies the bulk of the remainder, with the Philippines, the only other sizable supplier, providing more than 4% of the total. Table II lists the respective exporters of fuel to Hong Kong by fuel type. Within the region the only producer of significance which supplies Hong Kong is Indonesia, and its exports to Hong Kong are comparatively minor. Thus, the majority of fuels coming to Hong Kong from within the region are originally from the Middle East, passing to Singapore, Japan, the Philippines and South Korea for refining in the first instance. Hong Kong is, of course, as much dependent on the Middle East for fuel supplies as are these, since in a fuel crisis the proximity of the regional suppliers does not assure continued supplies.

The Hong Kong Government is considering the development of a refinery—petrochemical complex, ostensibly to increase the stability of its energy supplies. This development will not alter Hong Kong’s dependency on petroleum products from the Middle East.
### TABLE I

Global and regional comparison of energy consumption with Hong Kong, 1971

<table>
<thead>
<tr>
<th>Place</th>
<th>MJ $\times 10^1$ per capita¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>59</td>
</tr>
<tr>
<td>Developed countries**</td>
<td>183</td>
</tr>
<tr>
<td>Developing countries***</td>
<td>11</td>
</tr>
<tr>
<td>United States</td>
<td>342</td>
</tr>
<tr>
<td>Australia</td>
<td>166</td>
</tr>
<tr>
<td>Far East, average*</td>
<td>15</td>
</tr>
<tr>
<td>Japan</td>
<td>99</td>
</tr>
<tr>
<td>Singapore</td>
<td>26</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>31¹</td>
</tr>
<tr>
<td>Korea</td>
<td>26</td>
</tr>
<tr>
<td>Malaysia</td>
<td>14</td>
</tr>
<tr>
<td>Philippines</td>
<td>9</td>
</tr>
<tr>
<td>Thailand</td>
<td>10</td>
</tr>
<tr>
<td>China</td>
<td>17</td>
</tr>
<tr>
<td>Macau</td>
<td>9</td>
</tr>
<tr>
<td>Vietnam Republic</td>
<td>10</td>
</tr>
<tr>
<td>India</td>
<td>6</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4</td>
</tr>
<tr>
<td>Burma</td>
<td>2</td>
</tr>
<tr>
<td>Khmer Republic</td>
<td>0.7</td>
</tr>
<tr>
<td>Nepal</td>
<td>0.3</td>
</tr>
</tbody>
</table>

¹Far East includes Japan, Ryukyu Island, Afghanistan, Brunei, Burma, Khmer Republic, Sri Lanka, Hong Kong, India, Indonesia, West Iran, Korean Republic, Laos, Macau, West Malaysia, Sabah, Sarawak, Nepal, Pakistan, Philippines, Portuguese Timor, Singapore, Thailand, Vietnamese Republic.

The Developed Market economies of Australia, Canada, Israel, Japan, New Zealand, South Africa, United States and West Europe (inc. Yugoslavia).

The Developing Market economies of Africa, Caribbean America, North America, other America, Middle East (inc. Turkey), Far East and Oceania.

¹Data derived from 'World Energy Supplies' 1968—1971, Statistical Papers series J, No. 16, United Nations, 1973. 1 kg of coal equivalent has been taken as roughly 30.59 MJ.

²Per capita figure for Hong Kong 1971 arrived at independently is 31.5 compared with 31.09. This difference of 1.3% is probably due to differences in conversion factors in use.

### LOCAL ENERGY CONFIGURATION

Table II shows the various energy forms which are imported and retained in Hong Kong, discounting bunker fuels and exports. The data presented in the table differs slightly from the import statistics provided by the trade section of the Hong Kong Census and Statistics Department. It is more accurate to obtain figures of actual use in Hong Kong. These are provided by figures for fuels released from bond which are recorded on a monthly basis for excise purposes. Table III is an analysis of energy used in 1971 by amount and percentage of the total energy consumption.
Table IV is the energy matrix for 1971 showing a division of end-use by sectors. It includes the total amount of energy passing through Hong Kong in that year in bunker fuels and exports, as well as the fuels actually used in Hong Kong, and details the conversion of primary energy to secondary energy in the form of town gas and electricity. The amounts actually sold to consumers of these forms of secondary energy are specified in brackets and do not figure in the first balance presented by the matrix. Sources for the information used to compile the matrix, which is the basis of much of the data presentation throughout the paper, are listed as footnotes.
The figures in Table III show clearly that gasoils and fuel oils make up more than 85% of the total energy use, excluding bunkers and exports, comprising 64 and 21.5% respectively. Of considerably less importance in proportion are kerosenes, 6.2%, motor spirits, 4.2% and liquefied petroleum gas, 1.8%. Total solid fuels provide no more than 2% of the total consumption, even given a generous estimate, using Trade Statistics (1972) of firewood consumed which is locally grown or scavenged as scrap building timber. Fig.3 is a diagrammatic representation of the energy matrix in flow chart form. It shows clearly the high proportion of transport energy which is essentially a direct throughput in the system as overseas bunkers, and highlights other significant features of the local energy flow, such as the loss of primary energy in conversion to town gas and electricity. The comparative volume of use by each sector is readily seen, and will be discussed in more detail elsewhere. (Newcombe, 1975).

Table V presents a further breakdown for fuel oil use for 1971. Fuel oil is the major energy form used to generate electricity; of the locally used fuel oil, 81% is used in this manner. Fuel oil is used mainly to fire pressure generating equipment and only relatively small amounts are used by direct combustion such as in the iron, steel and basic metals industries, or in the assisted incineration of refuse for the Urban Services Department of Government. Apart from fuel oil used to generate electricity, most is used in industry, comprising 14.9% of the total — the remainder being made up of 1.5% for commercial and about 2.3% for gas production. Other very minor end-uses include local marine transport for tugs and salvage vessels. The textile industry uses 73% of all fuel oil used industrially and about 11% of all fuel oil consumption in Hong Kong.

Table VI shows an analysis of the end-use of gasoil, diesel fuel and distillates. Transport use accounts for 60.2% of the total of this category of fuels. A detailed analysis of gasoil use accompanies a description of energy use in transport in Newcombe (1975). Outside of transport use, 21.2% is used commercially, 8.3% industrially, 5.1% is exported and 2.9% is used for power generation. The function of this category of fuel in power generation is as an auxiliary fuel, except in the case of Cheung Chau Electric Company which uses diesel fuel exclusively. However, the company used less than 1 500 tonnes of diesel oil in 1971 (R.J. Purves, personal communication, 1974).

Restaurants are the largest commercial users of diesel fuels, consuming about 63% of total commercial diesel and about 19% of all gasoil and diesel fuel consumption. Diesel fuel for restaurants is pressurised sufficiently to provide a fine spray at the point of combustion giving an open flame for cooking purposes.

POWER GENERATION IN HONG KONG

As the conversion of primary to secondary energy is significant both as a user of primary fuels and as a major loss of energy in the energy flow system, it is worth examining the secondary fuels in further detail. Table VII shows
TABLE II

Imports to Hong Kong of petroleum products by country 1971 (MJ x 10^4)

<table>
<thead>
<tr>
<th>Country exporting Fuel type</th>
<th>Middle East (Bahrain, Kuwait, Iran and Saudi Arabia)</th>
<th>Singapore</th>
<th>Taiwan</th>
<th>Philippines</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviotion spirit</td>
<td>0.76</td>
<td>0.65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor spirit</td>
<td>26.29</td>
<td>28.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerosene</td>
<td>43.79</td>
<td>28.87</td>
<td>6.62</td>
<td>3.0</td>
<td>17.29</td>
</tr>
<tr>
<td>Aviation Turbine Fuel</td>
<td>97.11</td>
<td>107.72</td>
<td></td>
<td>5.53</td>
<td></td>
</tr>
<tr>
<td>Gasoils, Diesel and distillate fuel</td>
<td>128.42</td>
<td>116.82</td>
<td>16.12</td>
<td>59.98</td>
<td>9.18</td>
</tr>
<tr>
<td>Fuel oils</td>
<td>586.65</td>
<td>463.01</td>
<td></td>
<td>7.17</td>
<td></td>
</tr>
<tr>
<td>Liquefied petroleum gas</td>
<td>12.42</td>
<td></td>
<td>0.57</td>
<td></td>
<td>3.32</td>
</tr>
<tr>
<td>TOTALS</td>
<td>883.02</td>
<td>756.33</td>
<td>22.74</td>
<td>76.25</td>
<td>29.79</td>
</tr>
<tr>
<td>PERCENTAGES</td>
<td>49.34</td>
<td>42.26</td>
<td>1.27</td>
<td>4.26</td>
<td>1.66</td>
</tr>
</tbody>
</table>

*Note that this figure of imports in 1971 does not correspond with actual consumption in 1971 as given in Table IV.

Source: Trade Statistics, Imports, December 1971, Census and Statistics Department, Hong Kong.

TABLE III

Configuration of fuels actually used in Hong Kong, 1971 (excluding bunker fuels and exports)

<table>
<thead>
<tr>
<th>Energy type</th>
<th>MJ x 10^4</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td>4.49</td>
<td>0.4</td>
</tr>
<tr>
<td>Charcoal</td>
<td>7.83</td>
<td>0.6</td>
</tr>
<tr>
<td>Coke</td>
<td>2.62</td>
<td>0.2</td>
</tr>
<tr>
<td>Coal</td>
<td>9.30</td>
<td>0.7</td>
</tr>
<tr>
<td>Motor Spirit</td>
<td>51.76</td>
<td>4.2</td>
</tr>
<tr>
<td>Kerosene</td>
<td>77.60</td>
<td>6.2</td>
</tr>
<tr>
<td>Aviation turbine fuel</td>
<td>2.41</td>
<td>0.2</td>
</tr>
<tr>
<td>Aviation spirit</td>
<td>0.21</td>
<td>*</td>
</tr>
<tr>
<td>Gasoils, diesel oil and distillate fuel</td>
<td>267.66</td>
<td>21.5</td>
</tr>
<tr>
<td>Fuel oils</td>
<td>800.69</td>
<td>64.2</td>
</tr>
<tr>
<td>Liquefied petroleum gas</td>
<td>22.20</td>
<td>1.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1 246.77</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*less than 0.05%.

Source: Derived from Table IV.
the characteristics of the conversion processes. In electricity generation
$468.03 \times 10^8$ MJ is lost at the site of production and $13.1 \times 10^8$ MJ is lost in reticulation. This gives a thermal efficiency of 29.22% and transmission losses on that sent out of 7.27% which includes in-plant transmission losses.

For gas production, $8.61 \times 10^8$ MJ is lost at the point of production and $0.55 \times 10^8$ MJ in transmission. This represents a thermal efficiency of 55.50% and a transmission loss of 4.88% (J. Murphy, Hong Kong and China Gas Company, personal communication, 1973). By 1974 the electricity production in Hong Kong had attained thermal efficiencies of 33%, while the thermal efficiency of gas production had increased very considerably to over 80%, largely as a result of switching from a fuel oil to a naphtha feedstock.

END-USE OF ELECTRICITY AND GAS

Table VIII provides an analysis of the sector by sector end-use of electricity. Although there is little difference, electricity is first an industrial fuel and then a commercial fuel with 40.5 and 35.1% of total use respectively. Domestic consumption is still significant at 23.7% of the total, while transport consumption is negligible.

Table VIII also shows a similar analysis for gas consumption and reveals
### TABLE IV

**Energy Matrix — Hong Kong, 1971 (MJ x 10^4)**

<table>
<thead>
<tr>
<th>Fuel item</th>
<th>Domestic</th>
<th>Commercial</th>
<th>Industrial</th>
<th>Local transport</th>
<th>Bankers</th>
<th>Export</th>
<th>Total(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td>4.49</td>
<td>4.49</td>
<td>4.49</td>
<td>4.49</td>
<td></td>
<td></td>
<td>137.93</td>
</tr>
<tr>
<td>Charcoal</td>
<td>3.91</td>
<td>3.13</td>
<td>0.79</td>
<td>7.83</td>
<td></td>
<td></td>
<td>4.90</td>
</tr>
<tr>
<td>Coke</td>
<td>1.31</td>
<td>1.31</td>
<td>1.31</td>
<td>2.62</td>
<td></td>
<td></td>
<td>7.83</td>
</tr>
<tr>
<td>Coal</td>
<td>0.46</td>
<td>8.84</td>
<td>0.10</td>
<td>0.40</td>
<td></td>
<td></td>
<td>4.00</td>
</tr>
<tr>
<td>Motor spirit</td>
<td></td>
<td></td>
<td></td>
<td>51.76</td>
<td></td>
<td>197.73</td>
<td>51.76</td>
</tr>
<tr>
<td>Kerosene</td>
<td>64.60</td>
<td>12.38</td>
<td>6.22</td>
<td>80.51</td>
<td></td>
<td></td>
<td>80.51</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>11.14</td>
<td>118.70</td>
<td>270.04</td>
<td>401.79</td>
<td></td>
<td></td>
<td>401.79</td>
</tr>
<tr>
<td>Liquefied petroleum gas</td>
<td>18.74</td>
<td>4.13</td>
<td>118.70</td>
<td>180.12</td>
<td></td>
<td>401.79</td>
<td></td>
</tr>
<tr>
<td>Electricity (f.o.e. and d.o.e.)</td>
<td>157.38</td>
<td>234.70</td>
<td>216.17</td>
<td>652.61 (f.o.e.)</td>
<td></td>
<td>18.24 (f.o.e.</td>
<td>119.46</td>
</tr>
<tr>
<td>Electricity sold</td>
<td>22.20</td>
<td>0.56</td>
<td>401.79</td>
<td>1.11 (d.o.e.)</td>
<td></td>
<td>119.46</td>
<td></td>
</tr>
<tr>
<td>Town gas (f.o.e. and d.o.e.)</td>
<td>10.27</td>
<td>7.32</td>
<td>1.76</td>
<td>119.46</td>
<td></td>
<td>119.46</td>
<td></td>
</tr>
<tr>
<td>Town gas sold</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>119.46</td>
<td></td>
<td>119.46</td>
<td></td>
</tr>
<tr>
<td>TOTAL including conversion losses</td>
<td>257.39</td>
<td>244.08</td>
<td>427.73</td>
<td>1779.42</td>
<td></td>
<td>1779.42</td>
<td></td>
</tr>
<tr>
<td>Subtracting conversion losses</td>
<td>119.46</td>
<td>174.18</td>
<td>195.19</td>
<td>490.29</td>
<td></td>
<td>490.29</td>
<td></td>
</tr>
<tr>
<td>Total end-use</td>
<td>137.93</td>
<td>169.9</td>
<td>232.54</td>
<td>231.11</td>
<td></td>
<td>231.11</td>
<td></td>
</tr>
</tbody>
</table>

**Sources:**

A.J.S. Lack and R.J. Purves, Department of Oil Supplies, personal communication, 1974.


Hong Kong Monthly Digest of Statistics, 'Releases from bond Tables', January to December 1971, and January 1972, Hong Kong.

D. Newbury and F. Chan, Air Pollution Control Unit, Public Works Department, personal communication, 1974.

Mr Läufer, China Light and Power Co., personal communication, 1974.


Additional sources of information as listed under tables referring to the analysis of Industrial, Commercial and Transport Sectors (see Tables V, VI and Newcombe, 1975, Table V).

f.o.e. = fuel oil equivalent, d.o.e. = diesel oil equivalent.

Charcoal, coke and coal totals came from import data; firewood is the addition of import data and 2.5% of conifer logs imports to compensate for scavenging of scrap bunker and unaccounted local production; petroleum based fuels are from 'Releases from Bond' data rather than imports since the former gives a more accurate representation of actual use in 1971, with the exception of gasoils, diesel fuel and distillates where investigation produced greater confidence in Shell Co. data on usage in 1971.
Fig. 3. Extraneous energy flow chart: Hong Kong, 1971 (units are Mil x 10^9).

INPUT

PETROLEUM PRODUCTS

WOOD & SAWMILL

COAL

NUCLEAR POWER PLANT

EXPORTS

TOWN GAS

ELECTRICITY

INDUSTRIAL

COMMERCIAL

DOMESTIC

TRANSPORT

OVERSEAS SHIPMENTS

END USE

87
<table>
<thead>
<tr>
<th>TABLE V</th>
</tr>
</thead>
<tbody>
<tr>
<td>End use of fuel oil — Hong Kong 1971</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power generation:</th>
<th>MJ x 10^6</th>
<th>% of that used in Hong Kong</th>
<th>% of throughput for Hong Kong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity(a))</td>
<td>652.61</td>
<td>81.4</td>
<td>60.8</td>
</tr>
<tr>
<td>Town gas(b))</td>
<td>18.24</td>
<td>2.3</td>
<td>1.7</td>
</tr>
</tbody>
</table>

**Industrial:** \(c)\

<table>
<thead>
<tr>
<th></th>
<th>MJ x 10^6</th>
<th>% of that used in Hong Kong</th>
<th>% of throughput for Hong Kong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textiles</td>
<td>86.32</td>
<td>10.8</td>
<td>8.0</td>
</tr>
<tr>
<td>Clothing (wigs and shoes only)</td>
<td>1.54</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Food and drink</td>
<td>10.59</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Chemicals and paints</td>
<td>1.38</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Metals, glass and related products</td>
<td>4.26</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Rubber and plastics including toys</td>
<td>1.50</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Engineering and dockyards</td>
<td>0.69</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>3.80</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Paper and printing</td>
<td>0.46</td>
<td>0.1</td>
<td>*</td>
</tr>
<tr>
<td>Woodworks and tanneries</td>
<td>0.31</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Construction</td>
<td>2.53</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Miscellaneous and unaccounted</td>
<td>5.32</td>
<td>0.7</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**Industrial sub-total** | 118.70 | 14.9 | 10.9

**Commercial:** \(c)\

<table>
<thead>
<tr>
<th></th>
<th>MJ x 10^6</th>
<th>% of that used in Hong Kong</th>
<th>% of throughput for Hong Kong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam laundry and dry cleaning</td>
<td>1.38</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Hotels and restaurants</td>
<td>3.11</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Hospitals</td>
<td>1.61</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Government</td>
<td>3.48</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Armed services</td>
<td>0.50</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Educational institutions</td>
<td>0.55</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Miscellaneous and unaccounted</td>
<td>0.51</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Commercial sub-total** | 11.14 | 1.5 | 1.2

**Transport:** \(d)\

<table>
<thead>
<tr>
<th></th>
<th>MJ x 10^6</th>
<th>% of that used in Hong Kong</th>
<th>% of throughput for Hong Kong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local marine</td>
<td>0.56</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Sub-Total** | 801.25 | 100.0 |

**Export**\(e)\) | 1.35 | 0.1 |

**Bunkers**\(d)\) | 270.04 | 26.2 |

**TOTAL** | 1072.64 | 100.0 |

*less than 0.05%.

\(a\)Hong Kong Electric Co., China Light and Power Co., personal communication, 1974 and Department of Census and Statistics, monthly digests, 1971, Hong Kong Government Printer.

\(b\)Hong Kong and China Gas Co., personal communication, 1974.

\(c\)The following documents and sources of information were used to compile and crosscheck industrial fuel oil consumption: 'Air Pollution Control Unit, Public Works Department; point sources of fuel consumption and emission; Pressure Equipment Unit, Labour Depart-
ment; records of ownership and size of pressure equipment; Department of Oil Supplies; 'Sales of Oil in Hong Kong — sales patterns by main sectors and products' document reference CR/OS 601, and 'Estimated oil consumption by manufacturing industry 1973' Enclosure 4 of Department of Oil Supplies, Hong Kong; Taikoo Sugar Refinery; Shiu Wing Steel Company; Sales Department, Shell Company, Hong Kong.

d) H.K. Yip, Trade Research, Census and Statistics Department, Hong Kong, personal communication, 1974.


TABLE VI

End use of gasoils, diesel oil and distillate fuel — Hong Kong 1971

<table>
<thead>
<tr>
<th>End use</th>
<th>MJ's x 10^8</th>
<th>% of that used in Hong Kong</th>
<th>% of throughput for Hong Kong</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power generation:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity(^a)</td>
<td>8.64</td>
<td>3.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Town gas(^b)</td>
<td>1.11</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Industrial:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction sites</td>
<td>11.29</td>
<td>4.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Water pumping</td>
<td>1.65</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Textiles</td>
<td>7.60</td>
<td>2.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Food and drink</td>
<td>2.70</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Metals, glass and related products</td>
<td>1.50</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Rubber and plastics including toys</td>
<td>1.00</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Chemicals and paints</td>
<td>0.60</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Electrical and mechanical (e.g. watches and electrical appliances)</td>
<td>0.30</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Clothing (as shoes and wigs only)</td>
<td>0.10</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>0.05</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Farming</td>
<td>0.44</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Industrial sub-total</strong></td>
<td>27.23</td>
<td>10.1</td>
<td>8.3</td>
</tr>
<tr>
<td><strong>Commercial:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotels and restaurants</td>
<td>62.90</td>
<td>23.5</td>
<td>19.2</td>
</tr>
<tr>
<td>Hospitals</td>
<td>1.10</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Educational institutions</td>
<td>0.10</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Steam laundry and dry cleaning</td>
<td>2.50</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Armed services</td>
<td>2.80</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Government</td>
<td>0.11</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Commercial sub-total</strong></td>
<td>69.51</td>
<td>25.9</td>
<td>21.2</td>
</tr>
<tr>
<td><strong>Local Transport:</strong></td>
<td>161.17</td>
<td>60.2</td>
<td>49.3</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>267.66</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Export(^d)</td>
<td>16.79</td>
<td></td>
<td>5.1</td>
</tr>
<tr>
<td>Bunkers</td>
<td>42.57</td>
<td></td>
<td>13.0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>327.02</td>
<td></td>
<td>100.0%</td>
</tr>
</tbody>
</table>
*less than 0.05%.

a) Shell Company, Hong Kong, personal communication, 1974.
b) Hong Kong and China Gas Co., personal communication, 1974.
c) The following documents and sources of information were used to compile and crosscheck industrial gasoil consumption: Point sources of fuel use and emission data, Air Pollution Control Unit, Public Works Department, Hong Kong; 'Sales of Oil in Hong Kong — sales patterns by main sectors and products' document reference CR/OS 601, and 'Estimated oil consumption by manufacturing industry 1973'. Enclosure 4 of Department of Oil Supplies, Hong Kong; Waterworks Office, Public Works Department re-water pumping; Agriculture and Fisheries Department re farming, and re pattern of Iron and Steel fuel use; Shiu Wing Steel Company, Hong Kong.
d) as in c) and, Hong Kong and Kowloon Restaurant Association; District Offices of Urban Services Department, Hong Kong; 20 cooked food stalls, light refreshment restaurants and tea houses in Wanchai district, Hong Kong; 'Hoi Tin' Ocean Terminal restaurant proprietors.
e) monthly digests of Statistics, January—December 1971, January 1972, Hong Kong Government Printer and H.K. Yip, Trade Research Section, Census and Statistics Department, Hong Kong. For a detailed analysis see Newcombe, 1975, Tables V and VI.

**TABLE VII**

<table>
<thead>
<tr>
<th>Characteristics of primary to secondary fuel transformation in Hong Kong: 1971</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel item inputs</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Diesel Oil</td>
</tr>
<tr>
<td>Fuel Oil</td>
</tr>
<tr>
<td>Overalla)</td>
</tr>
<tr>
<td>Actually used</td>
</tr>
<tr>
<td>Losses</td>
</tr>
<tr>
<td>Thermal efficiency:</td>
</tr>
<tr>
<td>Transmission loss of sent out:</td>
</tr>
</tbody>
</table>

a) Excludes inputs of electricity and recycling of by-products of the generating processes.
b) As a result of more sophisticated equipment thermal efficiencies of up to 33% are now being obtained by Hong Kong power companies.
c) Lower than usual in 1971. A thermal efficiency of over 60% was obtained by Hong Kong and China Gas by including for production, recycling and sales in the thermal efficiency calculation. In 1974 conversion to Naptha as a feedstock was completed with overall efficiencies exceeding 80%.

that gas use is greatest in the domestic sector where 53% of total consumption takes place. Secondly, it is a commercial fuel being used largely in hotels and to a limited extent in restaurants for cooking and water heating. Thirdly, and minimally, it is an industrial fuel accounting for 9% of the total consumption, being used mainly for textiles and paper production. Gas represents only 5.4% of the total energy value of gas and electricity production.
TABLE VIII

Electricity production and sector end-use in Hong Kong: 1971

<table>
<thead>
<tr>
<th>Sector end-use</th>
<th>Energy use (MJ x 10^4)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>42.78</td>
<td>23.7</td>
</tr>
<tr>
<td>Commercial</td>
<td>63.22</td>
<td>35.1</td>
</tr>
<tr>
<td>Industrial</td>
<td>72.99</td>
<td>40.5</td>
</tr>
<tr>
<td>Transport</td>
<td>0.56</td>
<td>0.3</td>
</tr>
<tr>
<td>Street lighting</td>
<td>0.77</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>180.12</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Town Gas production and sector end-use in Hong Kong: 1971

<table>
<thead>
<tr>
<th>Sector end-use</th>
<th>Energy use (MJ x 10^4)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>5.41</td>
<td>53.1</td>
</tr>
<tr>
<td>Commercial</td>
<td>3.85</td>
<td>37.8</td>
</tr>
<tr>
<td>Industrial</td>
<td>0.93</td>
<td>9.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10.19</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>


LOSSES OF ENERGY

Losses of energy can be considered in the following terms:

1. conversion losses in the generation of electricity and town gas,
2. inefficient use of energy in, for example, industrial processes,
3. losses of energy caused by the inability of an appliance to convert into useful work, all the energy made available for its operation.

Conversion and transmission losses in Hong Kong amount to 39% of total energy use, compared with 15.8% in the United States (Summers, 1971).

The U.S. data includes losses through such non-energy uses as in the manufacture of lubricants and the conversion of coal to coke, however hydro-power and the more efficient use of a range of fossil fuel feedstocks contributes to lower overall conversion losses.

It is also difficult to make a valid comparison between a country with refining capacity and one without such capacity. Nevertheless, even given these difficulties, it is clear from the data that Hong Kong loses a substantial and comparatively large amount of its energy inputs through conversion and transmission losses. Calculations have not been made to estimate the total loss of energy by inefficient end-use in each sector in addition to conversion and transmission losses. Such a calculation for the United States in 1970 estimates a 60% total loss after excluding exports (Cook, 1971).
A further aspect of losses in conversion is the potential environmental impact of large amounts of artificial heat generated within the urban area, as is the case in Hong Kong. Table IX shows the location of major point losses, including those from the incineration of refuse in the urban area, which are considerable. The spatial and temporal distribution of artificial heat over all of Hong Kong has been calculated in complementary research in the Hong Kong Ecology Programme by Kalma and Newcombe (1975). It can be said here that losses from power generating stations in Hong Kong add significantly both to the urban heat load and to air pollution in the urban area and further, that energy use per unit area in Hong Kong, for some highly populous regions of the urban area is two times that previously recorded in any Western industrialised city. In all, $481.13 \times 10^8$ MJ was lost from four point sources of electricity production, and $18.95 \times 10^8$ MJ from urban incinerators in 1971. The incinerators make use of the heat produced in combustion to generate, on average 67% of their electricity requirements. On other occasions when they produce more than their own operating requirements they power other utilities, such as abattoirs and workshops. (G. Rowlands, personal communication, 1974).

**TABLE IX**

Major point losses, Hong Kong 1971*

<table>
<thead>
<tr>
<th>Location</th>
<th>Source</th>
<th>Amount (MJ $\times 10^8$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hung Hom Kowloon</td>
<td>Hok Un Electric Power Plant</td>
<td>182.20</td>
</tr>
<tr>
<td></td>
<td>Tokwawan Gas Plant</td>
<td></td>
</tr>
<tr>
<td>Lai Chi Kok New Kowloon</td>
<td>Urban Services, Lai Chi Kok Incinerators</td>
<td>9.26</td>
</tr>
<tr>
<td>Tsing Yi Island New Territories</td>
<td>Tsing Yi Power Plant</td>
<td>154.08</td>
</tr>
<tr>
<td>Kennedy Town West Hong Kong Island</td>
<td>Urban Services, Kennedy Town Incinerators</td>
<td>9.69</td>
</tr>
<tr>
<td>North Point Hong Kong Island</td>
<td>North Point Electric Power Plant</td>
<td>46.80</td>
</tr>
</tbody>
</table>

*Transmission losses of $13.60 \times 10^8$ MJ have not been included, thereby accounting for the discrepancy between Table VII and the above power generating point losses.

Source: Personal communication with:
(a) Air Pollution Control Unit, Labour Department, 1974.
(b) Chief Health Inspectors, Urban Services Department, 1974.
(c) Chief Electrical and Mechanical Engineers, Public Works Department, 1974.
The inefficient use of energy at the point of utilisation, particularly in industrial processes, has been noted by Berg (1974) and Lincoln (1973) who have shown that an increased energy consciousness can effect quick and significant saving to the benefit of industry and society. During the 'energy crisis' in Hong Kong, Labour Department engineers examined the energy efficiency of the operation of a large textile dyeing, bleaching and printing factory. The factory had been recommended to the engineers as one operating at reasonable efficiency in fuel and steam usage. They estimated conservatively that the factory could be operated on 20% less fuel with little additional cost (Air Pollution Control Unit, 1974). This example provides a basis for estimating the considerable energy savings that could result from an enhanced awareness of energy utilisation locally.

TRENDS AND ALTERNATIVES IN ENERGY USE

McHale (1971) has shown that in the world as a whole, in 1850 wood made up 42% of total energy use, coal 27%, dung 8% and muscle energy 17%. By 1900, coal had a 46% share of total consumption, wood had declined to 33% and dung and muscle to 10 and 9% respectively. Oil contributed 2% of total consumption in 1900. Significantly, solid fuels were still the vast majority of the fuel energy consumption at that time. By 1950 coal consumption had increased to 54%, wood was reduced to 9% and oil had increased to about 30% of total consumption. In 1950 the relative consumption of dung and muscle energy against other fuels had declined to insignificance from a global perspective.

Darmstadter et al.'s (1971) research on trends in energy consumption in the world between 1925 and 1965 provide statistics which can be compared with Hong Kong trends and their findings tend to support the more generalised data presented above. It is shown that in 1950 solid fuels formed 61% of the world energy consumption and liquid fuels 27.7%. (The consideration of natural gas and hydroelectricity is not applicable to Hong Kong discussions.)

By 1968 the world consumption of solid fuels had fallen below total liquid fuel consumption, the latter forming 42.8% and the former 36.7% of the total.

Within the region, considering Asia without Japan which holds considerable coal reserves, solid fuels were 57% of the configuration in 1950 and 39.6% in 1965. Similarly, liquid fuels were 39% in 1950 and 50.2% in 1965.

Table X shows the trends in Hong Kong fuel consumption by type of fuel over the period 1954 to 1971. In Fig.4 these trends are presented on a log scale. In 1954 solid fuels made up nearly 30% of consumption and liquid fuels 70%. By 1971 solid fuels were virtually insignificant constituting only 1.9% of the total, while liquid fuels form 98.1%. The major shift in solid fuel use came about though the fall in use of firewood and coal. The decline of the domestic fuel firewood seems to have been inversely proportional to the growth of the resettled or rehoused section of the urban population. It is reported by the Commissioner for Resettlement (1971) that the high density
TABLE X

Trends in consumption of energy by energy form, Hong Kong 1954—1971 (MJ × 10^4)

<table>
<thead>
<tr>
<th>Selected years</th>
<th>1954 % of total</th>
<th>1957 % of total</th>
<th>1961 % of total</th>
<th>1961 % of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954—1971</td>
<td>29.00</td>
<td>8.6</td>
<td>8.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Firewood</td>
<td>13.10</td>
<td>3.9</td>
<td>3.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Charcoal</td>
<td>0.48</td>
<td>0.1</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Coke</td>
<td>58.10</td>
<td>17.2</td>
<td>16.3</td>
<td>13.5</td>
</tr>
<tr>
<td>Coal</td>
<td>58.10</td>
<td>17.2</td>
<td>16.3</td>
<td>13.5</td>
</tr>
<tr>
<td>SOLID FUEL</td>
<td>100.68</td>
<td>29.8</td>
<td>28.3</td>
<td>20.4</td>
</tr>
<tr>
<td>SUB-TOTAL</td>
<td>100.68</td>
<td>29.8</td>
<td>28.3</td>
<td>20.4</td>
</tr>
<tr>
<td>Motor spirit</td>
<td>21.55</td>
<td>6.4</td>
<td>4.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Kerosene</td>
<td>15.61</td>
<td>4.6</td>
<td>5.4</td>
<td>9.8</td>
</tr>
<tr>
<td>Gas oils, diesel fuels</td>
<td>36.8</td>
<td>10.9</td>
<td>46.80</td>
<td>10.7</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>163.4</td>
<td>48.3</td>
<td>50.7</td>
<td>52.2</td>
</tr>
<tr>
<td>LIQUEFIED FUELS</td>
<td>100.68</td>
<td>29.8</td>
<td>28.3</td>
<td>20.4</td>
</tr>
<tr>
<td>SUB-TOTAL</td>
<td>237.36</td>
<td>70.2</td>
<td>71.7</td>
<td>79.6</td>
</tr>
<tr>
<td>OVERALL TOTAL</td>
<td>338.04</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Figure represents imports of firewood is opposed to adjusted figure in Table IV. The import figure has been used for comparison with previous years unadjusted figures.

Source: H.K. Yip, Trade Research Section, Census and Statistics Department, personal communication, 1974.

housing environments grew rapidly from 1954, thereby placing a restriction on the use of smoky and voluminous fuels.

Coal was dispensed with as a primary fuel in two steps: first with the change to fuel oil for electricity generation and then with the shift away from coal to fuel oil for gas generation between 1958 and 1968.

Charcoal has also declined because of the switch in restaurant and domestic cooking use to the more clean and efficient liquid and gaseous fuels. Charcoal remains important, however, in the preparation of roast meats and the brewing of Chinese medicines. Coke has actually increased slightly in volume over the period, while remaining a small percentage of total consumption. Its use as a smokeless fuel for restaurants and as a smelting fuel maintains its popularity.

Of the liquid fuels, gasoils and diesel fuels are the most rapidly increasing in volume. Their widespread use for transport and in restaurants has ensured a growth in their consumption in line with the respective demands for those services. Motor spirit has increased steadily in absolute terms but has declined relative to the total fuel consumption. A report on Air Pollution in Hong Kong
(1969) made recommendation to restrict the use of the more visibly polluting gasoils and diesel fuels. If implemented, this change will cause an increase in the motor spirit share of the transport market. Fuel oil increased both relatively and absolutely until 1964, but since then has levelled out relative to other fuel consumption. This fact tends to obscure the importance of fuel oil which has by far the largest share of consumption in volume terms, and must be considered the key fuel in the local economy.

Kerosene has decreased both relatively and absolutely over the past 7 years, following a rapid growth rate in consumption in the 1950's. Liquefied petroleum gas introduced in negligible proportions in 1960 as an experimental fuel has quickly encroached on the kerosene market as its major competitor as a domestic fuel. It has the fastest growth rate of all fuels in Hong Kong, at 11.6% per annum since its introduction.

Table XI shows Hong Kong's solid and liquid fuel trends against those of selected regions of the world over the period 1950–1965. Hong Kong's rapid shift away from solid fuels during that period is greater than any of the regions

<table>
<thead>
<tr>
<th>Year</th>
<th>% of total</th>
<th>% of total</th>
<th>% of total</th>
<th>% of total</th>
<th>Annual rate of change 1954—1971</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964</td>
<td>5.3</td>
<td>0.9</td>
<td>2.83</td>
<td>0.3</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>12.06</td>
<td>2.0</td>
<td>7.10</td>
<td>0.9</td>
<td>7.83</td>
</tr>
<tr>
<td></td>
<td>1.86</td>
<td>0.3</td>
<td>1.62</td>
<td>0.2</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td>49.28</td>
<td>8.1</td>
<td>33.23</td>
<td>4.0</td>
<td>9.30</td>
</tr>
<tr>
<td>1967</td>
<td>68.50</td>
<td>11.3</td>
<td>44.78</td>
<td>5.4</td>
<td>21.28</td>
</tr>
<tr>
<td></td>
<td>30.84</td>
<td>5.1</td>
<td>38.62</td>
<td>4.6</td>
<td>51.76</td>
</tr>
<tr>
<td></td>
<td>59.76</td>
<td>9.8</td>
<td>81.66</td>
<td>9.8</td>
<td>77.60</td>
</tr>
<tr>
<td></td>
<td>71.65</td>
<td>11.8</td>
<td>105.6</td>
<td>12.7</td>
<td>267.66</td>
</tr>
<tr>
<td></td>
<td>375.29</td>
<td>61.7</td>
<td>556.56</td>
<td>66.7</td>
<td>800.69</td>
</tr>
<tr>
<td></td>
<td>2.12</td>
<td>0.3</td>
<td>6.64</td>
<td>0.8</td>
<td>22.20</td>
</tr>
<tr>
<td>1971</td>
<td>539.66</td>
<td>88.7</td>
<td>789.08</td>
<td>94.6</td>
<td>1 219.91</td>
</tr>
<tr>
<td></td>
<td>608.16</td>
<td>100.0</td>
<td>833.86</td>
<td>100.0</td>
<td>1 241.19*</td>
</tr>
</tbody>
</table>

(1969) made recommendation to restrict the use of the more visibly polluting gasoils and diesel fuels. If implemented, this change will cause an increase in the motor spirit share of the transport market. Fuel oil increased both relatively and absolutely until 1964, but since then has levelled out relative to other fuel consumption. This fact tends to obscure the importance of fuel oil which has by far the largest share of consumption in volume terms, and must be considered the key fuel in the local economy.

Kerosene has decreased both relatively and absolutely over the past 7 years, following a rapid growth rate in consumption in the 1950's. Liquefied petroleum gas introduced in negligible proportions in 1960 as an experimental fuel has quickly encroached on the kerosene market as its major competitor as a domestic fuel. It has the fastest growth rate of all fuels in Hong Kong, at 11.6% per annum since its introduction.

Table XI shows Hong Kong's solid and liquid fuel trends against those of selected regions of the world over the period 1950–1965. Hong Kong's rapid shift away from solid fuels during that period is greater than any of the regions
Fig. 4. Trends in energy consumption by type of energy for the 17-year period 1954–1971. The vertical axis is a log scale.
TABLE XI
Consumption of solid and liquid energy forms by selected regions 1950—1965

<table>
<thead>
<tr>
<th>Selected area</th>
<th>As a % of the regions total energy consumption</th>
<th>Annual rate of change in period</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>61.0</td>
<td>27.7</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>42.3</td>
<td>37.7</td>
</tr>
<tr>
<td>Oceania</td>
<td>72.0</td>
<td>64.1</td>
</tr>
<tr>
<td>Asia</td>
<td>68.4</td>
<td>24.8</td>
</tr>
<tr>
<td>Japan</td>
<td>83.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Other Asia</td>
<td>57.0</td>
<td>39.0</td>
</tr>
<tr>
<td>Hong Kong*</td>
<td>35.0</td>
<td>65.0</td>
</tr>
</tbody>
</table>

*by extrapolation from Table X.

Source: Darmstadter et al., 1971, p. 89 and 91 and Table X.
shown, and its continued growth in liquid fuel consumption is greater than the regional trend, outside Japan, and is roughly comparable to the world trend in the time period considered. The trend towards liquid fuels will level out as the solid fuels are almost negligible in comparison with liquid fuels at the present time.

Hong Kong's rapid shift to liquid fuels partly reflects its non-energy producing status. Liquid fuels are preferred for importation over solid fuels because of their decreased volume for equivalent calorific value and convenience of handling. Hence a totally importing country would be likely to use liquid fuels as soon as it becomes a competitive proposition in the world market.

The fact that wood was a significant fuel in the early 1950's is worthy of comment. Cottrell (1969) has suggested that the village communities of China were essentially 'low energy communities' and were traditionally conservative in moving from a traditional to a modern energy form. Luten (1971) has pointed to this feature in the European and North American communities in the nineteenth century. Through changes in living conditions in Hong Kong, the 10-year period 1957–1967 marked a transition from the prominent use to the exceptional use of firewood for domestic purposes and, within a generation, from its universal consumption to its virtual extinction. It is only in the remaining squatter areas and the New Territories villages that wood is found in use as a domestic fuel today.

If Hong Kong is to utilise alternative sources of energy, then those likely to be introduced in the immediate future will be more sophisticated liquid and gaseous fuels. Nuclear energy may be in use in Hong Kong during the late 1980's.

There are numerous possibilities for the installation of recently developed solar energy collectors for water and space heating which are already in use in some parts of the world (C.S.I.R.O., 1964; Davey, 1966; Close et al., 1968; Morse, 1970; Hammond, 1974). Recent research supported by U.S. Department of Commerce (1972) on alternative uses of solar energy presents preliminary findings which are of interest to the Hong Kong situation and which, if implemented, could contribute significantly to Hong Kong's energy supply.

Given that research in progress solves some of the technical problems of moisture removal and sulphur oxide scrubbing, pyrolysis might be attractive. Hong Kong has major animal sewage and urban refuse disposal problems, all of which will require expensive and energy-intensive solutions in the near future. According to the Civil Engineering Office (1971), the urban area generates 2 561 tonnes of refuse per day, with a potential 16 000 MJ per tonne, giving a possible energy source of $150 \times 10^8$ MJ per year, or about 12% of present requirements. However, the moisture removal can often be quite demanding of energy making net energy production minimal.

More attractive is the application of new bioconversion techniques to use organic wastes from urban refuse and animal sewage to generate methane. Agriculture and Fisheries (1973) have estimated that there are about 1 770 tonnes of animal sewage generated per day in a relatively small area which is concentrated enough to allow convenient collection. The techniques do not
require energy-expensive drying processes. By fermentation to methane, this sewage could generate up to 14,000 MJ per tonne or, allowing for 50% moisture content, $45 \times 10^8$ MJ per annum, which is 3.5% of current energy demands. Given the availability of suitable technology, both urban organic wastes, animal sewage wastes and some human sewage could be used to generate more than 10% of Hong Kong's power requirements and at the same time reduce an aggravating solid waste disposal problem. Solar air conditioning, drying, space heating and water heating could also contribute at least 5% of total energy requirements. It is therefore clear that through direct and indirect consumption of solar energy, a significant contribution can be made to the total energy budget of Hong Kong.

DISCUSSION

This study represents an attempt to provide a detailed overview of energy flow and end-use in a contemporary urban settlement. It is preliminary to a detailed, sector end-use analysis (Newcombe, 1975), analysis of energy use at the individual and family level (K. Newcombe, in preparation), and to research into the biological and climatological impact of artificial heat generation (J.D. Kalma et al., in preparation).

If energy problems are to be dealt with properly in ever increasingly complex urban societies, and if critical areas of need in the metabolism of cities are to be identified and sustained in a time of impending energy shortages, then such studies will have to become universal. Of even greater importance is the fact that such research can be used to distinguish between the real and illusory needs for energy deployment.

Hong Kong represents a classical focal point in the ecology of the region and of the globe where the consumption of energy and materials far outweighs production. In consequence, a critical state of dependence is established on the continued stability of the complex networks of supply that enable Hong Kong to survive and prosper economically. Its ecological strategy must be to maintain stability in the supply networks of all essential materials, and energy.

Diversification of the sources of energy is one means of creating such stability. Current storage holds only 40 days' supply, compared with 60—90 day storage capacities in many countries (Shell Company of Hong Kong, personal communication, 1974).

Hong Kong receives its main fuels through the major suppliers in 18,000 to 70,000 tonne vessels. It takes about one week for a ship to reach Hong Kong from Singapore. Depending on the circumstances, it is possible for a delay in shipping to squeeze fuel supplies in Hong Kong and the need for greater storage capacity to provide a buffer period in a time of erratic or uncertain energy supply has been appreciated by the government. During 1973, China began to export to Hong Kong, kerosene and gasoils. In that year these made up 4% and 3%, respectively, of the total imports of these fuel types. While relatively small in volume then, the construction of rail-fed storage tanks for
fuels of Chinese origin in Shatin New Town and sea-fed storage tanks at Tsing Yi Island promises a more significant volume for the future. If fuels of Chinese origin can comprise a large percentage of consumption, Hong Kong's dependence on fuels of Middle East origin can be reduced, allowing the desired increase in stability of energy supply networks.

Diversification of the type of energy used presents another option to Hong Kong for improving the stability of energy supply. Continued dependence on oil-based fuels offers no long-term panacea. It is well documented that oil-based fuels will be nearly exhausted during the next 30 years, and the immediate future does not offer great security since alternatives to fossil fuels, or the better exploitation of existing coal reserves may be decades away from matching ever-increasing energy demands. Within the oil industry it has been suggested that shortages are due to occur by 1978 because of a decline in drilling success (Warman, 1973). Landsberg (1974) has forewarned of shortages because of increased drilling costs. Thomas (1973) has suggested, and it is already evident, that the lack of incentive for oil-producing countries to continue to produce when they have unspent oil revenues may severely disrupt supply in the next few years. Two of these forecast problems are not directly related to the size of power resources, yet viewed together with the inevitable depletion of supplies they further support the need for reducing the current reliance on oil-based fuels.

Hong Kong has expressed interest in a nuclear alternative, but as with the establishment of an oil refinery, it would still compete for raw materials with powerful industrialised states. However, by generating up to 15% of its total energy requirements from its own wastes and direct solar radiation, it could simultaneously reduce its dependence on external energy supply networks and alleviate part of its already critical waste disposal problems.

A further option which natural systems already exploit is the maximisation of work performed per unit of energy entering the system. Almost two-fifths of the fuels imported to Hong Kong are lost by inefficient conversion to electricity. An increased consumption of town gas, with its significantly higher thermal efficiency (see Table VII) could compensate for the serious loss of energy in conversion of fuel oil to electricity. This is particularly so where the appliance efficiency achieved by using town gas is equal to, or marginally less than, that obtained using electricity. This applies for cooking and water heating in the domestic sector and with steam raising and various direct heat requiring applications in commerce and industry.

Policy changes regarding subsidy of reticulation networks in government housing estates allowing a larger domestic market for town gas, could in the long term significantly increase the overall thermal efficiency of converting oil-based feedstocks to more sophisticated fuels.

Potential for long-term energy conservation was shown by the marked decreases in domestic consumption induced by government campaigns to reduce energy consumption during the 1973–1974 oil crisis. January 1974 electricity consumption dropped by more than 7% over January 1973 con-
sumption (Census and Statistics Department, 1974). There was no evidence of hardship as a result of these energy savings. Unfortunately, this option was immediately forgone once it was announced that new oil contracts were signed in May 1974. Advertising by Hong Kong electricity companies shows that they are now openly soliciting increased consumption of electricity on the basis that there is no longer an 'oil crisis' (Sing Pao, 1974).

Similarly, it has been shown in Hong Kong, and elsewhere (Berg, 1974), that relatively simple changes in industrial consumption practices could result in saving significant amounts of energy.

From examination of trends in energy use in Hong Kong it was shown that there has been a rapid transition from using particularly firewood and coal solid fuels to an almost entirely liquid fuel base. Such a complete change in domestic fuels from traditional to modern in less than a generation implies a significant shift in cultural practices and it provides a clear indication of the potential impact that changing patterns of energy consumption can have on life style and living conditions.

Certainly there is need to establish efficient means of monitoring energy flows and patterns of energy use in urban settlements.

An understanding of the urban energy system can lead to the development of new methods of energy use and alternative technology to measure the efficiency of energy use and to predict well in advance the demands that growth of settlements will make on global energy resources. Contemporary shortages and uncertainties in supply of energy clearly demand a further, more thorough, understanding of how much energy is required to operate essential services at the minimal level, for example, food supply, water supply, basic mobility and health care services.

The emphasis throughout this paper has been on stabilizing the supply of energy, searching out feasible alternative energy sources and commenting on potential energy savings in the system. This emphasis must not be taken to suggest either that Hong Kong is in need of more energy or that its present level of energy consumption is optimal. Indeed, there is no evidence to suggest that a higher per capita consumption will solve the pressing social problems of housing, health, poverty and so on. The data presented here is in fact being used in association with additional information to test the hypothesis that many contemporary problems in Hong Kong relate directly to the use of either too much energy or the use of existing energy supplies inappropriately, thereby generating air, water and noise pollution and inadequate public transport.

Research of this kind can hopefully contribute to the development of sensible energy economics through conservation and recycling, perhaps introducing a more stable era of energy use to urban settlements such as Hong Kong.

ACKNOWLEDGEMENTS

I would like to gratefully acknowledge the advice of S.V. Boyden, J.D.
Kalma and A.R. Aston during the process of research and in the preparation of the manuscript.

REFERENCES

Agriculture and Fisheries, 1973, Pollution: A Preliminary Report on Agricultural Pollution in Hong Kong. Department of Agriculture and Fisheries, Hong Kong, mimeographed.

Air Pollution Control Unit, 1974. Appraisal of thermal efficiency of potential fuel savings. Extract from a report, 28th March, Labour Department, Hong Kong, mimeographed.


Civil Engineering Office, 1971. Report on Refuse Disposal by Controlled Tipping at Gin Drinkers Bay and Alternative Sites in Kowloon and Hong Kong. Department of Public Works, Appendix C.


Sing Pao, 1974. Hong Kong Electric Co. advertisement, 12th July, p. 11.


Energy Resource. Report PB-221659, prepared for National Science Foundation and
National Aeronautical and Space Administration by Maryland University. Distributed
by National Technical Information Service, pp. 22—45.
Scientist, 27th September, p. 762.

APPENDIX I

Gross calorific values

<table>
<thead>
<tr>
<th>Fuel</th>
<th>MJ/kg</th>
<th>MJ/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor spirit</td>
<td>47.5</td>
<td>34.6</td>
</tr>
<tr>
<td>Gas oils, diesel fuels, distillates</td>
<td>44.4</td>
<td>36.8</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>43.1</td>
<td>40.4</td>
</tr>
<tr>
<td>Aviation spirit</td>
<td>47.5</td>
<td>33.3</td>
</tr>
<tr>
<td>Aviation turbine fuel</td>
<td>46.5</td>
<td>36.5</td>
</tr>
<tr>
<td>LPG</td>
<td>50.0</td>
<td>26.6</td>
</tr>
<tr>
<td>Coal</td>
<td>28.4</td>
<td>—</td>
</tr>
<tr>
<td>Coke</td>
<td>29.6</td>
<td>—</td>
</tr>
<tr>
<td>Charcoal</td>
<td>29.8</td>
<td>—</td>
</tr>
<tr>
<td>Firewood</td>
<td>17.4</td>
<td>—</td>
</tr>
<tr>
<td>Kerosene</td>
<td>45.8</td>
<td>36.6</td>
</tr>
</tbody>
</table>

*Source: Shell Co. Hong Kong Ltd: Petroleum Information Bureau, Australia.*
CHAPTER III

ENERGY USE IN HONG KONG, PART II: SECTOR END-USE ANALYSIS
ENERGY USE IN HONG KONG: PART II, SECTOR END-USE ANALYSIS

KEN NEWCOMBE

Urban Biology Group, John Curtin School of Medical Research, Australian National University, Canberra, A.C.T. (Australia)
(Received February 10th, 1975)

ABSTRACT


A sector end-use analysis of extrasomatic energy in Hong Kong has been made for 1971. The sectors into which consumption has been divided are domestic, commercial, industrial and transport. In moving towards heavier industries, adopting more energy expensive modes of transport and through the higher energy requirements of new commercial complexes Hong Kong is rapidly elevating its total energy requirements, although options to alleviate this trend are available. The consequences of, and alternatives to unabated increases in energy use in Hong Kong are discussed.

INTRODUCTION

The analysis of the sector-confined end uses of energy in urban settlements is pertinent not only to the determination of contemporary demands for energy supply and their importance vis-a-vis the economy and public well-being, but also to long-term energy planning. This is particularly so in societies undergoing industrialisation. Moreover, understanding the division of energy consumption provides a rational basis for policies aimed to ensure that the most vital activities receive sufficient supply. Similarly it is of obvious value to know where efforts to conserve energy through improved efficiency are likely to be most effective in terms of over-all energy use.

This paper provides a detailed description of energy end-use in Hong Kong. It is complimentary to the preceding paper (Newcombe, 1975) which provided an overview of the patterns of energy use in this urban area.

The sectors to be considered in this analysis are: domestic, commercial, industrial and transport. This division of activities has been chosen mainly to provide ease of comparison with other similar studies (Guyol, 1971, Kalma et al., 1972; Stanford Research Institute, 1972). Government energy use which might appropriately be considered a consumption sector in its own right has been allocated according to the type of activity undertaken, e.g. government transport energy use has been included in the transport sector, and so on.
In advanced industrial states a meaningful division of energy use between commercial and industrial activities is made increasingly difficult because multi-faceted corporations hold interests across both clearly commercial and industrial areas without accounting for the actual distribution of resources between them. The task of dividing energy use between these sectors in Hong Kong was facilitated by defining commercial activities as “wholesale and retail trade, communications, finance, property, public authority, defence, amusements, hotels and restaurants” (Kalma and Aston, 1973).

An overall energy matrix for fuel use in the industrial and commercial sectors is given in Appendix I. The data presented therein form the basis of much of the discussion under the commercial and industrial sectors. It was only possible to define an end-use for 88% of industrial and commercial fuels. This was largely because an analysis of end-use of “general tariff” electricity produced by China Light and Power was not carried out by the company within the industrial and commercial sectors.

Inevitably, records were not sufficient to supply all information and in such cases considerable data have come from careful estimations and assumptions based on field work. Data gathered in this way is unlikely to deviate more than 10% from the actual situation. Negligible amounts of fuel used for minor activities have been disregarded or classified as miscellaneous.

Table I indicates the broad division of energy use by sector for Hong Kong in 1971. Bunker fuels are excluded from the transport energy use in this presentation which only considers energy used in Hong Kong itself. Losses of energy in conversion from fuel oil and diesel oil to electricity and town gas are included as a separate sector in this division to emphasise the importance of conversion losses to the Hong Kong economy.

The transport sector is dealt with in some detail because of the complexity of transportation in Hong Kong, including extensive marine transport systems, and because of its relevance to the on-going debate on the efficiency and desirability of particular transport modes in urban areas.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Amount of fuel (MJ x 10⁸)</th>
<th>Percentage of total, excluding losses</th>
<th>Percentage of total, including losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>137.93</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>Commercial</td>
<td>169.90</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>Industrial</td>
<td>232.54</td>
<td>31</td>
<td>19</td>
</tr>
<tr>
<td>Transport</td>
<td>215.67</td>
<td>29</td>
<td>17</td>
</tr>
<tr>
<td>Losses</td>
<td>490.29</td>
<td></td>
<td>39</td>
</tr>
<tr>
<td></td>
<td><strong>1,247.33</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*Source: Derived from Newcombe (1975, Table IV).*
Industry

Industrial energy use makes up 31% of total energy consumption, excluding losses from electricity and gas generation — or 19% of the total if these losses are included (Table I).

Table II shows the type of energy used for industrial purposes. Fuel oils represent more than 50% of industrial consumption, followed by electricity with 31.6% and gasoils, etc. with 11.8%. Coal, although small in comparison with the total industrial use, is still more commonly used than town gas, liquefied petroleum gas, kerosene and all solid fuels besides coal, combined. Appendices I and II contain details of the end-use of solid fuels in Hong Kong. They show that the major industrial usage of coal is for smelting and metal works.

Reference to Appendix I shows that textiles use 76% of all fuel oil used in industry. The tobacco industry uses 10%; the machining of such metals as aluminum and copper, and glass and ceramics manufacture uses 4% and the iron and steel industry uses 3% of the fuel oil used in industry. About 41% of the consumption of diesel fuel is in the construction industry.

TABLE II

Type of fuel used for industrial purposes Hong Kong: 1971

<table>
<thead>
<tr>
<th></th>
<th>MJ $\times 10^4$</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal</td>
<td>0.79</td>
<td>0.3</td>
</tr>
<tr>
<td>Coke</td>
<td>1.31</td>
<td>0.6</td>
</tr>
<tr>
<td>Coal</td>
<td>8.84</td>
<td>3.8</td>
</tr>
<tr>
<td>Kerosene</td>
<td>0.62</td>
<td>0.3</td>
</tr>
<tr>
<td>Gasoils, diesel oils and distillate</td>
<td>27.23</td>
<td>11.7</td>
</tr>
<tr>
<td>Fuel oils</td>
<td>118.70</td>
<td>51.0</td>
</tr>
<tr>
<td>L.P.G.</td>
<td>1.33</td>
<td>0.6</td>
</tr>
<tr>
<td>Electricity</td>
<td>72.79</td>
<td>31.3</td>
</tr>
<tr>
<td>Town gas</td>
<td>0.93</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>232.54</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Source: Derived from Newcombe (1975, Table IV)

Textile production, including printing, dyeing and apparel manufacturing processes, use 28%, and the food and beverage industry, 10% of the total industrial diesel fuel consumption.

With respect to industrial electricity, textiles consume 57% and water pumping 10%.

Fig. 1 presents the estimated end-use of all industrial energy by type of industry and as a percentage of total commercial-industrial energy consumption (see Appendix I for more detail). As anticipated from the discussion of
end-use of major industrial fuels, the textile* industry is the major fuel consuming industry, using 61% of all industrially used energy. Hong Kong has changed very rapidly from an entrepot to a manufacturing centre where textiles are the major product. According to Liang (1973) the export of manufactured goods increased from 10% of total export value in 1947 to 75% in

*Textiles are taken throughout to include printing, dyening and related processes, plus the manufacture of clothing other than footwear.
1971. The Census of Manufacturing Establishments (1971) shows that the textile industry is split into two major portions (for the purpose of discussing energy use), namely textiles production and clothing manufacture. In 1971 there were 1,769 and 7,939 establishments respectively, occupying virtually the same quantity of floor area. Between them they employed 45% of the industrial workforce, and generated 48% of the total industrial income. Most of the establishments are small, as only 9% of industrial establishments employ a work force of greater than 50 people. (With most of the industrial energy going into textile production, Hong Kong is confirmed as a light industrial centre.)

The manufacture of metals, such as copper and aluminum, and glassware, ceramics and porcelain consume about 9%, and foodstuffs and construction about 7% each of the total energy.

The food industry is concerned with both baking, refining and brewing for the local market and with canning and food preparation for export. Food manufacturers provide 12.6% of local sales and 2.3% of export sales.

Construction and demolition are an ever present feature of urban settlements. This is especially so for Hong Kong. According to Szczepanik (1958), the construction boom began in Hong Kong in 1953. The pattern of growth was to increase the vertical rather than the horizontal size of the city. The Commissioner for Resettlement (1971) reported that 1.2 million people were accommodated in a 17-year period of government housing programmes. In addition, middle and upper class flat developments have increased in number in recent years. Census and Statistics (1972) report the completion of 20,000,000 ft² of building space in 1971. The 14% annual increase in motor vehicles places immense pressure on existing road structures and engineering developments for traffic are continually under construction. Other significant areas of construction included water catchments and reclamation areas.

The highly energy intensive industries such as iron and steel, chemicals and fertilizers and heavy industry are not prominent, with the result that the industrial energy use profile is almost opposite that in the United States and Australia. It has been shown that metals and machinery manufacture used 37% of industrial energy in 1970, in the United States (Stanford Research Institute, 1972). Kalma and Aston (1973) provide data for the State of New South Wales, Australia, showing that metals and machinery use 67%, and chemicals and paints 15% of industrial energy in 1970.

In the immediate future, heavier, more energy-intensive industries, such as petrochemicals, plastics and machinery are to be developed in Hong Kong under the auspices of Dow Chemicals and Johnson Outboard companies. Similarly, proposals for an oil refinery for Hong Kong include the construction of adjacent petrochemical complexes. If Government approval is forthcoming for the construction of a refinery-petrochemical complex, it would be in operation in the early 1980's. In 1971, however, Hong Kong remained a light industrial centre in which industrial energy accounts for 31% of the total usage as compared with 44% in Australia, (Kalma et al., 1972) and 42% in the United States (Stanford Research Institute, 1972).
Commercial

Commercial energy use in Hong Kong is 22% of total local consumption (Table I).

It will be seen from Table III that commercial fuels are predominantly gasoils and electricity, a situation which reflects the main pattern of commercial activity in Hong Kong. These services together comprise over 80% of all commercial energy consumption, making other energy types relatively insignificant.

More than 90% of gasoil used commercially is for cooking in restaurants and hotels. Of electricity used in commerce, 64% is consumed in shops and administration where it is used for lighting, cooling, heating and the operation of office appliances and automata such as computers. More than 30% is used in hotels and restaurants for lighting, cooling, display and ancillary services such as lifts.

**TABLE III**

<table>
<thead>
<tr>
<th>Type of fuel used for commercial purposes Hong Kong: 1971</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MJ x 10^6</strong></td>
</tr>
<tr>
<td>Charcoal</td>
</tr>
<tr>
<td>Coke</td>
</tr>
<tr>
<td>Coal</td>
</tr>
<tr>
<td>Kerosene</td>
</tr>
<tr>
<td>Gasoils, diesel oils and distillates</td>
</tr>
<tr>
<td>Fuel oils</td>
</tr>
<tr>
<td>L.F.G.</td>
</tr>
<tr>
<td>Electricity</td>
</tr>
<tr>
<td>Town gas</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

*Source: Derived from Newcombe (1975, Table IV)*

Commercial energy end-use has been examined in the same manner as industrial energy end-use in Fig.1 and Appendix I. Hotels and restaurants consume 67% of all commercial energy and also rank as the second highest consumer in the industrial-commercial category. Shops, offices and administration make up 20% of the energy use between them.

The high consumption of hotels and restaurants reflects, particularly, the frequency with which the Chinese family and the individual tend to eat away from home for all meals of the day. The acknowledged tradition of entertaining at a restaurant provides business for 2,350 restaurants and light refreshment houses, 10% of which seat more than 300 people, and the 1,670 food stalls licensed in 1971 (J. Hayes, Urban Services Department, personal com-
The vast majority of restaurants use diesel fuel as the principal cooking fuel, with liquid petroleum gas, coal and charcoal or coke as an auxiliary fuel or for special purposes such as roasting meats. Only the older, poorer restaurants continue to use coal as a major fuel (M.S. Lee, Hong Kong and Kowloon Restaurants Association, personal communication, 1974). In contrast, most major hotels use town gas for cooking purposes. Cooked food-stalls which line many of the streets, alleyways and housing estate lots, use mostly kerosene. Here, liquid petroleum gas is the invading, less traditional and more sophisticated energy type. Since cooked food-stalls are not really permanent establishments, few have the security or position to erect pressure equipment to utilise the more economical gasoils.

The second largest "commercial" energy consumer is the government. This consumption largely reflects the energy overheads of office administration. Government transport consumption is mentioned under the transport sector analysis.

A noticeable energy-expensive trend is taking place with the construction of the larger, more recent commercial buildings with total energy systems, (e.g. Connaught Centre, Hutchison House) which utilise no external ventilation and allow little manual manipulation of the energy systems built in. When an energy shortage prevails, such buildings must still be operated at high energy inputs or be closed down. A useful comparison of the energy use per capita of commercial worker in several Australian cities is given by Kalma and Aston (1973) which reflects this energy-expensive trend. They show that average per capita energy consumption of commercial workers in the newly constructed administration centres of Canberra are five and two times higher respectively than in Melbourne and Sydney, where a conglomeration of old and new office buildings exist.

### Transport

Transport energy use accounts for 29% of total use, with the exclusion of ocean going and aviation bunkers (Table I). The per capita use in transport is shown in Appendix III. If bunkers are included it amounts to $18 \times 10^3$ MJ/head/year or, if only transport energy used in Hong Kong itself is considered, $4.8 \times 10^3$ MJ/head/year. The per capita consumption by land transport is $3.3 \times 10^3$ MJ/head/year, which is low in comparison to the industrial city of Sydney, Australia, where Kalma et al. (1972) have shown that per capita consumption is $26 \times 10^3$ MJ/head/year. The analysis of transport energy use has been divided into local energy use and bunker fuel use. Local use is further categorised by land, as road and rail, marine and air. While in the analysis of energy flow in most urban centres, marine transport use within the urban complex would be small or non-existent, in Hong Kong this is not the case. Here, the central business district lies on Hong Kong Island, separated from the major commercial area of Kowloon and the industrial areas of Tsuen Wan and Kwun Tong by Victoria Harbour, into which also protrudes the interna-
tional airport of Kai Tak. The major recreational areas, and quickly developing commercial centres of Lantau Island, Lamma Island and Cheung Chau lie within a few miles' radius, with most of the traffic to them going through the harbour. Victoria Harbour is therefore used as a midstream unloading depot for international shipping, a major thoroughfare for cargo and commuter traffic, and is for most purposes within the urban complex.

A difficulty arises with the definition of transport in respect of some marine energy uses. This has been resolved for the purposes of this study by including all mobile uses of energy as transport. This, however, introduces the anomaly that a major primary industry — fishing — is included within the transport section as energy expenditure on fishing vessels. Similarly, the essentially commercial ventures of floating restaurants are included in the transport sector because many serve a mobile recreational function as well as providing dining facilities.

Table IV shows the energy used in transport by type of fuel for all local transport. Locally automotive and industrial gasoil are the predominant transport fuels, contributing 73.9% of the total usage.* Motor spirit is the second major fuel making up 23.7% of the total. Other transport fuels are confined to particular end-uses in the local context with electricity used for traction for trams, fuel oil for ocean-going tugs and salvage vessels and the limited aviation fuel use for government, military and private aircraft.

For bunker fuels, shipping uses fuel oil and diesel oil; the latter is used mostly for auxiliary motors. They form 53% and 8.4% of the bunker fuels respectively. Jet aircraft use 38.4% of the aviation fuel and propeller craft 0.2%.

Table IV also provides a breakdown of transport energy use by vehicle type for each area of transport use. Of road vehicles, private cars constitute the largest number, but consume only 32% of the total, compared with 70% in the United States (Leach, 1973). However, the rate of growth of private car ownership (Table VI) indicates that the only restriction to increased fuel consumption for their operation is the lack of an extensive road network. Barden and Pang (1971) report that there are 975 km of roads and traffic congestion is building up rapidly. Passenger-carrying vehicles make up roughly 75% of road transport and cargo-carrying vehicles about 25%, given the slight overlap in purpose.

Of the passenger-carrying vehicles, public light buses and the mostly double-decked public buses use 10% of road transport energy each. Reports on Transport in Hong Kong (1974) and Eberman et al. (1968) show that public buses move 1,050,000 passengers per day. Buses can legally transport 125 passengers, whereas public light buses are strictly limited to 14 passengers. A comparison of passenger capacity indicates that public buses are under-

*Automotive gasoil and industrial gasoil are identical in all energy respects. A dye is added to distinguish them for duty payment purposes; industrial gasoil being nondutiable and used for industrial purposes.
TABLE IV

Transport use of fuel

<table>
<thead>
<tr>
<th></th>
<th>Fuel oil</th>
<th>Diesel</th>
<th>Petroleum</th>
<th>Avturb</th>
<th>Avgas</th>
<th>Electricity f.o.e.</th>
<th>Total</th>
<th>Sub %</th>
<th>Overall % not including bunkering fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road vehicles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private cars</td>
<td>1.15</td>
<td>39.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40.76</td>
<td>32.2</td>
<td>18.7</td>
</tr>
<tr>
<td>Pak Pai (illegal taxis)</td>
<td>3.17</td>
<td>5.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.55</td>
<td>6.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Goods vehicles</td>
<td>24.00</td>
<td>3.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27.00</td>
<td>21.3</td>
<td>12.4</td>
</tr>
<tr>
<td>Public light buses</td>
<td>12.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.42</td>
<td>9.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Buses</td>
<td>12.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.38</td>
<td>9.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Taxies</td>
<td>21.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21.34</td>
<td>16.8</td>
<td>9.8</td>
</tr>
<tr>
<td>Government</td>
<td>0.49</td>
<td>3.77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.26</td>
<td>3.3</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td>74.95</td>
<td>51.76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>126.71</td>
<td>100.0</td>
<td>58.1</td>
</tr>
<tr>
<td><strong>Rail vehicles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tramways</td>
<td></td>
<td></td>
<td>2.02</td>
<td></td>
<td></td>
<td></td>
<td>2.02</td>
<td>66.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Trains</td>
<td>1.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.02</td>
<td>33.6</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td>1.02</td>
<td></td>
<td>2.02</td>
<td></td>
<td></td>
<td></td>
<td>3.04</td>
<td>100.0</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Marine vehicles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrofoils</td>
<td>2.86</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.86</td>
<td>3.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Ferries</td>
<td>7.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.15</td>
<td>8.3</td>
<td>3.2</td>
</tr>
<tr>
<td>Motorized cargo boats</td>
<td>3.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.90</td>
<td>4.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Dumb steel lighter mechanisation</td>
<td>1.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.53</td>
<td>1.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Passenger-carrying Wallah-Wallahs</td>
<td>0.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.43</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Kaitos and trading junks</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.23</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Tugs for dumb steel lighters</td>
<td>4.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.70</td>
<td>5.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Government craft</td>
<td>1.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.26</td>
<td>1.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Floating restaurants</td>
<td>0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.58</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Ceremonial boats</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.23</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Pleasure craft</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.16</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Ocean-going tugs/salvage vessels</td>
<td>0.56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.56</td>
<td>1.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Miscellaneous ice boats, fish drying hulks, pontoon repair boats and oil supply boats</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.16</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Fishing fleet</td>
<td>61.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61.26</td>
<td>71.4</td>
<td>28.1</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td>0.56</td>
<td>85.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>85.76</td>
<td>100.0</td>
<td>39.3</td>
</tr>
</tbody>
</table>

* * *
<table>
<thead>
<tr>
<th>TABLE IV (continued)</th>
<th>Fuel oil</th>
<th>Diesel</th>
<th>Petroleum</th>
<th>Avturb</th>
<th>Avgas</th>
<th>Electricity f.o.e.</th>
<th>Total</th>
<th>Sub %</th>
<th>Overall % not including bunkering fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>aviation</strong>&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government and military</td>
<td>2.32</td>
<td>0.17</td>
<td></td>
<td></td>
<td></td>
<td>2.49</td>
<td>95.0</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>0.09</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td>0.13</td>
<td>5.0</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td>2.41</td>
<td>0.21</td>
<td></td>
<td></td>
<td></td>
<td>2.62</td>
<td>100.0</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td><strong>Overall total (1)</strong></td>
<td>0.56</td>
<td>161.17</td>
<td>51.76</td>
<td>2.41</td>
<td>0.21</td>
<td>2.02</td>
<td>218.13</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Percentage of local use</td>
<td>0.30</td>
<td>73.90</td>
<td>23.70</td>
<td>1.10</td>
<td>0.10</td>
<td>0.90</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bunker fuels</strong>&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocean bunkers</td>
<td>270.04</td>
<td>42.57</td>
<td></td>
<td></td>
<td></td>
<td>312.61</td>
<td>196.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviation bunkers</td>
<td></td>
<td></td>
<td></td>
<td>195.32</td>
<td>1.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td>270.04</td>
<td>42.57</td>
<td></td>
<td>195.32</td>
<td>1.05</td>
<td>508.98</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of bunker use</td>
<td>53.00</td>
<td>8.40</td>
<td></td>
<td>38.40</td>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Final overall total</strong></td>
<td>270.60</td>
<td>203.74</td>
<td>51.76</td>
<td>197.73</td>
<td>1.26</td>
<td>2.02</td>
<td>727.11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>f.o.e.</sup> = fuel oil equivalent.
<sup>a</sup>Road transport data was derived from the following: Bus consumption from Hong Kong monthly digest of statistics, January 1972; public light bus consumption — Public Light Bus Report, Traffic and Transport Survey Division, Public Works Department, Hong Kong, 1972; goods vehicle consumption — Goods Vehicle Report, unpublished report of Traffic and Transport Survey Division, Public Works Department; government consumption calculated from data provided by J.A. Wallace, Chief Government Electrical and Mechanical Engineer, Public Works Department; Pak Pais, (Transport department, personal communication, 1974) showing about 4,500 Pak Pais in 1971, 29% of which were diesel and using estimation that they operated about 40% of the time of taxis, using 18 l/day on average; taxis, which are exclusively diesel, use about 46 l/day on average based on 320 km/day and 3,410 cars, personal communication with drivers and H.K. Monthly Digest of Statistics, January 1972; private cars from taking 2.5% as diesel and 97.5% as motor spirit powered and using average annual distance travelled as roughly 8,000 km at about 6 km/l and by deduction from total spirit and diesel use.
### TABLE IV (continued)

*Marine Transport as follows: Far Eastern and Hong Kong Hydrofoil Companies, personal communication, 1974; Ferries: Star Ferry Co. and Hong Kong and Yaumatei Ferry Co., personal communication, 1974; motorised cargo boats, Dumb Steel Lighter Mechanisation and Tugs for Dumb Steel Lighters from unpublished document, *Fuel consumption figures of a representative sample of motor cargo boats and dumb steel lighters*, Supplies Department, External Transport Division, and H. Ng Quinn, Small Craft Licensing Section, Marine Department and T. Prawley, Marine Cargo Handling Unit, personal communication, 1974, and Statistical Summary No. 9D, a quarterly report on launches, small craft and pleasure vessels, Marine Department; Kaitos and Trading Junks, passenger-carrying wallah-wallahs, floating restaurants, ceremonial boats, miscellaneous boats etc.: A.J.S. Lack, Department of Oil Supplies, personal communication, 1974; calculations from an analysis of claimed and estimated fuel consumption for 50 kaitos and trading junks, 77 passenger-carrying wallah-wallahs, all floating restaurants and ceremonial boats, and 45 fish carriers, bulks, oil barges, ice boats, store and water boats; H. Ng Quinn, personal communication, 1974, reanalysis of Statistical Summary No. 9D (see above); government craft: D. Sandison, Marine Department, personal communication, 1974; pleasure craft: estimates based on Statistical Summary No. 9D and A.J.S. Lack, Department of Oil Supplies, personal communication, 1974; fishing fleet: Marine Department, personal communication, 1974, re numbers, A.J.S. Lack, Oil Supplies, personal communication, 1974, re theoretical consumption per unit time of given horse-power and operating speeds, Statistical Summary No. 9D (see above) re numbers mechanised and Agriculture and Fisheries Department, personal communication, 1974, for documentation on estimated fuel consumption of every motorised fishing vessel and by deduction of maximum possible consumption from total local marine sales, H.K. Yip, Census and Statistics Department, and Shell Co. Hong Kong, personal communication, 1974.


utilised and could come much closer to their high potential efficiency as a transport mode (see Table VI). At peak hours a double decker bus can carry as many passengers as are usually carried by nine public light buses or by 50 cars or taxis.

Government road vehicles use only 3.3% of road transport consumption, and more than 75% of this energy is used by police, the Public Works Department and the Urban Services Department. Pak Pai, or illegal taxis, use about 7% of road transport energy, less than half that used by legal taxis. They probably carry up to 300,000 passengers per day, and they are often used to move groups of people, such as school children, to and from places at arranged times.

Rail vehicles use very little energy in comparison to other land vehicles, but they fulfil a vital passenger-moving, and in the case of trains, cargo-moving role.

**Marine transport**

Marine transport presents the greatest variety of transport modes. Hydrofoils move people between Hong Kong and Macau, a distance of 40 miles, catering mostly for recreational journeys. Ferries are a vital link in the home-to-work traffic at peak hours and general individual and vehicular cross-harbour traffic at all times. Ferry patronisation did not drop significantly when the cross-harbour tunnel opened and trans-harbour bus services began operation. More particularly, on weekends and public holidays, ferries provide a major recreational service, linking the urban centres with sparsely populated outlying islands and peninsular. Most ferry traffic is nevertheless in the harbour itself.

Altogether in 1971 there were 74 passenger ferries of 400—500 HP, carrying up to 600 passengers each, and 14 vehicular ferries. They used about 9% of the marine transport energy.

Approximately 11% of marine energy use goes into cargo handling in Victoria Harbour. This is carried out by motorised cargo boats of 47—72 HP carrying up to 40 tonnes each, and dumb steel lighters which carry up to 400 tonnes each. They are flat bottomed barges rarely possessing motorisation for more than winch power, and are pulled by 150 HP tugs.

Apart from the fishing fleet, no other category of marine vehicle is a major energy user, although some, like the kaitos and trading junks, fulfil an indispensable role in supplying outlying communities with goods and services which would be difficult to provide in any other way.

Hong Kong’s fishing fleet is composed of 5,200 vessels ranging from junks to trawlers. The fleet travels as far as the Paracel Islands 400 miles to the south, on voyages lasting several weeks at a time. It supplies 80% of local seafood requirements and in doing so consumes 28% of the total transport energy and 71% of that used for all marine purposes.

Aviation fuel used locally is mostly for government and military purposes. Private air charter companies and aeronautical clubs use the remainder of aviation energy which altogether comprises only 1.2% of total transport energy.
Materials carried

The data in Table IV can also be manipulated to indicate that passenger-carrying vehicles consume about 50% of transport energy and cargo-carrying vehicles about 17%. If the fishing fleet's energy use is excluded from the analysis, the distribution of transport energy becomes 69% for passenger-carrying, 24% for cargo-carrying and 7% for other purpose transport. Some indication of the energy expended in carrying various types of goods can be gained from Table V. The data have been adapted from information supplied by the Traffic and Transport Survey Division (1971). Foodstuffs, machinery, building materials and textiles and related products are carried in that order of frequency. This is likely to correspond to a certain extent with the goods carried by marine cargo vehicles since road vehicles feed off marine transport in much of the cargo handling process.

TABLE V

Energy use by commodity carried for goods vehicles on land. Hong Kong 1971*

<table>
<thead>
<tr>
<th>Commodity</th>
<th>%</th>
<th>Energy used (MJ x 10^8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foodstuff</td>
<td>26.0</td>
<td>7.02</td>
</tr>
<tr>
<td>Machinery and manufactures</td>
<td>21.5</td>
<td>5.81</td>
</tr>
<tr>
<td>Building materials</td>
<td>11.7</td>
<td>3.16</td>
</tr>
<tr>
<td>Textiles and paper</td>
<td>9.6</td>
<td>2.59</td>
</tr>
<tr>
<td>Fuels</td>
<td>9.6</td>
<td>2.59</td>
</tr>
<tr>
<td>Raw materials</td>
<td>3.8</td>
<td>1.03</td>
</tr>
<tr>
<td>Dutiable goods</td>
<td>3.7</td>
<td>1.00</td>
</tr>
<tr>
<td>Scrap, refuse and garbage</td>
<td>1.2</td>
<td>0.32</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>12.9</td>
<td>3.48</td>
</tr>
<tr>
<td>100.0</td>
<td>27.00**</td>
<td></td>
</tr>
</tbody>
</table>

* Assuming that "empty trips" energy use can be allocated in proportion to time spent carrying each commodity.
** See transport energy use data, Table IV
Adapted from information extracted from the unpublished report on "Goods Vehicles", 1971, as supplied by Traffic and Transport Survey Division, Public Works Department, May 7th, 1974.

Efficiency of energy use in local transport

Landsberg (1974), and Hirst and Moyers (1973) have shown that the energy efficiency of transport tends to decrease as the volume of transport increases in urban systems. Trends in the energy efficiency of transport have been examined for Hong Kong and are presented in Table VI. Comparison is made with data provided by Leach (1973) for many transport modes in the United Kingdom. The table also shows the annual rate of increase in number
<table>
<thead>
<tr>
<th>Transport mode</th>
<th>Energy use* in MJ per tonne/km and per passenger km</th>
<th>Per annum % increase in vehicle number</th>
<th>Per annum % change in passenger journeys</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CARGO CARRYING:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Land:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goods vehicles:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) approx. 1 tonne(^1)</td>
<td>8.36</td>
<td>8.67</td>
<td>12.93</td>
</tr>
<tr>
<td>(b) approx. 5 tonnes</td>
<td>3.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train, diesel(^1)</td>
<td>0.28</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Bicycle — 27 kg load(^3)</td>
<td>5.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedicab — 136 kg load(^4)</td>
<td>1.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scooter — 27 kg load(^3)</td>
<td>48.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Marine:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Towage of dumb steel lighters(^6)</td>
<td>0.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorised cargo boats(^7) (average)</td>
<td>0.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PASSENGER CARRYING:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Land:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public light buses(^8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) actual average occupancy</td>
<td>1.04</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>(b) full load</td>
<td>0.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi and Pak Pai(^9), 2.5 passengers</td>
<td>3.34</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Double decker buses(^9):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) standard</td>
<td>0.24</td>
<td>0.23–0.38</td>
<td></td>
</tr>
<tr>
<td>(b) ’Jumbo’</td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tramways(^9), two decks:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) maximum</td>
<td>0.078</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) usual</td>
<td>0.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train, diesel(^11), 15 carriage</td>
<td>0.087</td>
<td>0.27</td>
<td>0</td>
</tr>
<tr>
<td>Private car:(^9) (a) five people</td>
<td>1.51</td>
<td>1.47</td>
<td>13.36</td>
</tr>
<tr>
<td>(b) two people</td>
<td>3.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scooter: (a) one passenger(^14)</td>
<td>1.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) two passengers</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle: (a) one passenger(^14)</td>
<td>1.45</td>
<td>12.50</td>
<td></td>
</tr>
<tr>
<td>(b) two passengers</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedicab — two passengers(^16)</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycle(^17)</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Marine:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrofoils:(^18) (a) maximum</td>
<td>2.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) actual</td>
<td>3.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferry:(^19) (a) maximum</td>
<td>0.46</td>
<td>0.07%</td>
<td></td>
</tr>
<tr>
<td>(b) actual</td>
<td>1.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALL VEHICLES</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE VI (continued)

* Direct energy use only.
** Leach (1973)

1 Approximately 1 tonne and 5 tonne vehicles are the two major classes in Hong Kong. Assumed petrol consumption is 7 km/l petrol and 4 km/l diesel respectively. U.K. data: 1 tonne van at 7 km/l. Sources: Goods Vehicle report, unpublished; Traffic and Transport Survey Division, Public Works Department.


3 Adapted from Clark (1973).

4 As footnote 3.

5 Using Leach (1973).

6 Tug of 150 HP pulling dumb steel lighter carrying 300-400 tonnes at 4 knots, consuming 34 l/h. Cargo Handling Unit, Marine Department Hong Kong, personal communication, 1974.

7 Motorised Cargo Boats of 72 HP carrying the average load of 29 tonnes at 7 knots, consuming 4.6 l/h (A.G.O.). Marine Department, Cargo Handling Unit and Marine Fuel Use Section, Department of Oil Supplies, Hong Kong, personal communication, 1974.


9 Taxi and Pak Pai (illegal taxis, private cars used for carrying passengers). Assuming an occupancy of 2.5 passengers or half load, consuming 7 km/l (A.G.O.).

10 Double decker bus operating at about 2.7 km/l. Diesel. Ordinary bus carries 91 passengers including standers, Jumbo bus carries 125 passengers including standers. China Motor Bus Company, Hong Kong and Kowloon Motor Bus Company, personal communication, 1974, U.K. data: 2.3-3.9 km/l with 70 passengers.

11 Tramways — double deck trams operating at roughly 5.4 MJ/km. Peak loads of 24 lower deck, 35 upper deck and 50-60 standers, and more usual occupancy of 40 people total for off peak loads. Hong Kong Tramways Ltd., personal communication, 1974.


13 Private cars in Hong Kong assumed to consume 7 km/l average petroleum. Maximum load five people. average about two people. U.K. data is overall actual car consumption.

14 As in footnote 5.

15 As footnote 14.

16 Adapted from Clark (1973), using Macau, pedicab as the example.

17 As footnote 3.

18 Hydrofoils consume about 7 l/km (I.G.O.). Macau payload 125 passengers and actual 1971 occupancy rates were about 68%. Hong Kong Hydrofoil Co., personal communication, 1974.


of each of the major forms of vehicular transport over the period 1967-1973, and the rate of change in total passenger journeys for each vehicle type where applicable.

The comparative data on energy efficiency for vehicles in the United Kingdom shows compatibility with the Hong Kong findings in most cases. Of the cargo-carrying vehicles, the 1-tonne goods vehicle, the most common size, is
the least energy efficient (Traffic and Transport Survey Division, 1971), and rail cargo-carrying is the most efficient. In local meat, fish and vegetable markets, bicycles are used to deliver smaller amounts of provisions to restaurants and stalls. This efficient transport mode could be improved further if modified to a pedicab like those in Macau or Singapore. Another option would be the heavy frame bicycle of Korea which can carry 140 kg. The introduction of these forms of bicycle should be accompanied by improvements in road systems to ensure reasonable safety. It is shown that scooters, carrying 27 kg loads are a very inefficient form of transportation and as passenger vehicles they are only a marginal improvement over cars, except in terms of mobility and indirect energy input to maintenance over an extended period.

Marine cargo handling is from three to ten times more efficient than road vehicles.

Rail vehicles, trains, or trams, are clearly more efficient as passenger carriers than all other forms of transport, excluding pedicabs. Private cars, taxis and pak pais are very inefficient means of transportation compared with double decker bus services. In marine passenger transport, the ferries are quite efficient at high load factors, whereas the hydrofoils are extravagant in energy terms.

By comparing the per annum increase in vehicle types and the passenger journeys taken in each over the same time period, it is clear that transport in Hong Kong is rapidly decreasing in energy efficiency. Trains are the only form of passenger transport that have made significant gains in the total passenger journeys provided over the period, but this transport mode moves less than 2—3% of all passengers.

**Domestic**

Domestic energy use is 18% of total energy consumption excluding losses in power generation and bunkers (Table I). Table VII shows that six energy forms are utilised, of which three are major. The major energy types in use are kerosene with 47% of domestic consumption, electricity with 31% and liquefied petroleum gas with 12%. Liquefied petroleum gas was introduced in 1960 and has grown rapidly as a domestic fuel since that time. Liquefied petroleum gas and kerosene are predominantly domestic fuels, and it is in this sector that more than 80% of their consumption takes place. Town gas is also a largely domestic fuel but remains a small component of the profile of domestic energy use because of its small overall production. Electricity use is distributed more evenly across all sectors of consumption.

Firewood is widely used in squatter, cottage and temporary housing areas and among boat people in the urban areas, and in the many villages of the New Territories.

At present there is no detailed quantitative breakdown of the end-use of domestic energy. Some quantitative data on domestic energy consumption will come from the Biosocial Survey (1974) and the Hong Kong Continuous
TABLE VII

Type of fuel used for domestic purposes Hong Kong: 1971

<table>
<thead>
<tr>
<th>Fuel</th>
<th>MJ x 10^4</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td>4.49</td>
<td>3</td>
</tr>
<tr>
<td>Charcoal</td>
<td>3.91</td>
<td>3</td>
</tr>
<tr>
<td>Kerosene</td>
<td>64.60</td>
<td>47</td>
</tr>
<tr>
<td>L.P.G.</td>
<td>16.74</td>
<td>12</td>
</tr>
<tr>
<td>Electricity</td>
<td>42.78</td>
<td>31</td>
</tr>
<tr>
<td>Town gas</td>
<td>5.41</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>137.93</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Derived from Newcombe (1975, Table IV).

Household Expenditure Survey (1974). However, Will (1972) and Darkarkis-Smith (1973) provide some useful factual information. This together with the preliminary results of the Biosocial Survey (1974) allow a partly quantitative description to be provided here.

With respect to the type of end-use of each of the domestic fuels, kerosene is largely for cooking, water heating and limited space heating and lighting. Liquefied petroleum gas is a cooking and water heating fuel with some lighting usage. Electricity, which is connected, legally or illegally to 98% of households, is almost invariably used for lighting, displacing the more traditional methods of illumination of kerosene and oil lamps and candles. Its application to cooking is confined to the use of rice-cookers, apart from 10% of the population with electric cookers. Open flame cooking is desirable for the Chinese cuisine.

Electricity is especially convenient for cooling. There are few kerosene or gas refrigerators and gas air conditioners. Therefore, electricity is used almost invariably for fans, air conditioners and refrigeration. About 95% of the population have one or more fans; about 10% have air conditioners and about 75% have refrigerators, although only about 60% of resettlement estate dwellers possess them.

Examination of the monthly domestic sales of electricity throughout the year shows that domestic consumption rises by as much as 75% from the month of March, when no heating or cooling is usually required, to the month of August, which is the peak of the summer season. The major contributor to this increased consumption, which is of the order of 160 million Kwh per annum (6 x 10^8 MJ), is air conditioning, followed by fans and domestic refrigeration. It has been estimated that air conditioning uses about 18% of the total electricity consumption in Hong Kong during the summer period.

The water heating application is less common for electricity and more common for kerosene with over 60% of use and liquefied petroleum gas with over 30% of use or with town gas wherever it is supplied.
Electricity is also used for a large number of other appliances. Approximately 90% of households have television sets, nearly all have radios, about half of which use electricity and half use batteries. About 50% have tape-recorders, some of which use AC only rather than batteries. Washing machines are owned by about 30% of households, but notably only 5% of families in housing estates possess them.

Where town gas is used its application is mainly for cooking and water heating. Firewood and charcoal are used for cooking and rarely for water heating.

An interesting feature of the domestic energy use is that the Chinese family has the opportunity to use at least five or even six fuels for cooking, and they frequently have facilities for using all six forms of energy. Certainly, kerosene and liquefied petroleum gas are common, and the switch from one to the other can be made between meals. Many families retain a charcoal burner which can also burn firewood, coke or coal. These fuels are most commonly used to roast meats and to brew Chinese medicines, and are used annually for the preparation of special foods on such occasions as the Dragon Boat Festival and Chinese New Year.

During the months of the energy crisis in late 1973 and early 1974, Hong Kong residents were accused of hoarding kerosene since there was a significant upswing in the sales of this fuel and a noticeable decline in the rate of growth of the liquefied petroleum gas market. However, no significant hoarding was discovered despite active searching by officials of the Government, which was concerned about the explosive potential of huge private stocks of kerosene. Subsequently a genuine shift in the fuel market was confirmed

TABLE VIII

Relative cost of readily available domestic energy forms 1971—1974*

<table>
<thead>
<tr>
<th>Domestic fuel</th>
<th>December 1971</th>
<th>December 1973</th>
<th>1st quarter 1974</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MJ per HK$1</td>
<td>Cost ratio to kerosene</td>
<td>MJ per HK$1</td>
</tr>
<tr>
<td>Kerosene</td>
<td>72</td>
<td>1.0</td>
<td>65</td>
</tr>
<tr>
<td>L.P.G.</td>
<td>42</td>
<td>2.2</td>
<td>31</td>
</tr>
<tr>
<td>Charcoal</td>
<td>33</td>
<td>2.7</td>
<td>19</td>
</tr>
<tr>
<td>Electricity</td>
<td>23</td>
<td>4.0</td>
<td>22</td>
</tr>
</tbody>
</table>

*The discussion around Table VIII is in regard to the major end-uses of domestic energy i.e. cooking and water heating, where a negligible variation in the efficiency of appliances using each energy type is assumed.

Source: Calculated from Continuous Household Expenditure Survey data used for compilation of the Hong Kong Consumer Price Index. A. Yau, Census and Statistics Department, personal communication, 1974.
(Shell Company, Hong Kong, personal communication, 1974). It seems probable that the more price-conscious households actually took advantage of the cheaper fuel — kerosene — rather than continuing to use, or switch to, liquefied petroleum gas at that time. Table VIII shows the relative cost of readily available domestic fuels during 1971, 1973 and the first quarter of 1974 when the energy crisis conditions still applied. Throughout, it can be seen that kerosene is the cheapest of domestic fuels, and was half the cost of liquefied petroleum gas and one quarter the cost of electricity in 1971. Its relative cost increased during 1972, but during the first quarter of 1974 prices began to rise steeply, leaving kerosene still less in per unit energy terms. Whereas the slight fluctuation of liquefied petroleum gas against kerosene in this period are unlikely to have been sharply observed, the fact that it was generally half the cost for the same amount of work during a time of rapidly increasing prices may well have been noted by sections of the public who were willing to sacrifice the more convenient liquefied petroleum gas for kerosene. Firewood was also scavenged more frequently by those who could use it during the energy crisis (Wah Kiu Man Po, 1974).

**DISCUSSION**

Hong Kong is fast becoming a large industrial consumer of energy, with 31% of its total energy consumption (Table VII) for industrial purposes, being midway between non-industrialised states in the third world and advanced industrial states such as the U.S.A. Light industry such as textiles is predominant, with relatively little heavy industry which characterises more heavily industrialised states, such as the manufacture of iron, steel and machinery. During the next decade it is expected that more heavy industry will develop in Hong Kong. Further development in, say, 10—15 years’ time, will be restricted by the availability of suitable land (i.e. accepting the status quo regarding the British lease of the New Territories from China).

Plans laid down for desalination imply an additional consumption of about 350,000 tonnes of fuel oil per annum before 1980. This consumption is of the same order of Hong Kong Electric’s present consumption in supplying electricity to Hong Kong Island and must be noted as an energy-expensive trend. Certainly during the next 15 years there is likely to be a continued shift to more energy-intensive industrial and commercial processes and future policy makers must be cognisant of the energy demands and potential environmental impact that this trend will bring.

Commercial energy use, at 22% of total consumption (Table VII) highlights the popularity of restaurant and food stall patronage as part of the local culture.

The construction of large commercial buildings dependent on total energy systems which take minimal advantage of the external environment to ventilate, heat or light their facilities, implies increasing energy overheads for each commercial worker, and exposes key commercial complexes to inactivity during ‘brown outs’.
Transport, using 29% (Table VII) of total energy consumption, is shown to be rapidly decreasing in energy efficiency. In this respect it mirrors trends in the huge transport systems of the industrial states. Local policy directions, such as bus-only lanes, and higher fees for private car registration and parking, when fully implemented will slow down this trend but will not altogether eradicate it. Rail vehicles in Hong Kong move people efficiently and with the lowest energy consumption per mile. According to a report on Transport in Hong Kong (1974), the construction of the underground railway mass transit system is designed to cater for a third of an anticipated 7,500,000 passenger journeys per day by 1985. If it goes ahead the energy-expensive trend in transport efficiency is likely to be considerably reduced. The construction of mass transit systems would simultaneously increase the efficiency and equity of transport energy use. Understanding patterns of energy use is important when considering transport alternatives for social, as well as resource use reasons. The data presented here provides strong support for the contention by Hirst and Moyers (1973) that moving from energy-expensive to energy-efficient transport modes can result in very significant energy savings for the system as a whole.

Domestic energy consumption is high in Hong Kong in comparison to other sectors, but has not received the same quantitative analysis of end-use. It can be seen that Chinese families are sensitive to variations in cost and have an unusual opportunity to shift fuel consumption patterns accordingly. Some domestic energy use is necessary for an acceptable life style in contemporary urban settlements. Information on present patterns of domestic energy consumption can reveal the biological and cultural significance of particular end-uses, and help determine the minimal needs for the future; for example, the impact of particular forms of energy use on the capacity of the individual to adapt to increasing physical densities and rapid changes in the urban environment is unknown. In this regard the present study is considered preliminary to the examination of psycho-social variables interacting with energy use to alleviate stress in the residential environment in particular.

Only with an analysis of energy use can planners regulate an economy without disruptions during times of energy shortages. Energy availability is now fundamental to the ongoing existence of contemporary urban settlements. For some, a state of complete dependence on a high level of energy use has only recently evolved. Hong Kong uses ten times more energy now than it did 20 years ago. This is not to say that Hong Kong 'needs' ten times more energy; however, only if current patterns of energy use are evaluated can the question of 'current needs' versus 'current consumption' be intelligently tackled.

ACKNOWLEDGEMENTS

I would like to gratefully acknowledge the advice of S.V. Boyden, J.D. Kalma and A.R. Aston during the process of research and in the preparation of the manuscript.
REFERENCES


Biosocial Survey, 1974. A survey of 4,000 households selected by housing type and area in Hong Kong as part of the Hong Kong Human Ecology Programme. The survey will be processed during 1975. It asks questions on both somatic and extrasomatic energy use of the individual and the household amongst other mostly health-orientated questions. Directed by S.E. Millar, S.V. Boyden and Ken Newcombe, Urban Biology Group, Australian National University, Canberra, A.C.T.


Census of Manufacturing Establishments, 1971. Census and Statistics Department, Hong Kong Government Printer, Hong Kong.


Hong Kong Continuous Household Expenditure Survey, 1974. Transcription of data collected for the Continuous Household Expenditure Survey by the Department of Census and Statistics, Hong Kong. Data from 1,500 households from 1971 and 1973 records has been transcribed on nutritional, energy use and other factors in relation to socio-economic variables. Directed by Ken Newcombe, Urban Biology Group, Australian National University, Canberra, A.C.T.


Transport in Hong Kong, 1974. A Paper for Public Information and Discussion. Hong Kong Government Printer, Hong Kong.


Wah Kiu Man Po, 1974. Comments on increased fuel prices and a resulting tendency to scavenge scrap wood from building sites. Wah Kiu Evening News, 3rd May.

Will, B.F., 1972. Unpublished results of a survey of residents in two housing estates, Li Cheng Uk and Chai Wan, Hong Kong. Department of Architecture, University of Hong Kong.
APPENDIX I

Sector end-use by fuel type, Hong Kong: 1971 (MJ × 10^4)*

<table>
<thead>
<tr>
<th>Sector</th>
<th>Electricity^a</th>
<th>Town gas^b</th>
<th>Fuel oil^c</th>
<th>Liquefied petroleum gas^d</th>
<th>Gasoils, diesel fuel^e</th>
<th>Kerosene^f</th>
<th>Solid fuels^g</th>
<th>Total^1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food</td>
<td>1.38</td>
<td>10.59</td>
<td></td>
<td>2.70</td>
<td>0.09</td>
<td>0.20</td>
<td>14.96</td>
<td></td>
</tr>
<tr>
<td>Textiles (incl. printing, dyeing)</td>
<td>31.77</td>
<td>0.19</td>
<td>86.32</td>
<td>0.89</td>
<td>7.60</td>
<td>0.19</td>
<td>126.96</td>
<td></td>
</tr>
<tr>
<td>Clothing (wigs and shoes)</td>
<td>2.31</td>
<td>1.54</td>
<td></td>
<td>0.10</td>
<td></td>
<td></td>
<td>3.95</td>
<td></td>
</tr>
<tr>
<td>Woodworks, tanneries, etc.</td>
<td>0.01</td>
<td>0.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>Paper, printing</td>
<td>0.03</td>
<td>0.20</td>
<td>0.46</td>
<td></td>
<td></td>
<td></td>
<td>0.20</td>
<td>0.89</td>
</tr>
<tr>
<td>Chemicals and paints</td>
<td>3.22</td>
<td>1.38</td>
<td>0.10</td>
<td>0.60</td>
<td>0.05</td>
<td></td>
<td>5.35</td>
<td></td>
</tr>
<tr>
<td>Metals, glass and related products</td>
<td>2.95</td>
<td>4.26</td>
<td>0.10</td>
<td>1.50</td>
<td>0.14</td>
<td></td>
<td>10.54</td>
<td>19.49</td>
</tr>
<tr>
<td>Farming</td>
<td>5.63</td>
<td></td>
<td></td>
<td>0.44</td>
<td></td>
<td></td>
<td>6.07</td>
<td></td>
</tr>
<tr>
<td>Engineering and shipbuilding</td>
<td>0.58</td>
<td>0.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td>Waterworks</td>
<td>5.35</td>
<td></td>
<td></td>
<td>1.65</td>
<td></td>
<td></td>
<td>7.00</td>
<td></td>
</tr>
<tr>
<td>Rubber, plastic (incl. toys)</td>
<td>1.07</td>
<td>1.50</td>
<td>0.10</td>
<td>1.0</td>
<td></td>
<td></td>
<td>3.67</td>
<td></td>
</tr>
<tr>
<td>Iron and steel</td>
<td>0.14</td>
<td>3.80</td>
<td></td>
<td>0.05</td>
<td></td>
<td></td>
<td>3.85</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>0.14</td>
<td>2.53</td>
<td></td>
<td>11.29</td>
<td></td>
<td></td>
<td>13.96</td>
<td></td>
</tr>
<tr>
<td>Electronics, electrical and fine</td>
<td>1.66</td>
<td>0.39</td>
<td>113.38</td>
<td>1.19</td>
<td>27.23</td>
<td>0.47</td>
<td>10.94</td>
<td>209.67</td>
</tr>
<tr>
<td>mechanical products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-total (1)</td>
<td>56.07</td>
<td>0.39</td>
<td>113.38</td>
<td>1.19</td>
<td>27.23</td>
<td>0.47</td>
<td>10.94</td>
<td>209.67</td>
</tr>
</tbody>
</table>
### APPENDIX I (continued)

<table>
<thead>
<tr>
<th>Commercial</th>
<th>1.38</th>
<th>2.50</th>
<th>3.88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam laundry and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dry cleaning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offices</td>
<td>6.25</td>
<td></td>
<td>6.25</td>
</tr>
<tr>
<td>Shops and wholesale</td>
<td>6.50</td>
<td></td>
<td>6.50</td>
</tr>
<tr>
<td>trade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Godowns and cold</td>
<td>1.11</td>
<td></td>
<td>1.11</td>
</tr>
<tr>
<td>storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotels and restaurants</td>
<td>10.75</td>
<td>3.23</td>
<td>3.11</td>
</tr>
<tr>
<td>Cinemas and theatres</td>
<td>0.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film studios and</td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rediffusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitals</td>
<td>0.08</td>
<td>0.08</td>
<td>1.61</td>
</tr>
<tr>
<td>Schools and education</td>
<td>1.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>institutions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Armed services</td>
<td>1.60</td>
<td>0.38</td>
<td>0.50</td>
</tr>
<tr>
<td>Communications</td>
<td>1.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>5.59</td>
<td>0.15</td>
<td>4.50</td>
</tr>
<tr>
<td>Sub-total (2)</td>
<td>35.96</td>
<td>3.84</td>
<td>11.65</td>
</tr>
<tr>
<td>Overall Total</td>
<td>92.03</td>
<td>4.23</td>
<td>125.03</td>
</tr>
</tbody>
</table>

*Represents a breakdown of identifiable significant end-uses in the given categories. Total identifiable end-use within the commercial—industrial sectors is 88% of the total of the combined commercial—industrial sector consumption.

11% of the total is from China light and power "general tariff" sales for which no breakdown of end-use other than "commercial" and "industrial" and "domestic" is available. For the construction of Fig.1 all amounts of energy with unidentified end-use have been allocated pro-rata.

**Sources:**

- General and Bulk tariff analysis provided by C.P. Man, Hong Kong Electric and Mr Laufer, China Light and Power. Cheung Chau Electric represents a negligible proportion of total electricity generation and end-use.
- Sales records by major consumers provided by R. Chan, Hong Kong and China Gas Co.
- As per Newcombe (1975) Table V.
- As per Newcombe (1975) Table VI.
- As in (d).
- As shown in Appendix II.
## APPENDIX II

**Solid fuels — end-use in Hong Kong: 1971**

### Firewood:
- Imported as such: $1.53 \times 10^8$ MJ
- Estimated to be used as stolen, sold scrap from building sites, and scrap from locally grown (neg.). Taken as 5% of total roughly hewn and cleaned conifer logs, i.e.: $2.96 \times 10^8$ MJ
- **Total**: $4.49 \times 10^8$ MJ  
  *(All domestic use)*

### Coal:
- Imported: $9.40 \times 10^8$ MJ
- Re-export: $0.10 \times 10^8$ MJ
- Net import: $9.30 \times 10^8$ MJ

Personal communication with Coal Depot Staff, major coal dumping centre, Kowloon, April 24th, 1974 gave estimates:
- Smelting, metal works 95%: $8.84 \times 10^8$ MJ  
  *(Industrial)*
- Restaurants (particular grade) 5% used for some roasting: $0.46 \times 10^8$ MJ  
  *(Commercial)*

### Coke:
- Imported: $2.62 \times 10^8$ MJ

Personal communication with Depot Staff, Kowloon, April 24th, 1974. Coke is used for smelting and for restaurants because of its smokeless quality.
- 1.31 $\times 10^8$ MJ  
  *(Commercial)*
- 1.31 $\times 10^8$ MJ  
  *(Industrial)*

### Charcoal:
Extract from interview with the major importer, wholesaler and retailer in Hong Kong, NAM HOP Co., May 7th, 1974
- Total import: $7.83 \times 10^8$ MJ
- 40% by restaurants: $3.13 \times 10^8$ MJ  
  *(Commercial)*
- 0.5% melting lead and pig iron moulding: $0.39 \times 10^8$ MJ  
  *(Industrial)*
- 2.5% drying paper: $0.20 \times 10^8$ MJ  
  *(Industrial)*
- 2.5% preparing foodstuffs, medicines: $0.20 \times 10^8$ MJ  
  *(Industrial)*
- 50% domestic use: $3.91 \times 10^8$ MJ  
  *(Domestic)*

**Overall**
- Domestic: $3.91 \times 10^8$ MJ
- Commercial: $3.13 \times 10^8$ MJ
- Industrial: $0.79 \times 10^8$ MJ

**Total**: $7.83 \times 10^8$ MJ
APPENDIX III

Per capita estimations of energy use in transport: 1971

<table>
<thead>
<tr>
<th>Description</th>
<th>Energy</th>
<th>Energy</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>originating</td>
<td>used in</td>
<td>NOT used in</td>
</tr>
<tr>
<td></td>
<td>in Hong Kong</td>
<td>Hong Kong</td>
<td>Hong Kong</td>
</tr>
<tr>
<td></td>
<td>(MJ x 10^8)</td>
<td>territory</td>
<td>territory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MJ x 10^8)</td>
<td>(MJ x 10^8)</td>
</tr>
<tr>
<td>Population, 1971:</td>
<td>3,939,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per capita consumption for transport, including bunkers:</td>
<td>727.11 x 10^8</td>
<td>18.5 x 10^8</td>
<td></td>
</tr>
<tr>
<td>Per capita consumption for transport actually used in Hong Kong territory (see Table IV and &quot;Fuel released for use in Hong Kong but not actually used in Hong Kong: 1971&quot;)</td>
<td>189.73 x 10^8</td>
<td>4.8 x 10^8</td>
<td></td>
</tr>
<tr>
<td>Per capita consumption for land transport:</td>
<td>219.75 x 10^8</td>
<td>3.3 x 10^8</td>
<td></td>
</tr>
<tr>
<td>Fuel released for use in Hong Kong but not actually used in Hong Kong: 1971</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Energy</th>
<th>Energy</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>originating</td>
<td>used in</td>
<td>NOT used in</td>
</tr>
<tr>
<td></td>
<td>in Hong Kong</td>
<td>Hong Kong</td>
<td>Hong Kong</td>
</tr>
<tr>
<td></td>
<td>(MJ x 10^8)</td>
<td>territory</td>
<td>territory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MJ x 10^8)</td>
<td>(MJ x 10^8)</td>
</tr>
<tr>
<td>(1) Hydrofoils: 40% of hydrofoils' passage to Macau is in Hong Kong waters. (see Table IV)</td>
<td>2.86</td>
<td>1.16</td>
<td>1.70</td>
</tr>
<tr>
<td>(2) Fishing fleet: 90% of fishing fleet's operations are outside Hong Kong waters. (see Table IV)</td>
<td>61.26</td>
<td>6.12</td>
<td>55.14</td>
</tr>
<tr>
<td>(3) Aviation bunkers: 196.37 x 10^8 MJ of aviation fuel is for international flights leaving 2.62 x 10^8 MJ for local use. Aircraft moving in and out of Hong Kong use about 36.78 x 10^8 MJ in Hong Kong airspace, half of which is from Hong Kong bunkers (R.J. Watson, Cathay Pacific, personal communication, 1974).</td>
<td>196.37</td>
<td>18.39</td>
<td>177.98</td>
</tr>
<tr>
<td>(4) Ocean-going vessel bunkers: Fuel oil and diesel use in Hong Kong Harbour by ships. Conservatively about 33.16 x 10^8 MJ of fuel oil and diesel oil are used in Hong Kong Harbour. Calculations based on data of in harbour fuel consumption and bunkering requirements (A.J.S. Lack, personal communication, 1974)</td>
<td>312.61</td>
<td>33.16</td>
<td>279.45</td>
</tr>
<tr>
<td>(5) Export: to Macau and Oceania in the form of coal, motor spirit, kerosene, gasoil and fuel oil. (See Newcombe, 1975, Table IV)</td>
<td>23.11</td>
<td></td>
<td>23.11</td>
</tr>
<tr>
<td>Total:</td>
<td>596.21</td>
<td>58.83</td>
<td>537.38</td>
</tr>
</tbody>
</table>
CHAPTER IV

SPATIAL AND TEMPORAL PATTERNS OF ENERGY USE IN HONG KONG
INTRODUCTION

It is now common to describe energy-use in a country or a large defined area such as a state or province in terms of its end-use in major sectors of the economy and even to extend the analysis to a description of end-use by major activities within each broad sector (e.g. see S.R.I., 1972; N.E.D.O., 1974; Hedley, 1974; Myers, 1974). Such studies are useful in determining the capacity for energy conservation, for establishing the economies of alternative fuels and are important in directing general energy management policies. However, while broad patterns of energy-use and input-output analysis at the level of the nation, region or even settlement are informative about the overall energetic behaviour of the system under study, they cannot, except in the most general way, be used to predict the physicochemical and biosocial consequences of energy-use. In order to understand the impact of varying levels and differing kinds of applications of energy-use on the physicochemical and biosocial environment more exhaustive analyses, including spatial and temporal and socio-economic patterns of energy-use, must be undertaken.

It has long been understood that spatial patterns of fossil fuel consumption are closely related to patterns of air pollution in urban settlements. It is also well documented that artificial heat generation from man's energy consumption is an important component in the modification of urban microclimates (Landsberg, 1973) and that an inventory of energy-use documenting both spatial and temporal, i.e. seasonal and diurnal, patterns of energy
consumption is vital to an understanding of the changing climate in the urban environment (Bach and Patterson, 1969).

Nevertheless, only a very few detailed studies of spatial and/or temporal aspects of energy-use in urban areas have been reported in the literature (Garnett and Bach, 1965; U.S. Department of Health, Education and Welfare, 1967; Kalma et al, 1972; Geiger, 1974). This present study, which is part of the Hong Kong Human Ecology Programme, adopts and refines methodology developed by Kalma et al (1972) in their study of the Sydney statistical district in Australia. The data gathered and presented here, apart from their direct implications for urban planning and the human environment, provides information basic to numerical modelling of SO₂ or CO dispersal and to studies on urban heat islands (Kalma, Johnson and Newcombe, in preparation). This data has also enabled detailed studies on the impact of energy-use on human health and well-being in Hong Kong. The basic data on input-output and sector end-use analysis from which these spatial and temporal patterns of energy-use are derived have been published elsewhere (Newcombe, 1975a and b).

1. The Hong Kong Human Ecology Programme is co-ordinated by the Urban Biology Group at the Australian National University. Field work was based in the Centre of Asian Studies, University of Hong Kong and the Social Research Centre of the Chinese University of Hong Kong. The programme, supported by UNEP/UNESCO funds (MAB Project 11) also received co-operation from the Hong Kong Government.

2. A paper on this topic, entitled 'Energy use and human well-being in urban centres: the case of Hong Kong' was presented by the author to the Energy Symposium, 13th Pacific Science Congress, Vancouver, August 1975.
Background Information on Hong Kong applicable to the Study

Hong Kong had a population of 3.9 million people in March 1971, distributed over a land area of 1,046 km$^2$. 88% of the population was concentrated in wholly urban areas covering 146 km$^2$ or 14% of the Hong Kong territory.

The yearly mean temperature in Hong Kong is 22.3°C, but the monthly mean temperatures range from 15.2°C in February, the coldest month of the year, to 27.9°C in July, the warmest month. In summer the temperature often reaches 32°C or higher.

The relative humidity is highest in summer, reaching a maximum in the months of April and May. The winter months have a much lower humidity with the lowest monthly mean of the year (69%) occurring in November.

The mean yearly duration of bright sunshine is 1963 hours. The shortest duration occurs in the month of February, March and April and is due to shorter daylight hours as well as the prevalence of extensive low cloud.

For the spatial distribution of energy, secondary planning units alone or groupings of tertiary planning units, as drawn up by the Hong Kong Government for its population data collection, were adopted and are referred to as 'defined areas' (see Figures 1 and 2). The names of the coded areas are referred to in footnotes to Table 1.

These defined areas vary from 1 to 38 km$^2$ in the major urban area to from 1 to 221 km$^2$ in the New Territories of Hong Kong. Similarly, population densities vary from 600 to 141,000 persons km$^2$ in the urban area to from 1 to 19,000 persons km$^2$ in the New Territories.
A. Spatial Distribution

Methodology: Energy use in each of the defined areas was divided between industrial, commercial, domestic and transport sectors of activity. This process of allocation involved analysis of end-use in terms of industry, commerce, transport, households and major point losses (e.g. power utilities and incinerators) for each fuel type in each defined area. Overall energy-use in each defined area was then obtained by merely summing the expenditure under each fuel type.

Groundrules were drawn up using existing information to enable an analysis of the spatial distribution of consumption of fuel types for which no information was available. Reliable information on the spatial distribution of electricity consumption was obtained from the company which generates 75% of Hong Kong's electricity (E.M. Laufer, China Light and Power Co. personal communication, 1974). The spatial units and activity categories utilised by the company in accounting for its sales to consumers were easily transformed to fit the defined areas and sectors of activity adopted in the present study. Most of the remaining 25% of electricity generated in Hong Kong was consumed on Hong Kong and Lamma Island. While information on the spatial distribution of consumption of this electricity was not available its end-use by activity was documented (C.P. Man, Hong Kong Electric Co. personal communication, 1974). On the basis of local knowledge and from the location of major industries and detailed land-use maps, the spatial pattern of electricity consumption in these remaining areas was
estimated with reasonable accuracy. The pattern of spatial
distribution of electricity consumed for domestic purposes
was assumed to follow the pattern of population distribution
as did the electricity consumed for domestic purposes for
which the spatial distribution of consumption was available.

The pattern of spatial distribution of fuel oil
was determined from detailed records provided by the Air
Pollution Control Unit of the Public Works Department
(D. Newberry, personal communication, 1974) showing the
exact location and amount of fuel oil consumption for each
commercial and industrial activity. These data were derived
from information supplied by the Department of Labour, specifying
the exact location, size and nature of pressure equipment
installed in Hong Kong and the activity for which it was
used (Mr. Lobo, Pressure Equipment Unit, personal
communication, 1974). Fuel oil accounted for in this manner
represented 61% of total fuel oil consumption, leaving 39%
which was assumed to follow the same distribution pattern as
commercial and industrial electricity in each defined area.

Records from the Air Pollution Control Unit also
provided information on the spatial distribution of the 39%
of gasoils, diesel fuels and distillates not used for
transport. 64% of industrial consumption and 50% of
commercial consumption of these fuels was allocated according
to commercial and industrial electricity spatial distribution.

83% of kerosene consumption is domestic. The
pattern of distribution of consumption in this sector was
assumed to follow population density. Industrial and
commercial consumption of kerosene was assumed to exhibit
the same spatial distribution as industrial and commercial
electricity consumption in each defined area.

Liquefied petroleum gas (L.P.G.) is also largely a domestic fuel, and the domestic component, or 75% of its use, was also assumed to be directly related to the distribution of population. The spatial patterns of consumption of the remaining 19% used for commercial purposes and 6% used for industrial purposes were assumed to be the same as for electricity in each of these sectors.

Information describing the spatial distribution of town gas by end-use was provided by Hong Kong and China Gas Co. (W. Chan, personal communication, 1974).

Solid fuels represent only 1.9% of total energy consumption. 95% of coal is used for industrial purposes and hence was distributed following the pattern of industrial electricity consumption. The patterns of consumption of electricity consumed for industrial and commercial purposes were also used to estimate the spatial distribution of charcoal use, apart from its domestic consumption for which population density was taken as an indication. Coke was distributed in the same manner. Firewood consumption, which was solely for domestic purposes, was distributed spatially according to the distribution of squatters and temporary housing dwellers, including boat people (K.S. Pun, Public Works Department, personal communication, 1974) as these were the only groups of people regularly observed to use firewood.

Transport energy use is considered in terms of road, rail, marine and air transport categories. The frequency and distribution of road transport in Hong Kong is monitored by 270 check points covering all
road reticulation in the Colony. Heavily trafficked areas are monitored daily and less trafficked areas, weekly, monthly or yearly, depending on their suspected importance for transport movement. Records of traffic flow for each point were available for 1971 (Barden and Pang, 1973). Using these records the road networks were mapped, facilitating the allocation of all or portions of particular checkpoint traffic flows to be made to each defined area. The energy economy of each vehicle type, recorded as part of the spectrum of transport at each checkpoint has been evaluated previously (Newcombe, 1975b). From these data a division of light and heavy vehicles according to fuel consumption and fuel type, i.e. motor spirit and automotive gasoil, was established. Total fuel consumption in litres, which could then be converted into MJ, was determined by the following formula:

\[
\frac{C_T}{C_H} = \frac{H\% A \times K}{H\% A \times K} \times \frac{(100 - H\%) A \times K}{(100 - H\%) A \times K}
\]

where

- \(C_T\) = total fuel consumption (km/litre)
- \(C_H\) = fuel consumption of heavy vehicles (km/litre)
- \(C_L\) = fuel consumption of light vehicles (km/litre)
- \(H\%\) = % heavy vehicles make up of total vehicles
- \(A\) = annual average daily traffic (AADT), (numbers of vehicles)
- \(K\) = kilometres of roadway covered by checkpoint

The theoretical values calculated for each checkpoint and totalled for each defined area were used to determine the proportion each defined area contributed to the total road transport energy consumption. These proportions
multiplied by the known overall consumption of motor spirit and automotive gasoil in Hong Kong (Newcombe, 1975b) provided data on the transport energy-use for each defined area. The difference between theoretical energy-use per defined area and that calculated as a proportion of known total transport energy consumption was less than 10%.

For the purposes of this study, marine transport energy-use was considered for only two major areas; Aberdeen Harbour and Victoria Harbour. In each case field work on transport mode and location of operation enabled an estimate of the proportion of total energy consumption by each to be allocated to these major areas (Newcombe, 1975b). In addition to this, the amount of fuel used in Victoria Harbour by ships loading and unloading was calculated and added to total artificial heat generation in this area (Appendix 1).

Rail transport energy consumption was distributed according to the frequency of scheduled travel over the specified routes in each defined area.

Energy-use in Hong Kong airspace was calculated using data supplied by the Hong Kong-based airline, Cathay Pacific (R.J. Watson, personal communication, 1974) and was allocated to defined areas in accordance with the on-ground, taxiing, take off and landing manoeuvres and flight paths inside Hong Kong territory (Appendix 2). Local aviation energy-use was distributed in the same manner.

Major point losses of energy, including power stations and refuse incineration plants, were readily located in defined areas.
Estimations of somatic energy-use and hence heat contribution of humans and animals in the Hong Kong environment were made for the purposes of comparison, but were not tabulated with other data.

RESULTS

Tables 1 to 5 represent the distribution of energy-use by fuel type between each of the defined areas for domestic, industrial, commercial, transport and point losses respectively. Table 6 is a summation of the final columns of Tables 1 to 5, presenting the intensity of energy-use of all kinds except somatic energy in each of the defined areas. In the major urban areas, the intensity of energy use ranges from $0.14 \text{ MJ} \times 10^8/\text{km}^2/\text{yr}$ for the sparsely populated water catchment zone of southern Hong Kong Island (defined area 1.9) to $109.46 \times 10^8 \text{ MJ}/\text{km}^2/\text{yr}$ for Hung Hom, a populous area of Kowloon where the Hok Yuen Power Station and Tokwawan town gas plant are sited. In the New Territories region, the intensity of energy use ranges from $0.02 \times 10^8 \text{ MJ}/\text{km}^2/\text{yr}$ to $17.36 \times 10^8 \text{ MJ}/\text{km}^2/\text{yr}$ on Tsing Yi Island, the location of another major power generating utility.

Figures 1 and 2 present the data contained in Table 6 diagrammatically over the major urban areas and the New Territories respectively.

Table 7 compares, for defined parts of eleven large urban areas in 6 countries, area, population size,
population density, total energy-use, intensity of energy-use
and an index of the population's exposure to the physico-chemical
and biosocial biproducts of energy use, the 'energy exposure
index*'. Hong Kong has the second lowest intensity of energy-use,
considering areas of roughly comparable size. However, when
selected urban areas of Hong Kong are compared, the intensity
of energy use in Hong Kong is of the same order as that of
Cincinnati, Sheffield, Fairbanks and the highest consuming areas
of Sydney. Comparing data from Table 6 as well, it is clear
that small parts of the Hong Kong urban area have as high or
higher intensity of energy use as any of the urban settlements
listed for comparison. The energy exposure index shows that
in large parts of Hong Kong, more people are exposed to the
biproducts of energy use than in any of the urban areas subject
to comparison.

B) Temporal Distribution

1) SEASONAL:

Methodology: February, as mid-winter, and July as mid-summer
were taken to represent seasonal opposites in Hong Kong in order
to calculate seasonal variation in energy-use. All available
data on the seasonal variation in energy-use was used to calculate
factors determining the proportion of mid-summer and mid-winter
values made of the annual average daily energy-use by fuel type
in each defined area, the latter being calculated directly
from Tables 1 to 5.

*This index is simply the product of population density and intensi-
of energy use in a defined area. There is no unitary relationship
between the figures obtained in this way, although certain classes,
such as low, medium and high might be deduced. In effect the
index provides an indication of the likelihood of deleterious effect
of high energy consumption. The tacit assumption is that other
factors such as technology, climate and so on being constants, the
higher the energy-use per unit area, the greater the potential for
the physicochemical and biosocial environment to be changed to
the detriment of the health and well-being of the occupants of
that area. Clearly the more people exposed to an unhealthy
environment, the more serious the problem becomes.
Groundrules to predict the seasonal distribution of energy forms for which no precise information existed were established, using data on energy forms for which reasonably accurate information on seasonal trends was available.

Electricity production on a monthly basis by sector of consumption is recorded by the Department of Census and Statistics (1972), as is town gas production. Fuel oil for industrial and commercial use was distributed seasonally following the recorded mean of the seasonal variation of town gas and electricity consumption, and the same rule was applied to the seasonal variation of gasoils, diesel fuels and distillates used in industry. From the nature of their end-use it was assumed that gasoils, diesel oils and distillate consumption in the commercial sector exhibited no marked seasonal variation.

The seasonal variation in consumption of kerosene and LPG, both largely domestic fuels, was calculated from the records of monthly releases from customs bondage (Census and Statistics, 1972). This information was used in association with the available information on the seasonal variation of town gas consumption, another mostly domestic fuel, to predict the seasonal variation in both LPG and kerosene.

Seasonal variability in the industrial consumption of kerosene and LPG was determined using the mean of the seasonal variability in industrial town gas and industrial electricity consumption. The same rule was applied to seasonal variation in commercial consumption of kerosene and LPG in relation to commercially consumed town gas and electricity.
Amongst the solid fuels, firewood, because of the similarity of end-use, was assumed to exhibit the same seasonal variation as town gas consumed in the domestic sector. Seasonal variation in the industrial consumption of charcoal was taken to be the same as for industrial electricity and the seasonal variation in its commercial consumption was taken to follow that for town gas. The average of LPG, town gas and kerosene seasonal variation was taken as an indication of the seasonal variation in domestic charcoal consumption.

Seasonal variation in commercial coke consumption was taken to follow that for town gas, and the consumption of coke in the industrial sector was assumed to vary seasonally, as did the mean seasonal variation of electricity and town gas consumption in the industrial sector.

The commercial consumption of coal was taken to exhibit the same seasonal variation as the commercial consumption of town gas, and industrial consumption of coal was expected to exhibit the same seasonal variability as the consumption of electricity and town gas in the industrial sector.

Records of monthly releases from customs bond of automotive gasoil and motor spirit (Census and Statistics, 1971, 1972) indicated the seasonal variation in energy consumption of road transport. Similar data were made available by the Census and Statistics Department for industrial gasoil used for marine transport purposes (H.K. Yip, personal communication, 1974).

According to schedules of service, neither rail nor air transport showed significant variation of energy-use on a seasonal basis.
RESULTS

Tables 8 to 12 represent the estimated mid-winter and mid-summer values of energy-use by fuel type for each defined area, for the domestic, industrial, commercial transport and point losses respectively.

In the domestic sector (Table 8) electricity consumption increases by 37% in mid-summer over mid-winter whereas other fuels, such as kerosene and LPG show a 32% reduction in consumption in mid-summer against mid-winter. Town gas consumption is also down by 22% in the mid-summer period in relation to mid-winter consumption. Overall there are increases and decreases of up to 12% in the mid-summer consumption, compared with mid-winter consumption, depending on the proportion of the various fuels in use in each defined area.

Consumption of electricity in the industrial sector rises by 43% in mid-summer compared with mid-winter and town gas follows the same trend, but with a 32% increase. The average increase in consumption of energy in the industrial sector in mid-summer compared with the mid-winter period is greater than 40% (see Table 9).

In the commercial sector (see Table 10) the mid-summer consumption of electricity increases over consumption in mid-winter by 56%. However, there is a 12% average decline in the mid-summer consumption of other commercial fuels, giving rise to an overall increase in energy consumption in mid-summer over mid-winter of 16-18%.

Road transport energy consumption increased by 11% in mid-summer over mid-winter and marine consumption increased by 22% comparing the same periods. (see Table 11).
Point losses, that is artificial heat generation from power stations, is 46% higher in mid-summer than mid-winter, whereas heat generated from refuse incineration is about 50% less in mid-summer (see Table 12).

Table 13 represents a summation of the mid-winter and mid-summer values for each of the sectors of activity. It shows that total energy use in Hong Kong is 26% higher in mid-summer than mid-winter.

2) DIURNAL PATTERNS OF ENERGY-USE

Methodology: Load curves showing diurnal patterns of consumption of both electricity and town gas were available (C.P. Man, Hong Kong Electric and W. Chan, Hong Kong and China Gas Co., personal communication, 1974). The data on electricity included diurnal consumption patterns for both winter and summer. This basic data enabled groundrules to be drawn up to estimate the diurnal pattern of consumption of fuels for which no such data existed.

Summer consumption of electricity is considerably effected by the extensive use of cooling devices such as air conditioners. Cooling devices are rarely used extensively in the Hong Kong industrial setting. For that reason the pattern of diurnal variation exhibited by electricity consumed in winter was used to estimate diurnal variation in the consumption of fuels in the industrial sector. Nevertheless, even the winter diurnal consumption pattern for electricity included domestic and commercial activities, contributing an unavoidable error to the prediction of diurnal variation in consumption patterns for other industrial fuels.

The diurnal pattern of industrial consumption of
electricity was taken from the winter curve for all seasonal conditions. Domestic and commercial consumption was taken as following the summer curve in summer and the winter curve in winter. The diurnal load curve for town gas was applied to all sectors in both seasons, but was thought to reflect domestic consumption patterns in particular given its major domestic end-usage. Hence the pattern of LPG and kerosene consumption throughout the day were estimated using the town gas load curve.

The consumption of fuel oil was assumed to follow the same diurnal pattern as electricity in the winter period.

Diurnal variation in gasoils, diesel fuels and distillates consumed in the commercial and industrial sectors was estimated from direct field observation of the activity patterns of the major consumers (Newcombe, 1975b). These observations were supported by data on diurnal patterns of commercial and industrial activity collected by the Air Pollution Control Unit of the Public Works Department (F. Chan, personal communication, 1974).

For the solid fuels, town gas distribution patterns were applied to firewood consumption and to domestic consumption of charcoal. The diurnal pattern of consumption for electricity in winter was applied to charcoal, coke and coal consumed in the industrial and commercial sectors.

For road transport energy-use, a group of 10 major checkpoints in the urban area were selected and the magnitude of traffic flow for each 2-hourly period for the average day was read off graphs of diurnal variation in traffic flow plotted by the traffic survey division of the Public Works Department (Barden and Pang, 1974). A weighted mean of the percentage
of traffic flow for each 2-hourly period was then applied to road transport energy consumption in each defined area in mid-summer and mid-winter.

The diurnal pattern of marine transport activity was determined from operating schedules and field observation of major marine transport forms.

Operating schedules provided the diurnal patterns of energy consumption for rail and air transport.

Data on incoming solar radiation were collected for comparison with artificial heat generation in selected defined areas. The intensity of incoming solar radiation over 12 2-hourly periods for mid-winter and mid-summer days was taken as an average of 10 actinographs, for full cloud through to no cloud in each July and February of 1970 and 1971. The 40 actinographs were supplied by the Royal Observatory in Hong Kong (P.C. Chin, personal communication, 1974).

RESULTS

Figures 3 to 10 are graphs of sector by sector patterns of diurnal variation in mid-summer and mid-winter for all of Hong Kong and Hung Hom, Kwun Tong and Tsuen Wan respectively. The areas selected for graphical presentation are broadly representative of urban Hong Kong. Hung Hom is a populous urban area on the Kowloon peninsula where the Hok Yuen Power Station is sited. Kwun Tong is representative of a medium density industrial zone and Tsuen Wan is a new residential, commercial and industrial estate to the north-west of New Kowloon in the New Territories. Figures 5 and 6 for Hung Hom are drawn on log scale in order to compare
the size of artificial heat generation from the Hok Yuen Power station with that from the major sectors of activity in the area. These figures show that heat lost from the power station in particular is greater than an order of magnitude higher than from any sector of activity in the region.

The contribution of industrial activity to artificial heat generation in new industrial estates is depicted in Figures 7-10 for Kwun Ton and Tsuen Wan respectively. In Hung Hom, commercial activities are as important as industrial activities in generating heat during parts of the morning, particularly in the winter period (Figures 5 and 6). In both industrial areas domestic energy use is generally two to three times more important as a heat source than commercial activities (Figures 7-10). It is only in Kwun Tong that transport activity exceeds the contribution to artificial heat generation of any other sector, except during the morning peak hours in the more central urban areas (see Figures 5 and 6). Invariably transport energy-use falls to a lower level during the day than any other sector of activity, usually between 0300-0500 hours. Generally energy-use in all sectors reach minimum levels between 2300 and 0600 hours and show a marked upsurge between 0600 and 0900 hours.

Figures 11 to 14 illustrate the seasonal variation in diurnal trends for all of Hong Kong, Hung Hom, Kwun Tong and Tsuen Wan respectively. Invariably mid-summer artificial heat generation is higher than for mid-winter throughout the day and is slightly more sustained between 0800-1800 hours during the mid-summer period. As electricity is the energy form that exhibits the largest increase in
consumption in mid-summer over mid-winter, the areas with high electricity consumption compared with other fuels show more significant seasonal variation in energy use, such as in Hung Hom (Figure 12).

Tables 14 to 19 present artificial heat generation in mid-winter and mid-summer for 12, 2-hourly periods for all of Hong Kong and for Hung Hom, Kwun Tong and Tsuen Wan respectively.

Averaged over all of Hong Kong, artificial heat generation reaches between 1% and 4% of incoming solar radiation in the 0700-1700 period in mid-winter. Taken over the day, artificial heat generation is 2.3% in mid-winter and 1.7% in mid-summer of total incoming solar radiation. For representative urban areas of Hong Kong year round values for artificial heat generation of between 7 and 13% of total incoming solar radiation are obtained (Tables 16 and 17).

However, in Hung Hom (Table 15), the location of the Hok Yuen Power Station and the Tokwawan town gas plant, artificial heat generation nearly matches incoming solar radiation throughout the middle of both mid-winter and mid-summer days, and taken over the whole day is greater than 2 times incoming solar radiation in mid-winter and 1.7 times incoming solar radiation in mid-summer.

**DISCUSSION AND CONCLUSIONS**

The wide variation of energy use, even over the major urban areas of Hong Kong, reflects differing patterns of land-use ranging from predominantly residential, through to the central business district locations and areas in which power
utilities are sited. It is the location of power stations in the urban area, in conjunction with high population density, which obtains values of artificial heat generation as high as any previously recorded. For example, artificial heat generation in Hung Hom, Kowloon, is twice the average value recorded for Manhattan, New York (see Table 7). Some comparative data (e.g. Bach and Patterson, 1969) includes an estimate of heat generated from somatic energy-use. The Hong Kong data presented does not include somatic energy conversions. However, in such a densely populated urban settlement heat generated from somatic energy consumption can be significant. Given a conservative estimate of 10 MJ/day somatic energy consumption, 75% of which becomes heat energy, values of $327 \times 10^3$ MJ/km$^2$/day for North Point (1.5, Table 6) and $257 \times 10^3$ MJ/km$^2$/day for Kwun Tong (2.9, Table 6) are obtained for heat arising from human metabolic activity. This represents 6% of the intensity of extrasomatic energy use in North Point, and 14.5% for Kwun Tong.

Such high levels of artificial heat generation per unit area could not have been anticipated by utilising average per capita consumption data and land area parameters from general sources such as United Nations statistics. By examining the unique interaction of space, time, energy and population, it becomes
abundantly clear why Hong Kong, with only a small fraction of per capita energy consumption, experiences intensities of energy use per unit area of the same order as those found in the most industrialized, heavily populated urban areas of the developed world.

The higher energy consumption in summer over winter shown by a comparison of the seasonal patterns of energy-use (Figures 11 to 14) reflects, in particular, the influences of cooling devices on patterns of energy-use. Electricity is the only fuel used in large measure to power cooling appliances such as air conditioners. Hence the consumption of electricity in summer far exceeds that during the winter period, thereby counteracting the decline in consumption characteristic of all domestic and many commercial energy forms during the summer period. An order of magnitude increase in the number of air conditioners retained for use in Hong Kong over the 1964-1971 period (Census and Statistics, 1965-1972) is consistent with these findings and provides an insight to the impact of culture and technology on patterns of energy-use in urban settlements.

The diurnal patterns of energy-use documented in this study (Figures 3 to 10) suggest, amongst other things, that the concurrence of troughs and peaks in energy-use in each sector of activity significantly influences micro-climate and the severity of air pollution. In other words, phasing major activities to avoid concurrence of peaks in energy-use would reduce micro-climate modification and concentrations of pollutant byproducts.
A valuable measure of the importance of artificial heat generation is its magnitude in relation to incoming solar radiation. Artificial heat generation more than doubles incoming solar radiation in parts of the urban area in mid-winter and exceeds it by an order of magnitude during the early morning in both winter and summer (see Table 15).

Previously recorded levels of artificial heat generation, such as 49% of incoming solar radiation for a selected area in Sydney (Kalma et al, 1972), and the high average value of 15% of incoming solar radiation for all North American cities (Landsberg, 1973) attest that this is a common problem in contemporary urban settlements. Indeed, Jaske (1973) has suggested that de-intensification of energy-use should be an important criterion for future urban planning.

Many scientists take the view that the real limiting factor for energy-use is the potential for widespread climatic perturbations likely to occur when artificial heat generation reaches the level of incoming solar radiation over extensive areas. Jaske (1973) has forecast that by the year 2000 the Boston-Washington conurbation will yield artificial heat equal to 50% of incoming solar radiation in winter and 15% in summer. Weinberg (1974) has suggested that, with current growth rates in energy use, within 200 years the world-wide artificial heat generation will equal the total incoming solar radiation. Such estimates are illustrative of the problem faced rather than realistic predictions. Schneider &
Dennett (1975) argue that planning policies which concentrate rather than disperse urban power densities may well give rise to serious meso-scale (10-100 km scale) or even regional climatic disruption by 2000.

We have used the Hong Kong data on spatial and temporal patterns of energy-use to show, by numerical modelling techniques, that artificial heat generation contributes, on average, 1-2°C to the urban heat island (Kalma et al, in preparation). The fact that artificial heat generation is significant in climate modification, even at much lower levels, reinforces the need for energy conservation and a reduction in entropy generating processes in the urban area in general. The potential for energy conservation in Hong Kong has been discussed elsewhere (Newcombe, 1975a).

The implications of urban planning concepts on the physico-chemical and biosocial environment are clearly very important. For instance, it is through a lack of understanding of energy-related problems that there is no segregation of industrial, commercial, residential, major transport and power generating zones (Liang, 1973). Thus, while in many large urban areas energy-intensive industrial activities and power utilities are isolated from residential areas, in Hong Kong they are close together. Indeed, it is common to have commercial, industrial and residential activities displaced in a vertical rather than horizontal plane. In effect, heat energy and air pollutants are emitted into what, for the majority of the population, is the residential environment.
An index of this phenomenon, the energy-exposure index, is given in Table 7. By this index, Hong Kong is much more a high-energy environment, as far as its human occupants are concerned, than are any of the major urban areas for which comparative data is presented (see Table 7). The consequences of such intensities of energy-use for human health and well-being, with particular reference to Hong Kong, are the subject of further investigation (Newcombe, in preparation).

In conclusion, the importance of such detailed analysis of patterns of urban energy-use lies in the numerous end-uses to which the data can be put. Spatial and temporal patterns of energy-use are derived in logical manner from more basic input-output analyses (see Newcombe, 1975a) and sector end-use analyses (see Newcombe, 1975b). Dispersion models for air pollutants and surface-energy balance models for urban heat island detection are dependent on accurate analyses of spatial and temporal patterns of energy use. Much more can be said about the interaction between high levels of energy consumption and human well-being when more precise information is available detailing the physico-chemical modification of the urban environment. Finally, this information improves our capacity to develop urban planning concepts which emphasise both resource conservation and human well-being.
REFERENCES


TABLE 1: Spatial Distribution of Domestic Energy Use, Hong Kong 1971 (MJ's x $10^8$)

<table>
<thead>
<tr>
<th>Defined Area</th>
<th>Electricity¹</th>
<th>Kerosene</th>
<th>LPG</th>
<th>Gas</th>
<th>Charcoal</th>
<th>Firewood</th>
<th>Domestic Total² (not inc. sonic)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KOWLOON</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Tsim Sha Tsui</td>
<td>2.16</td>
<td>1.21</td>
<td>0.31</td>
<td>0.60</td>
<td>0.07</td>
<td></td>
<td>4.35</td>
</tr>
<tr>
<td>2.2 Mong Kok, Yaumati</td>
<td>2.87</td>
<td>6.16</td>
<td>1.60</td>
<td>0.12</td>
<td>0.37</td>
<td>0.04</td>
<td>11.16</td>
</tr>
<tr>
<td>2.3 Kowloon City</td>
<td>3.91</td>
<td>1.27</td>
<td>0.33</td>
<td>0.63</td>
<td>0.08</td>
<td>0.01</td>
<td>6.23</td>
</tr>
<tr>
<td>2.4 Hung Hom</td>
<td>2.51</td>
<td>3.09</td>
<td>0.80</td>
<td>0.08</td>
<td>0.19</td>
<td>0.02</td>
<td>6.69</td>
</tr>
<tr>
<td>2.5 Cheung Sha Wan</td>
<td>0.97</td>
<td>0.37</td>
<td>0.10</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>1.50</td>
</tr>
<tr>
<td>2.6 Sham Shui Po</td>
<td>1.83</td>
<td>7.14</td>
<td>1.85</td>
<td>0.16</td>
<td>0.43</td>
<td>0.18</td>
<td>11.59</td>
</tr>
<tr>
<td>2.7 Kowloon Tong</td>
<td>1.12</td>
<td>0.35</td>
<td>0.09</td>
<td>0.46</td>
<td>0.02</td>
<td>0.04</td>
<td>2.08</td>
</tr>
<tr>
<td>2.8 Sam Po Kong</td>
<td>2.36</td>
<td>9.12</td>
<td>2.36</td>
<td>0.17</td>
<td>0.55</td>
<td>0.62</td>
<td>15.18</td>
</tr>
<tr>
<td>2.9 Kwun Tong</td>
<td>3.61</td>
<td>7.34</td>
<td>1.90</td>
<td>0.08</td>
<td>0.44</td>
<td>0.21</td>
<td>13.58</td>
</tr>
<tr>
<td><strong>NEW TERRITORIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Shatin</td>
<td>0.38</td>
<td>0.39</td>
<td>0.10</td>
<td>0.02</td>
<td>0.11</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>B Sai Kung Peninsula</td>
<td>0.37</td>
<td>0.55</td>
<td>0.14</td>
<td>0.03</td>
<td>0.16</td>
<td></td>
<td>1.25</td>
</tr>
<tr>
<td>C Shum Tseng</td>
<td>0.13</td>
<td>0.17</td>
<td>0.04</td>
<td>0.01</td>
<td>0.05</td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td>D Castle Peak New Town</td>
<td>0.35</td>
<td>0.60</td>
<td>0.16</td>
<td>0.04</td>
<td>0.17</td>
<td></td>
<td>1.32</td>
</tr>
<tr>
<td>E Castle Peak West</td>
<td>0.04</td>
<td>0.09</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td>0.18</td>
</tr>
<tr>
<td>F Yuen Long</td>
<td>0.65</td>
<td>0.35</td>
<td>0.09</td>
<td>0.02</td>
<td>0.10</td>
<td></td>
<td>1.21</td>
</tr>
<tr>
<td>G Yuen Long Area</td>
<td>0.98</td>
<td>1.42</td>
<td>0.37</td>
<td>0.09</td>
<td>0.39</td>
<td></td>
<td>3.25</td>
</tr>
<tr>
<td>H Tai Po</td>
<td>0.44</td>
<td>0.34</td>
<td>0.09</td>
<td>0.02</td>
<td>0.10</td>
<td></td>
<td>0.99</td>
</tr>
<tr>
<td>I Tai Wo Shan</td>
<td>0.27</td>
<td>0.61</td>
<td>0.16</td>
<td>0.04</td>
<td>0.17</td>
<td></td>
<td>1.25</td>
</tr>
<tr>
<td>J Sheung Shui-Fanling Township</td>
<td>0.94</td>
<td>0.32</td>
<td>0.08</td>
<td>0.02</td>
<td>0.10</td>
<td></td>
<td>1.46</td>
</tr>
<tr>
<td>K Sheung Shui</td>
<td>0.46</td>
<td>1.01</td>
<td>0.26</td>
<td>0.06</td>
<td>0.29</td>
<td></td>
<td>2.08</td>
</tr>
<tr>
<td>L Fanling-Shewing Shui Area</td>
<td>0.18</td>
<td>0.16</td>
<td>0.04</td>
<td>0.01</td>
<td>0.04</td>
<td></td>
<td>0.43</td>
</tr>
<tr>
<td>M Lamma Island</td>
<td>0.13</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
<td>0.21</td>
</tr>
<tr>
<td>N Cheung Chau</td>
<td>0.19</td>
<td>0.24</td>
<td>0.06</td>
<td>0.01</td>
<td>0.06</td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>O Lantau Island</td>
<td>0.16</td>
<td>0.34</td>
<td>0.09</td>
<td>0.02</td>
<td>0.10</td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td>P Tsuen Wan</td>
<td>3.16</td>
<td>4.18</td>
<td>1.08</td>
<td>0.25</td>
<td>1.13</td>
<td></td>
<td>8.98</td>
</tr>
<tr>
<td>Q Tsing Yi</td>
<td>0.17</td>
<td>0.34</td>
<td>0.09</td>
<td>0.14</td>
<td>0.02</td>
<td></td>
<td>0.94</td>
</tr>
<tr>
<td><strong>HONG KONG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 West</td>
<td>3.64</td>
<td>3.51</td>
<td>0.91</td>
<td>0.19</td>
<td>0.21</td>
<td>0.04</td>
<td>8.50</td>
</tr>
<tr>
<td>1.2 Central</td>
<td>0.33</td>
<td>0.37</td>
<td>0.10</td>
<td>0.18</td>
<td>0.02</td>
<td>*</td>
<td>1.00</td>
</tr>
<tr>
<td>1.3 North Point</td>
<td>2.33</td>
<td>2.34</td>
<td>0.61</td>
<td>0.14</td>
<td>0.02</td>
<td></td>
<td>5.44</td>
</tr>
<tr>
<td>1.4 Shaukiwan</td>
<td>2.16</td>
<td>2.18</td>
<td>0.56</td>
<td>1.74</td>
<td>0.13</td>
<td>0.04</td>
<td>6.81</td>
</tr>
<tr>
<td>1.5 Castle Peak West</td>
<td>2.98</td>
<td>2.89</td>
<td>0.75</td>
<td>0.08</td>
<td>0.18</td>
<td>0.09</td>
<td>6.97</td>
</tr>
<tr>
<td>1.6 North Point</td>
<td>2.65</td>
<td>2.66</td>
<td>0.69</td>
<td>0.14</td>
<td>0.16</td>
<td>0.02</td>
<td>6.32</td>
</tr>
<tr>
<td>1.7 Lantau Island</td>
<td>1.99</td>
<td>1.93</td>
<td>0.50</td>
<td>0.14</td>
<td>0.12</td>
<td>0.10</td>
<td>4.78</td>
</tr>
<tr>
<td>1.8 Sheung Shui</td>
<td>0.17</td>
<td>0.14</td>
<td>0.04</td>
<td>0.48</td>
<td>0.01</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td>1.9 Sheung Shui</td>
<td>0.33</td>
<td>0.34</td>
<td>0.09</td>
<td>0.14</td>
<td>0.02</td>
<td>0.02</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>MARINE</strong></td>
<td>1.31</td>
<td>0.34</td>
<td>0.34</td>
<td>0.08</td>
<td></td>
<td></td>
<td>1.73</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>45.90</td>
<td>64.60</td>
<td>16.74</td>
<td>5.41</td>
<td>3.91</td>
<td>4.49</td>
<td>141.05</td>
</tr>
</tbody>
</table>

1. Has 3.12 units added for reticulation of electricity losses
2. Total is different from given domestic total use as a result of (1)

*Negligible

**Names of Defined Areas:**
2.1 Tsim Sha Tsui; 2.2 Mong Kok, Yaumati; 2.3 Kowloon City; 2.4 Hung Hom; 2.5 Cheung Sha Wan
2.6 Sham Shui Po; 2.7 Kowloon Tong; 2.8 Sam Po Kong; 2.9 Kwun Tong;
A Shatin; B Sai Kung Peninsula; C Shum Tseng; D Castle Peak New Town; E Castle Peak West
F Yuen Long; G Yuen Long Area; H Tai Po; I Tai Wo Shan; J Sheung Shui-Fanling Township;
K Fanling-Shewing Shui Area; L Sha Tau Kok; M Lamma Island; N Cheung Chau; O Lantau Island;
P Tsuen Wan; Q Tsing Yi
1.1 West; 1.2 Central; 1.3 Wanchai; 1.4 Causeway Bay-Tai Hang; 1.5 North Point;
1.6 Shaukiwan; 1.7 Aberdeen; 1.8 Peak; 1.9 South
<table>
<thead>
<tr>
<th>Defined Area</th>
<th>Charcoal</th>
<th>Coke</th>
<th>Coal</th>
<th>Kerosene</th>
<th>Gas Oils</th>
<th>Fuel Oil</th>
<th>LPG</th>
<th>Electricity</th>
<th>Gas</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOWLOON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>0.40</td>
<td>0.15</td>
<td>0.07</td>
<td>1.49</td>
<td>6.0</td>
<td>1.22</td>
<td>0.52</td>
<td>8.45</td>
<td>0.91</td>
<td>19.23</td>
</tr>
<tr>
<td>2.2</td>
<td>0.33</td>
<td>0.15</td>
<td>0.06</td>
<td>1.28</td>
<td>12.99</td>
<td>1.05</td>
<td>0.45</td>
<td>7.29</td>
<td>0.33</td>
<td>23.93</td>
</tr>
<tr>
<td>2.3</td>
<td>0.15</td>
<td>0.06</td>
<td>0.02</td>
<td>0.55</td>
<td>1.93</td>
<td>0.47</td>
<td>0.19</td>
<td>3.24</td>
<td>0.26</td>
<td>6.87</td>
</tr>
<tr>
<td>2.4</td>
<td>0.15</td>
<td>0.06</td>
<td>0.02</td>
<td>0.56</td>
<td>3.66</td>
<td>0.47</td>
<td>0.20</td>
<td>3.27</td>
<td>0.07</td>
<td>8.46</td>
</tr>
<tr>
<td>2.5</td>
<td>0.07</td>
<td>0.03</td>
<td>0.01</td>
<td>0.25</td>
<td>1.58</td>
<td>0.23</td>
<td>0.09</td>
<td>1.58</td>
<td>0.04</td>
<td>3.88</td>
</tr>
<tr>
<td>2.6</td>
<td>0.10</td>
<td>0.04</td>
<td>0.01</td>
<td>0.37</td>
<td>4.63</td>
<td>0.32</td>
<td>0.13</td>
<td>2.23</td>
<td>0.09</td>
<td>7.92</td>
</tr>
<tr>
<td>2.7</td>
<td>0.03</td>
<td>0.01</td>
<td></td>
<td>0.10</td>
<td>0.37</td>
<td>0.10</td>
<td>0.04</td>
<td>0.72</td>
<td>0.13</td>
<td>1.50</td>
</tr>
<tr>
<td>2.8</td>
<td>0.09</td>
<td>0.04</td>
<td>0.01</td>
<td>0.31</td>
<td>5.24</td>
<td>0.28</td>
<td>0.11</td>
<td>1.90</td>
<td>0.07</td>
<td>8.05</td>
</tr>
<tr>
<td>2.9</td>
<td>0.11</td>
<td>0.05</td>
<td>0.02</td>
<td>0.41</td>
<td>3.01</td>
<td>0.35</td>
<td>0.15</td>
<td>2.45</td>
<td>0.04</td>
<td>6.59</td>
</tr>
<tr>
<td>NEW TERRITORIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.02</td>
<td>0.01</td>
<td></td>
<td>0.04</td>
<td>0.21</td>
<td>0.06</td>
<td>0.02</td>
<td>0.41</td>
<td></td>
<td>0.77</td>
</tr>
<tr>
<td>B</td>
<td>0.02</td>
<td>0.01</td>
<td></td>
<td>0.05</td>
<td>0.22</td>
<td>0.06</td>
<td>0.03</td>
<td>0.44</td>
<td></td>
<td>0.83</td>
</tr>
<tr>
<td>C</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
<td>0.02</td>
<td>0.06</td>
<td>0.02</td>
<td>0.01</td>
<td>0.12</td>
<td></td>
<td>0.24</td>
</tr>
<tr>
<td>D</td>
<td>0.02</td>
<td>0.01</td>
<td></td>
<td>0.04</td>
<td>0.19</td>
<td>0.05</td>
<td>0.02</td>
<td>0.37</td>
<td></td>
<td>0.70</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.03</td>
<td>0.01</td>
<td></td>
<td>0.85</td>
<td>0.31</td>
<td>0.09</td>
<td>0.04</td>
<td>0.60</td>
<td></td>
<td>1.93</td>
</tr>
<tr>
<td>G</td>
<td>0.03</td>
<td>0.01</td>
<td></td>
<td>0.08</td>
<td>0.32</td>
<td>0.09</td>
<td>0.04</td>
<td>0.63</td>
<td></td>
<td>1.20</td>
</tr>
<tr>
<td>H</td>
<td>0.02</td>
<td>0.01</td>
<td></td>
<td>0.06</td>
<td>0.27</td>
<td>0.08</td>
<td>0.03</td>
<td>0.52</td>
<td></td>
<td>0.99</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>0.02</td>
<td>0.01</td>
<td></td>
<td>0.07</td>
<td>0.28</td>
<td>0.08</td>
<td>0.03</td>
<td>0.54</td>
<td></td>
<td>1.03</td>
</tr>
<tr>
<td>K</td>
<td>0.01</td>
<td>0.02</td>
<td></td>
<td>0.02</td>
<td>0.01</td>
<td></td>
<td></td>
<td>0.05</td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>L</td>
<td>0.01</td>
<td>0.03</td>
<td></td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td></td>
<td>0.07</td>
<td></td>
<td>0.12</td>
</tr>
<tr>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.09</td>
<td>0.04</td>
<td>0.01</td>
<td>0.34</td>
<td>1.71</td>
<td>0.31</td>
<td>0.12</td>
<td>2.08</td>
<td>0.06</td>
<td>4.76</td>
</tr>
<tr>
<td>Q</td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.32</td>
<td>0.06</td>
<td>0.02</td>
<td>0.39</td>
<td>0.03</td>
<td>0.92</td>
</tr>
<tr>
<td>HONG KONG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>0.20</td>
<td>0.08</td>
<td>0.04</td>
<td>0.77</td>
<td>3.33</td>
<td>0.64</td>
<td>0.27</td>
<td>4.42</td>
<td>0.27</td>
<td>10.02</td>
</tr>
<tr>
<td>1.2</td>
<td>0.39</td>
<td>0.16</td>
<td>0.07</td>
<td>1.48</td>
<td>5.95</td>
<td>1.21</td>
<td>0.51</td>
<td>8.39</td>
<td>0.63</td>
<td>18.79</td>
</tr>
<tr>
<td>1.3</td>
<td>0.23</td>
<td>0.10</td>
<td>0.04</td>
<td>0.89</td>
<td>5.95</td>
<td>0.74</td>
<td>0.31</td>
<td>5.11</td>
<td>0.17</td>
<td>13.54</td>
</tr>
<tr>
<td>1.4</td>
<td>0.13</td>
<td>0.05</td>
<td>0.02</td>
<td>0.49</td>
<td>2.74</td>
<td>0.41</td>
<td>0.17</td>
<td>2.85</td>
<td>0.56</td>
<td>7.42</td>
</tr>
<tr>
<td>1.5</td>
<td>0.22</td>
<td>0.09</td>
<td>0.02</td>
<td>0.86</td>
<td>4.07</td>
<td>0.71</td>
<td>0.30</td>
<td>4.91</td>
<td>0.07</td>
<td>11.25</td>
</tr>
<tr>
<td>1.6</td>
<td>0.12</td>
<td>0.05</td>
<td>0.02</td>
<td>0.46</td>
<td>2.05</td>
<td>0.39</td>
<td>0.16</td>
<td>2.71</td>
<td>0.03</td>
<td>5.99</td>
</tr>
<tr>
<td>1.7</td>
<td>0.08</td>
<td>0.03</td>
<td>0.01</td>
<td>0.30</td>
<td>1.51</td>
<td>0.26</td>
<td>0.11</td>
<td>1.82</td>
<td>0.03</td>
<td>4.15</td>
</tr>
<tr>
<td>1.8</td>
<td>0.05</td>
<td>0.02</td>
<td>0.01</td>
<td>0.16</td>
<td>0.53</td>
<td>0.15</td>
<td>0.06</td>
<td>1.04</td>
<td>0.06</td>
<td>2.08</td>
</tr>
<tr>
<td>1.9</td>
<td>0.02</td>
<td>0.01</td>
<td></td>
<td>0.07</td>
<td>0.32</td>
<td>0.06</td>
<td>0.02</td>
<td>0.39</td>
<td>0.03</td>
<td>0.92</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3.13</td>
<td>1.31</td>
<td>0.46</td>
<td>12.38</td>
<td>69.51</td>
<td>9.93</td>
<td>4.13</td>
<td>68.66</td>
<td>3.85</td>
<td>173.36</td>
</tr>
<tr>
<td>Defined Area</td>
<td>Charcoal (10^8)</td>
<td>Coke (10^8)</td>
<td>Coal (10^8)</td>
<td>Kerosene (10^8)</td>
<td>Gas Oil (10^8)</td>
<td>Fuel Oil (10^8)</td>
<td>LPG (10^8)</td>
<td>Electricity (10^8)</td>
<td>Gas (10^8)</td>
<td>Total (10^8)</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-----------------</td>
<td>----------------</td>
<td>----------------</td>
<td>------------</td>
<td>-------------------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>KOWLOON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>0.01</td>
<td>0.25</td>
<td>0.05</td>
<td>0.09</td>
<td>0.04</td>
<td>0.44</td>
<td>0.05</td>
<td>0.05</td>
<td>3.76</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>0.01</td>
<td>1.82</td>
<td>1.83</td>
<td>0.05</td>
<td>0.05</td>
<td>3.76</td>
<td></td>
<td></td>
<td>3.76</td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>0.01</td>
<td>0.10</td>
<td>0.01</td>
<td>0.31</td>
<td>0.51</td>
<td>0.01</td>
<td>0.07</td>
<td>0.09</td>
<td>1.92</td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>0.07</td>
<td>0.76</td>
<td>0.05</td>
<td>1.63</td>
<td>6.15</td>
<td>0.11</td>
<td>6.75</td>
<td>0.14</td>
<td>15.77</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>0.05</td>
<td>0.55</td>
<td>0.04</td>
<td>1.24</td>
<td>9.22</td>
<td>0.08</td>
<td>4.84</td>
<td>0.03</td>
<td>16.13</td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>0.01</td>
<td>0.11</td>
<td>0.01</td>
<td>1.68</td>
<td>0.98</td>
<td>0.02</td>
<td>0.93</td>
<td>0.07</td>
<td>3.83</td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>0.06</td>
<td>0.01</td>
<td>0.01</td>
<td>0.51</td>
<td>0.01</td>
<td>0.01</td>
<td>0.51</td>
<td>0.01</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td>0.06</td>
<td>0.71</td>
<td>0.05</td>
<td>3.69</td>
<td>8.95</td>
<td>0.11</td>
<td>6.29</td>
<td>0.11</td>
<td>20.08</td>
<td></td>
</tr>
<tr>
<td>2.9</td>
<td>0.13</td>
<td>1.49</td>
<td>0.11</td>
<td>4.20</td>
<td>36.37</td>
<td>0.23</td>
<td>13.28</td>
<td>0.13</td>
<td>56.17</td>
<td></td>
</tr>
<tr>
<td>NEW TERRITORIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.02</td>
<td>0.33</td>
<td>0.02</td>
<td>0.35</td>
<td>1.67</td>
<td>0.05</td>
<td>2.87</td>
<td>5.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.02</td>
<td>0.23</td>
<td>0.02</td>
<td>0.31</td>
<td>1.16</td>
<td>0.03</td>
<td>1.99</td>
<td>3.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.03</td>
<td>0.29</td>
<td>0.02</td>
<td>0.30</td>
<td>1.50</td>
<td>0.04</td>
<td>2.58</td>
<td>4.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0.02</td>
<td>0.17</td>
<td>0.01</td>
<td>0.26</td>
<td>0.88</td>
<td>0.03</td>
<td>1.52</td>
<td>2.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0.02</td>
<td>0.06</td>
<td>0.01</td>
<td>0.24</td>
<td>0.01</td>
<td>0.40</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
<td>0.29</td>
<td>0.41</td>
<td>0.02</td>
<td>0.70</td>
<td>1.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.02</td>
<td>0.18</td>
<td>0.01</td>
<td>0.10</td>
<td>0.22</td>
<td>0.01</td>
<td>0.37</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>0.02</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.11</td>
<td>0.20</td>
<td>0.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>0.02</td>
<td>0.15</td>
<td>0.01</td>
<td>0.30</td>
<td>0.65</td>
<td>0.02</td>
<td>1.13</td>
<td>2.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>0.01</td>
<td>0.09</td>
<td>0.07</td>
<td>0.09</td>
<td>0.35</td>
<td>0.01</td>
<td>0.61</td>
<td>1.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>0.01</td>
<td>0.01</td>
<td>0.03</td>
<td>0.01</td>
<td>0.05</td>
<td>0.03</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>0.01</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.07</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>0.01</td>
<td>0.03</td>
<td>0.03</td>
<td>0.09</td>
<td>0.17</td>
<td>0.01</td>
<td>0.30</td>
<td>0.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>0.01</td>
<td>0.37</td>
<td>2.47</td>
<td>0.17</td>
<td>3.32</td>
<td>33.56</td>
<td>0.27</td>
<td>21.90</td>
<td>62.44</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>0.01</td>
<td>0.15</td>
<td>0.01</td>
<td>0.14</td>
<td>0.75</td>
<td>0.02</td>
<td>1.29</td>
<td>2.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.23</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>0.01</td>
<td>0.44</td>
<td>0.99</td>
<td>0.01</td>
<td>0.44</td>
<td>0.99</td>
<td>0.07</td>
<td>0.01</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>HONG KONG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>0.01</td>
<td>0.15</td>
<td>0.01</td>
<td>0.79</td>
<td>0.61</td>
<td>0.02</td>
<td>0.80</td>
<td>0.02</td>
<td>3.56</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>0.01</td>
<td>0.02</td>
<td>0.14</td>
<td>0.62</td>
<td>0.85</td>
<td>0.02</td>
<td>1.23</td>
<td>0.02</td>
<td>5.91</td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.43</td>
<td>0.13</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.43</td>
<td>0.13</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.44</td>
<td>0.99</td>
<td>0.01</td>
<td>0.70</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.44</td>
<td>0.99</td>
<td>0.01</td>
<td>0.70</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.44</td>
<td>0.99</td>
<td>0.01</td>
<td>0.70</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.44</td>
<td>0.99</td>
<td>0.01</td>
<td>0.70</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.44</td>
<td>0.99</td>
<td>0.01</td>
<td>0.70</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>0.79</td>
<td>1.31</td>
<td>8.84</td>
<td>0.62</td>
<td>25.58</td>
<td>116.63</td>
<td>1.33</td>
<td>78.10</td>
<td>234.13</td>
<td></td>
</tr>
<tr>
<td>Defined Area</td>
<td>Fuel Oil</td>
<td>Electricity</td>
<td>Mogas and AGO/marine ISO in Harbour and Aberdeen</td>
<td>Avturb and Avgas</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td>-------------</td>
<td>-------------------------------------------------</td>
<td>----------------</td>
<td>------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>KOWLOON</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>4.64</td>
<td>0.02</td>
<td>4.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>13.01</td>
<td>0.03</td>
<td>13.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>5.61</td>
<td>0.02</td>
<td>5.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>5.34</td>
<td>0.02</td>
<td>5.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>5.16</td>
<td>0.83</td>
<td>5.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>12.04</td>
<td>0.83</td>
<td>12.87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>4.66</td>
<td>0.83</td>
<td>5.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td>11.98</td>
<td>8.89</td>
<td>20.87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.9</td>
<td>10.50</td>
<td>0.02</td>
<td>10.52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NEW TERRITORIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1.59</td>
<td>0.10</td>
<td>1.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2.46</td>
<td>2.21</td>
<td>4.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>2.70</td>
<td>0.44</td>
<td>3.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1.72</td>
<td>0.19</td>
<td>1.91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>0.34</td>
<td>0.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.91</td>
<td>0.01</td>
<td>0.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>1.34</td>
<td>0.99</td>
<td>2.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>0.57</td>
<td>0.02</td>
<td>0.59</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1.22</td>
<td>1.09</td>
<td>2.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>0.98</td>
<td>0.06</td>
<td>1.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>2.80</td>
<td>0.70</td>
<td>3.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>0.21</td>
<td>0.92</td>
<td>1.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>0.19</td>
<td>0.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>0.02</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>0.21</td>
<td>1.51</td>
<td>1.72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>2.80</td>
<td>0.16</td>
<td>2.96</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td></td>
<td>0.09</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HONG KONG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>0.03</td>
<td>5.03</td>
<td>5.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>0.14</td>
<td>4.37</td>
<td>4.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>0.14</td>
<td>4.72</td>
<td>4.87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>0.11</td>
<td>7.53</td>
<td>7.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>0.11</td>
<td>5.20</td>
<td>5.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td>0.03</td>
<td>1.62</td>
<td>1.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7</td>
<td>2.85</td>
<td>0.11</td>
<td>2.96</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>1.07</td>
<td>0.09</td>
<td>1.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>2.89</td>
<td>0.38</td>
<td>3.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HARBOUR</strong></td>
<td>34.63</td>
<td>0.83</td>
<td>35.46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ABERDEEN</strong></td>
<td>5.11</td>
<td>5.11</td>
<td>10.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>34.63</td>
<td>0.56</td>
<td>155.44</td>
<td>22.22</td>
<td>212.95</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defined Area</td>
<td>Incineration Losses</td>
<td>Power Utilities</td>
<td>Water Pumping Stations</td>
<td>Incineration Losses Garbage</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>------------------------</td>
<td>----------------------------</td>
<td>-------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KOWLOON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>184.46</td>
<td>0.44</td>
<td>8.78</td>
<td></td>
<td>184.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>0.48</td>
<td>0.01</td>
<td></td>
<td></td>
<td>9.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.9</td>
<td>0.34</td>
<td></td>
<td></td>
<td></td>
<td>0.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW TERRITORIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>154.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HONG KONG</td>
<td>0.54</td>
<td></td>
<td>9.15</td>
<td></td>
<td>9.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>46.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>46.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>93.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>93.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.02</td>
<td>479.45</td>
<td>1.65</td>
<td>18.03</td>
<td>500.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defined Area</td>
<td>Domestic</td>
<td>Commercial</td>
<td>Industrial</td>
<td>Transport</td>
<td>Local Losses</td>
<td>Total</td>
<td>Population x 10^6</td>
<td>Area Km²</td>
<td>Intensity of total use MJ x 10^8/km²</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>----------</td>
<td>------------</td>
<td>------------</td>
<td>-----------</td>
<td>--------------</td>
<td>-------</td>
<td>-------------------</td>
<td>----------</td>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td>KOWLOON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 1.15</td>
<td>4.35</td>
<td>19.23</td>
<td>0.44</td>
<td>4.66</td>
<td>28.68</td>
<td>0.073</td>
<td>1.95</td>
<td>14.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2 11.16</td>
<td>23.93</td>
<td>3.76</td>
<td>13.04</td>
<td></td>
<td>51.89</td>
<td>0.275</td>
<td>2.66</td>
<td>19.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3 6.23</td>
<td>6.87</td>
<td>1.92</td>
<td>5.63</td>
<td></td>
<td>20.65</td>
<td>0.077</td>
<td>2.41</td>
<td>8.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4 6.69</td>
<td>8.46</td>
<td>15.77</td>
<td>5.36</td>
<td></td>
<td>184.90</td>
<td>0.189</td>
<td>2.00</td>
<td>109.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 1.50</td>
<td>3.88</td>
<td>16.13</td>
<td>5.99</td>
<td>9.27</td>
<td>36.77</td>
<td>0.022</td>
<td>2.70</td>
<td>16.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6 11.59</td>
<td>7.92</td>
<td>3.83</td>
<td>12.87</td>
<td></td>
<td>36.21</td>
<td>0.435</td>
<td>6.91</td>
<td>5.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7 2.08</td>
<td>1.50</td>
<td>0.08</td>
<td>5.49</td>
<td></td>
<td>9.15</td>
<td>0.021</td>
<td>2.48</td>
<td>3.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8 15.18</td>
<td>8.05</td>
<td>20.08</td>
<td>20.87</td>
<td></td>
<td>64.18</td>
<td>0.555</td>
<td>12.62</td>
<td>5.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.9 13.58</td>
<td>6.59</td>
<td>56.17</td>
<td>110.52</td>
<td>0.34</td>
<td>87.20</td>
<td>0.447</td>
<td>12.95</td>
<td>6.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW TERRITORIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A 1.00</td>
<td>0.77</td>
<td>5.37</td>
<td>1.69</td>
<td>0.02</td>
<td>8.85</td>
<td>0.024</td>
<td>10.19</td>
<td>9.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B 1.25</td>
<td>0.83</td>
<td>3.79</td>
<td>4.67</td>
<td></td>
<td>10.54</td>
<td>0.035</td>
<td>221.00</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C 0.40</td>
<td>0.24</td>
<td>4.80</td>
<td>3.14</td>
<td></td>
<td>8.58</td>
<td>0.010</td>
<td>44.31</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D 1.32</td>
<td>0.70</td>
<td>2.92</td>
<td>1.91</td>
<td>0.02</td>
<td>6.87</td>
<td>0.037</td>
<td>19.07</td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E 0.18</td>
<td></td>
<td>0.34</td>
<td></td>
<td></td>
<td>0.54</td>
<td>0.006</td>
<td>34.18</td>
<td>0.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F 1.21</td>
<td>1.93</td>
<td>0.07</td>
<td>0.92</td>
<td>0.02</td>
<td>4.15</td>
<td>0.021</td>
<td>1.10</td>
<td>3.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G 3.25</td>
<td>1.20</td>
<td>1.00</td>
<td>2.33</td>
<td></td>
<td>7.78</td>
<td>0.087</td>
<td>97.74</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H 0.99</td>
<td>0.99</td>
<td>0.75</td>
<td>0.59</td>
<td>0.02</td>
<td>3.34</td>
<td>0.002</td>
<td>1.66</td>
<td>2.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I 1.25</td>
<td>1.42</td>
<td>2.31</td>
<td>0.04</td>
<td>5.02</td>
<td>0.037</td>
<td>109.21</td>
<td>0.05</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J 1.46</td>
<td>1.03</td>
<td>0.41</td>
<td>1.04</td>
<td>0.02</td>
<td>3.96</td>
<td>0.020</td>
<td>6.30</td>
<td>0.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K 2.08</td>
<td></td>
<td>3.58</td>
<td></td>
<td></td>
<td>7.93</td>
<td>0.062</td>
<td>78.36</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 0.43</td>
<td>0.09</td>
<td>1.15</td>
<td>1.13</td>
<td></td>
<td>2.80</td>
<td>0.010</td>
<td>92.13</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 0.21</td>
<td></td>
<td>0.19</td>
<td></td>
<td></td>
<td>0.46</td>
<td>0.003</td>
<td>18.84</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N 0.46</td>
<td>0.12</td>
<td>0.18</td>
<td>0.02</td>
<td>1.28</td>
<td>0.015</td>
<td>2.25</td>
<td>0.57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O 0.71</td>
<td></td>
<td>0.61</td>
<td>1.72</td>
<td></td>
<td>3.04</td>
<td>0.021</td>
<td>151.40</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P 8.98</td>
<td>4.76</td>
<td>62.44</td>
<td>2.96</td>
<td>0.78</td>
<td>79.92</td>
<td>0.255</td>
<td>15.49</td>
<td>5.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q 0.18</td>
<td>0.11</td>
<td>2.39</td>
<td>0.09</td>
<td>154.08</td>
<td>156.85</td>
<td>0.003</td>
<td>9.04</td>
<td>17.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HONG KONG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 8.50</td>
<td>10.02</td>
<td>2.36</td>
<td>5.08</td>
<td>9.69</td>
<td>35.65</td>
<td>0.214</td>
<td>2.18</td>
<td>16.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 1.00</td>
<td>18.79</td>
<td>0.17</td>
<td>4.52</td>
<td></td>
<td>24.48</td>
<td>0.023</td>
<td>1.05</td>
<td>23.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 5.44</td>
<td>13.54</td>
<td>2.91</td>
<td>4.87</td>
<td></td>
<td>26.76</td>
<td>0.143</td>
<td>1.25</td>
<td>21.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4 6.81</td>
<td>7.42</td>
<td>0.4</td>
<td>7.70</td>
<td></td>
<td>22.57</td>
<td>0.133</td>
<td>5.53</td>
<td>4.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5 6.97</td>
<td>11.25</td>
<td>12.0</td>
<td>5.35</td>
<td>46.80</td>
<td>82.46</td>
<td>0.177</td>
<td>4.02</td>
<td>20.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6 6.32</td>
<td>5.99</td>
<td>5.5</td>
<td>1.71</td>
<td></td>
<td>19.53</td>
<td>0.162</td>
<td>5.61</td>
<td>3.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7 4.78</td>
<td>4.15</td>
<td>2.25</td>
<td>2.96</td>
<td>93.65</td>
<td>107.79</td>
<td>0.117</td>
<td>9.01</td>
<td>9.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8 0.86</td>
<td>2.08</td>
<td>0.08</td>
<td>1.16</td>
<td></td>
<td>4.16</td>
<td>0.008</td>
<td>8.63</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9 0.94</td>
<td>0.92</td>
<td>0.29</td>
<td>3.27</td>
<td></td>
<td>5.42</td>
<td>0.024</td>
<td>37.68</td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HARBOUR</td>
<td>0.74</td>
<td></td>
<td></td>
<td></td>
<td>58.16</td>
<td>58.90</td>
<td>51.30</td>
<td>1.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABERDEEN</td>
<td>0.99</td>
<td></td>
<td></td>
<td></td>
<td>5.11</td>
<td>6.10</td>
<td>0.95</td>
<td>6.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>141.05</td>
<td>173.36</td>
<td>234.13</td>
<td>212.95</td>
<td>500.15</td>
<td>1,261.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name of Area</td>
<td>Area (Km²)</td>
<td>Population (x $10^6$)</td>
<td>Population density ($10^3$/km²)</td>
<td>Total energy use (MJ x $10^8$)</td>
<td>Intensity of energy use (MJ x $10^8$/Km²)</td>
<td>Energy Exposure Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------</td>
<td>------------</td>
<td>-----------------------</td>
<td>---------------------------------</td>
<td>---------------------------------</td>
<td>------------------------------------------</td>
<td>----------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nordrhein-Westfalen (1)</td>
<td>34,038</td>
<td>16.8</td>
<td>.494</td>
<td>45,080</td>
<td>1.32</td>
<td>0.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same, industrial area only (1)</td>
<td>10,295</td>
<td>11.3</td>
<td>1.098</td>
<td>33,117</td>
<td>3.22</td>
<td>3.54</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Berlin (urban) (1)</td>
<td>233</td>
<td>2.3</td>
<td>9.871</td>
<td>1,572</td>
<td>6.75</td>
<td>66.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheffield (1952) urban and industrial (2)</td>
<td>49</td>
<td>0.5</td>
<td>10.204</td>
<td>285</td>
<td>5.82</td>
<td>59.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Los Angeles County (3)</td>
<td>10,000</td>
<td>7.0</td>
<td>0.700</td>
<td>23,653</td>
<td>2.37</td>
<td>1.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Los Angeles (urban) (3)</td>
<td>3,499</td>
<td>7.0</td>
<td>2.001</td>
<td>23,178</td>
<td>6.62</td>
<td>13.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Jersey (4)</td>
<td>5,869</td>
<td>4.9</td>
<td>.826</td>
<td>12,541</td>
<td>214</td>
<td>1.77</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York City (4)</td>
<td>813</td>
<td>8.0</td>
<td>9.938</td>
<td>12,145.19</td>
<td>14.94</td>
<td>148.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manhattan (New York) (4)</td>
<td>57</td>
<td>1.7</td>
<td>29.834</td>
<td>2.866</td>
<td>50.29</td>
<td>1,500.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fairbanks (Alaska) (3)</td>
<td>36</td>
<td>0.03</td>
<td>0.833</td>
<td>211</td>
<td>5.86</td>
<td>4.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cincinnati (urban) (5)(6)</td>
<td>199</td>
<td>0.54</td>
<td>2.714</td>
<td>1,646</td>
<td>8.27</td>
<td>22.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sydney Statistical Division (7)</td>
<td>4,074</td>
<td>2.8</td>
<td>0.687</td>
<td>2,474</td>
<td>0.61</td>
<td>0.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City of Sydney (inc. South Sydney)</td>
<td>24</td>
<td>0.1</td>
<td>4.167</td>
<td>373</td>
<td>15.54</td>
<td>64.76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong total (8)</td>
<td>1,098</td>
<td>3.9</td>
<td>3.939</td>
<td>1,262</td>
<td>1.15</td>
<td>4.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong (urban area only) (8)</td>
<td>92</td>
<td>3.4</td>
<td>37.174</td>
<td>955</td>
<td>10.35</td>
<td>384.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kowloon, Hong Kong Peninsula (8)</td>
<td>9</td>
<td>.64</td>
<td>70.621</td>
<td>323</td>
<td>35.81</td>
<td>2,528.94</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The product of population density and intensity of energy-use

Sources:  
(1) Flohn (1970)  
(2) Garnett and Bach (1965)  
(3) Harlemann (1971)  
(5) Bach and Patterson (1969)  
(6) Bach (1970)  
(7) Kalma and Aston (1973)  
(8) This study
Table 8: Seasonal Variation in Energy-Use by Energy Type and Defined Area for the Domestic Sector, 1971 (MJ x 10^6/day)

<table>
<thead>
<tr>
<th>Defined Area</th>
<th>Gas</th>
<th>Mid-Winter (15th February)</th>
<th>Mid-Summer (15th July)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Electricity Other Total Gas</td>
<td>Electricity Other Total</td>
</tr>
<tr>
<td>KOWLOON</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>2.14</td>
<td>5.67</td>
<td>4.99</td>
</tr>
<tr>
<td>2.2</td>
<td>0.44</td>
<td>7.53</td>
<td>25.59</td>
</tr>
<tr>
<td>2.3</td>
<td>2.25</td>
<td>10.25</td>
<td>5.29</td>
</tr>
<tr>
<td>2.4</td>
<td>0.27</td>
<td>6.58</td>
<td>12.85</td>
</tr>
<tr>
<td>2.5</td>
<td>0.08</td>
<td>2.55</td>
<td>1.59</td>
</tr>
<tr>
<td>2.6</td>
<td>0.58</td>
<td>4.79</td>
<td>30.05</td>
</tr>
<tr>
<td>2.7</td>
<td>1.64</td>
<td>2.93</td>
<td>1.56</td>
</tr>
<tr>
<td>2.8</td>
<td>0.60</td>
<td>6.19</td>
<td>39.62</td>
</tr>
<tr>
<td>2.9</td>
<td>0.27</td>
<td>9.45</td>
<td>30.99</td>
</tr>
<tr>
<td>NEW TERRITORIES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.99</td>
<td>1.95</td>
<td>2.93</td>
</tr>
<tr>
<td>B</td>
<td>0.96</td>
<td>2.77</td>
<td>3.73</td>
</tr>
<tr>
<td>C</td>
<td>0.33</td>
<td>0.85</td>
<td>1.18</td>
</tr>
<tr>
<td>D</td>
<td>0.90</td>
<td>3.04</td>
<td>3.95</td>
</tr>
<tr>
<td>E</td>
<td>0.11</td>
<td>0.44</td>
<td>0.55</td>
</tr>
<tr>
<td>F</td>
<td>1.70</td>
<td>1.75</td>
<td>3.45</td>
</tr>
<tr>
<td>G</td>
<td>2.58</td>
<td>7.12</td>
<td>9.70</td>
</tr>
<tr>
<td>H</td>
<td>1.15</td>
<td>1.73</td>
<td>2.88</td>
</tr>
<tr>
<td>I</td>
<td>0.71</td>
<td>3.07</td>
<td>3.78</td>
</tr>
<tr>
<td>J</td>
<td>2.47</td>
<td>1.62</td>
<td>4.08</td>
</tr>
<tr>
<td>K</td>
<td>1.21</td>
<td>5.07</td>
<td>6.27</td>
</tr>
<tr>
<td>L</td>
<td>0.47</td>
<td>0.79</td>
<td>1.26</td>
</tr>
<tr>
<td>M</td>
<td>0.33</td>
<td>0.25</td>
<td>0.58</td>
</tr>
<tr>
<td>N</td>
<td>0.25</td>
<td>1.15</td>
<td>1.40</td>
</tr>
<tr>
<td>O</td>
<td>0.41</td>
<td>1.73</td>
<td>2.14</td>
</tr>
<tr>
<td>P</td>
<td>6.14</td>
<td>20.79</td>
<td>26.93</td>
</tr>
<tr>
<td>Q</td>
<td>0.19</td>
<td>0.36</td>
<td>0.55</td>
</tr>
<tr>
<td>HONG KONG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>0.63</td>
<td>9.53</td>
<td>14.63</td>
</tr>
<tr>
<td>1.2</td>
<td>0.63</td>
<td>0.88</td>
<td>1.53</td>
</tr>
<tr>
<td>1.3</td>
<td>6.11</td>
<td>9.75</td>
<td>15.86</td>
</tr>
<tr>
<td>1.4</td>
<td>6.16</td>
<td>5.67</td>
<td>12.92</td>
</tr>
<tr>
<td>1.5</td>
<td>0.27</td>
<td>7.81</td>
<td>12.25</td>
</tr>
<tr>
<td>1.6</td>
<td>0.49</td>
<td>6.96</td>
<td>11.07</td>
</tr>
<tr>
<td>1.7</td>
<td>0.49</td>
<td>5.21</td>
<td>8.30</td>
</tr>
<tr>
<td>1.8</td>
<td>1.70</td>
<td>0.44</td>
<td>0.60</td>
</tr>
<tr>
<td>1.9</td>
<td>0.49</td>
<td>0.88</td>
<td>1.48</td>
</tr>
<tr>
<td>TOTAL</td>
<td>19.18</td>
<td>120.33</td>
<td>275.74</td>
</tr>
</tbody>
</table>

TABLE 9: Seasonal Variation in Energy-Use by Energy Type and Defined Area for the Domestic Sector, 1971 (MJ x 10^6/day)
<table>
<thead>
<tr>
<th>Defined Area</th>
<th>Electricity</th>
<th>Diesel</th>
<th>Other</th>
<th>Total</th>
<th>Electricity</th>
<th>Diesel</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOWLOON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>18.43</td>
<td>16.44</td>
<td>13.67</td>
<td>48.54</td>
<td>28.68</td>
<td>16.44</td>
<td>12.19</td>
<td>57.31</td>
</tr>
<tr>
<td>2.2</td>
<td>15.89</td>
<td>35.59</td>
<td>10.44</td>
<td>61.92</td>
<td>24.72</td>
<td>35.59</td>
<td>9.32</td>
<td>69.65</td>
</tr>
<tr>
<td>2.3</td>
<td>7.07</td>
<td>5.29</td>
<td>4.88</td>
<td>17.24</td>
<td>10.99</td>
<td>5.29</td>
<td>4.33</td>
<td>20.61</td>
</tr>
<tr>
<td>2.4</td>
<td>7.12</td>
<td>10.03</td>
<td>4.38</td>
<td>21.53</td>
<td>11.10</td>
<td>10.03</td>
<td>3.92</td>
<td>25.05</td>
</tr>
<tr>
<td>2.5</td>
<td>3.45</td>
<td>4.33</td>
<td>2.05</td>
<td>9.83</td>
<td>5.37</td>
<td>4.33</td>
<td>1.84</td>
<td>11.54</td>
</tr>
<tr>
<td>2.6</td>
<td>4.85</td>
<td>12.68</td>
<td>3.04</td>
<td>20.57</td>
<td>7.56</td>
<td>12.68</td>
<td>2.71</td>
<td>22.95</td>
</tr>
<tr>
<td>2.7</td>
<td>1.56</td>
<td>1.01</td>
<td>1.18</td>
<td>3.75</td>
<td>2.44</td>
<td>1.01</td>
<td>1.04</td>
<td>4.49</td>
</tr>
<tr>
<td>2.8</td>
<td>4.14</td>
<td>14.36</td>
<td>2.60</td>
<td>21.10</td>
<td>6.44</td>
<td>14.36</td>
<td>2.33</td>
<td>23.13</td>
</tr>
<tr>
<td>2.9</td>
<td>6.33</td>
<td>8.25</td>
<td>3.23</td>
<td>17.81</td>
<td>8.33</td>
<td>8.25</td>
<td>2.88</td>
<td>19.46</td>
</tr>
<tr>
<td>NEW TERRITORIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.90</td>
<td>0.58</td>
<td>0.44</td>
<td>1.92</td>
<td>1.40</td>
<td>0.58</td>
<td>0.38</td>
<td>2.36</td>
</tr>
<tr>
<td>B</td>
<td>0.96</td>
<td>0.60</td>
<td>0.49</td>
<td>2.05</td>
<td>1.51</td>
<td>0.60</td>
<td>0.44</td>
<td>2.55</td>
</tr>
<tr>
<td>C</td>
<td>0.27</td>
<td>0.16</td>
<td>0.16</td>
<td>0.59</td>
<td>0.41</td>
<td>0.16</td>
<td>0.16</td>
<td>0.73</td>
</tr>
<tr>
<td>D</td>
<td>0.79</td>
<td>0.52</td>
<td>0.41</td>
<td>1.72</td>
<td>1.26</td>
<td>0.52</td>
<td>0.36</td>
<td>2.14</td>
</tr>
<tr>
<td>E</td>
<td>1.32</td>
<td>0.85</td>
<td>2.93</td>
<td>5.10</td>
<td>2.03</td>
<td>0.85</td>
<td>2.60</td>
<td>5.48</td>
</tr>
<tr>
<td>F</td>
<td>1.37</td>
<td>0.88</td>
<td>0.71</td>
<td>2.96</td>
<td>2.14</td>
<td>0.88</td>
<td>0.63</td>
<td>3.65</td>
</tr>
<tr>
<td>G</td>
<td>1.12</td>
<td>0.74</td>
<td>0.58</td>
<td>2.44</td>
<td>1.75</td>
<td>0.74</td>
<td>0.52</td>
<td>3.01</td>
</tr>
<tr>
<td>H</td>
<td>1.18</td>
<td>0.77</td>
<td>0.60</td>
<td>2.55</td>
<td>1.84</td>
<td>0.77</td>
<td>0.55</td>
<td>3.16</td>
</tr>
<tr>
<td>I</td>
<td>0.11</td>
<td>0.05</td>
<td>0.05</td>
<td>0.21</td>
<td>0.16</td>
<td>0.05</td>
<td>0.05</td>
<td>0.26</td>
</tr>
<tr>
<td>J</td>
<td>0.16</td>
<td>0.08</td>
<td>0.05</td>
<td>0.29</td>
<td>0.25</td>
<td>0.08</td>
<td>0.05</td>
<td>0.38</td>
</tr>
<tr>
<td>K</td>
<td>4.55</td>
<td>4.68</td>
<td>2.77</td>
<td>12.00</td>
<td>7.07</td>
<td>4.68</td>
<td>2.47</td>
<td>14.22</td>
</tr>
<tr>
<td>L</td>
<td>0.14</td>
<td>0.08</td>
<td>0.05</td>
<td>0.27</td>
<td>0.19</td>
<td>0.08</td>
<td>0.05</td>
<td>0.32</td>
</tr>
<tr>
<td>HONG KONG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>9.64</td>
<td>9.12</td>
<td>6.49</td>
<td>25.25</td>
<td>15.01</td>
<td>9.12</td>
<td>5.78</td>
<td>29.91</td>
</tr>
<tr>
<td>1.2</td>
<td>18.30</td>
<td>16.30</td>
<td>12.73</td>
<td>47.73</td>
<td>28.47</td>
<td>16.30</td>
<td>11.37</td>
<td>56.14</td>
</tr>
<tr>
<td>1.3</td>
<td>11.15</td>
<td>16.30</td>
<td>7.10</td>
<td>34.55</td>
<td>17.34</td>
<td>16.30</td>
<td>6.33</td>
<td>39.97</td>
</tr>
<tr>
<td>1.4</td>
<td>6.22</td>
<td>7.51</td>
<td>5.23</td>
<td>18.96</td>
<td>9.67</td>
<td>7.51</td>
<td>4.66</td>
<td>21.84</td>
</tr>
<tr>
<td>1.5</td>
<td>10.71</td>
<td>11.15</td>
<td>6.49</td>
<td>28.35</td>
<td>16.66</td>
<td>11.15</td>
<td>5.78</td>
<td>33.59</td>
</tr>
<tr>
<td>1.6</td>
<td>5.92</td>
<td>5.62</td>
<td>3.51</td>
<td>15.05</td>
<td>9.21</td>
<td>5.62</td>
<td>3.15</td>
<td>17.98</td>
</tr>
<tr>
<td>1.7</td>
<td>3.97</td>
<td>4.14</td>
<td>2.36</td>
<td>10.47</td>
<td>6.16</td>
<td>4.14</td>
<td>2.08</td>
<td>12.38</td>
</tr>
<tr>
<td>1.8</td>
<td>2.27</td>
<td>1.45</td>
<td>1.45</td>
<td>5.17</td>
<td>3.53</td>
<td>1.45</td>
<td>1.31</td>
<td>6.29</td>
</tr>
<tr>
<td>1.9</td>
<td>0.85</td>
<td>0.88</td>
<td>0.60</td>
<td>2.33</td>
<td>1.32</td>
<td>0.88</td>
<td>0.55</td>
<td>2.75</td>
</tr>
<tr>
<td>TOTAL</td>
<td>150.74</td>
<td>190.44</td>
<td>100.67</td>
<td>441.85</td>
<td>233.03</td>
<td>190.44</td>
<td>89.83</td>
<td>513.30</td>
</tr>
</tbody>
</table>
### TABLE 10
Seasonal Variation in Energy-Use by Energy Type and Defined Area for the Industrial Sector, 1971
(MJ x 10^5/day)

<table>
<thead>
<tr>
<th>Defined Area</th>
<th>Electricity</th>
<th>Gas</th>
<th>Other</th>
<th>Total</th>
<th>Electricity</th>
<th>Gas</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KOWLOON</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>0.19</td>
<td>0.08</td>
<td>0.85</td>
<td>1.12</td>
<td>0.27</td>
<td>0.11</td>
<td>1.23</td>
<td>1.61</td>
</tr>
<tr>
<td>2.2</td>
<td>0.11</td>
<td>0.11</td>
<td>7.86</td>
<td>8.08</td>
<td>0.16</td>
<td>0.16</td>
<td>11.23</td>
<td>11.55</td>
</tr>
<tr>
<td>2.3</td>
<td>1.89</td>
<td>0.19</td>
<td>2.05</td>
<td>4.13</td>
<td>2.68</td>
<td>0.27</td>
<td>2.93</td>
<td>5.88</td>
</tr>
<tr>
<td>2.4</td>
<td>14.6</td>
<td>0.30</td>
<td>19.10</td>
<td>34.00</td>
<td>20.9</td>
<td>0.44</td>
<td>27.23</td>
<td>48.57</td>
</tr>
<tr>
<td>2.5</td>
<td>10.47</td>
<td>0.05</td>
<td>24.19</td>
<td>34.71</td>
<td>14.99</td>
<td>0.08</td>
<td>34.52</td>
<td>49.59</td>
</tr>
<tr>
<td>2.6</td>
<td>2.00</td>
<td>0.14</td>
<td>6.08</td>
<td>8.22</td>
<td>2.88</td>
<td>0.22</td>
<td>8.68</td>
<td>11.78</td>
</tr>
<tr>
<td>2.7</td>
<td>0.03</td>
<td>0.03</td>
<td>0.14</td>
<td>0.19</td>
<td>0.03</td>
<td>0.03</td>
<td>0.19</td>
<td>0.25</td>
</tr>
<tr>
<td>2.8</td>
<td>13.61</td>
<td>0.25</td>
<td>29.4</td>
<td>43.26</td>
<td>19.48</td>
<td>0.33</td>
<td>41.94</td>
<td>61.75</td>
</tr>
<tr>
<td>2.9</td>
<td>28.74</td>
<td>0.27</td>
<td>91.92</td>
<td>120.93</td>
<td>41.1</td>
<td>0.38</td>
<td>130.82</td>
<td>172.3</td>
</tr>
<tr>
<td><strong>NEW TERRITORIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>6.22</td>
<td></td>
<td>5.37</td>
<td>11.6</td>
<td>8.88</td>
<td></td>
<td>7.67</td>
<td>16.55</td>
</tr>
<tr>
<td>B</td>
<td>4.30</td>
<td></td>
<td>3.86</td>
<td>8.16</td>
<td>6.16</td>
<td></td>
<td>5.51</td>
<td>11.67</td>
</tr>
<tr>
<td>C</td>
<td>5.59</td>
<td></td>
<td>4.77</td>
<td>10.36</td>
<td>7.97</td>
<td></td>
<td>6.79</td>
<td>14.76</td>
</tr>
<tr>
<td>D</td>
<td>3.29</td>
<td></td>
<td>3.01</td>
<td>6.30</td>
<td>4.74</td>
<td></td>
<td>4.30</td>
<td>9.04</td>
</tr>
<tr>
<td><strong>HONG KONG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>1.73</td>
<td>0.05</td>
<td>3.32</td>
<td>5.10</td>
<td>2.47</td>
<td>0.05</td>
<td>4.71</td>
<td>7.23</td>
</tr>
<tr>
<td>1.2</td>
<td>1.22</td>
<td>0.22</td>
<td>0.14</td>
<td>0.36</td>
<td>0.16</td>
<td>0.30</td>
<td>0.22</td>
<td>0.52</td>
</tr>
<tr>
<td>1.3</td>
<td>2.66</td>
<td>0.03</td>
<td>3.59</td>
<td>6.28</td>
<td>3.81</td>
<td>0.03</td>
<td>5.12</td>
<td>8.96</td>
</tr>
<tr>
<td>1.4</td>
<td>0.08</td>
<td>0.05</td>
<td>1.23</td>
<td>1.36</td>
<td>0.14</td>
<td>0.08</td>
<td>1.75</td>
<td>1.97</td>
</tr>
<tr>
<td>1.5</td>
<td>8.19</td>
<td>0.05</td>
<td>17.81</td>
<td>26.05</td>
<td>11.7</td>
<td>0.08</td>
<td>25.37</td>
<td>37.15</td>
</tr>
<tr>
<td>1.6</td>
<td>5.21</td>
<td>0.03</td>
<td>6.66</td>
<td>11.90</td>
<td>7.42</td>
<td>0.03</td>
<td>9.51</td>
<td>16.96</td>
</tr>
<tr>
<td>1.7</td>
<td>1.51</td>
<td></td>
<td>3.34</td>
<td>4.85</td>
<td>2.16</td>
<td></td>
<td>4.74</td>
<td>6.90</td>
</tr>
<tr>
<td>1.8</td>
<td>0.16</td>
<td>0.03</td>
<td>0.16</td>
<td>0.16</td>
<td>0.03</td>
<td>0.25</td>
<td>0.28</td>
<td>0.85</td>
</tr>
<tr>
<td>1.9</td>
<td>0.16</td>
<td>0.03</td>
<td>0.44</td>
<td>0.63</td>
<td>0.22</td>
<td></td>
<td>0.63</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>169.04</td>
<td>1.99</td>
<td>333.43</td>
<td>504.46</td>
<td>261.77</td>
<td>2.78</td>
<td>475.40</td>
<td>719.95</td>
</tr>
</tbody>
</table>
### TABLE 11
Seasonal Variation in Energy Use by Energy Type and Defined Area for the Transport Sector, 1971

(\(\text{MJ x 10}^5/\text{day}\))

<table>
<thead>
<tr>
<th>Defined Area</th>
<th>AGO and Mogas/ Marine IGO &amp; Fuel Oil</th>
<th>Avtur, Avgas and Rail AGO</th>
<th>Electricity</th>
<th>Total AGO and Mogas/ Marine IGO &amp; Fuel Oil</th>
<th>Avtur, Avgas and Rail AGO</th>
<th>Electricity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KOWLOON</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>11.42</td>
<td>0.05</td>
<td>11.47</td>
<td>12.68</td>
<td>0.05</td>
<td>12.74</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>32.0</td>
<td>0.08</td>
<td>32.08</td>
<td>35.56</td>
<td>0.08</td>
<td>35.64</td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>13.81</td>
<td>0.05</td>
<td>13.86</td>
<td>15.34</td>
<td>0.05</td>
<td>15.40</td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>13.15</td>
<td>0.05</td>
<td>13.20</td>
<td>14.60</td>
<td>0.05</td>
<td>14.66</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>12.68</td>
<td>2.27</td>
<td>14.95</td>
<td>14.31</td>
<td>2.27</td>
<td>16.38</td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>29.62</td>
<td>2.27</td>
<td>31.89</td>
<td>32.90</td>
<td>2.27</td>
<td>35.18</td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>11.45</td>
<td>2.27</td>
<td>13.72</td>
<td>12.74</td>
<td>2.27</td>
<td>15.01</td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td>29.48</td>
<td>24.36</td>
<td>53.84</td>
<td>32.74</td>
<td>24.36</td>
<td>57.10</td>
<td></td>
</tr>
<tr>
<td>2.9</td>
<td>25.84</td>
<td>0.05</td>
<td>25.89</td>
<td>28.68</td>
<td>0.05</td>
<td>28.74</td>
<td></td>
</tr>
<tr>
<td><strong>NEW TERRITORIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>3.92</td>
<td>0.27</td>
<td>4.19</td>
<td>4.36</td>
<td>0.27</td>
<td>4.63</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>6.05</td>
<td>6.05</td>
<td>12.10</td>
<td>6.71</td>
<td>6.05</td>
<td>12.76</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>6.63</td>
<td>1.21</td>
<td>7.84</td>
<td>7.37</td>
<td>1.22</td>
<td>8.59</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>4.22</td>
<td>0.52</td>
<td>4.74</td>
<td>4.71</td>
<td>0.52</td>
<td>5.23</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>2.25</td>
<td>0.03</td>
<td>2.28</td>
<td>2.49</td>
<td>0.03</td>
<td>2.52</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>3.29</td>
<td>2.71</td>
<td>6.0</td>
<td>3.67</td>
<td>2.71</td>
<td>6.38</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>1.40</td>
<td>0.05</td>
<td>1.45</td>
<td>1.56</td>
<td>0.05</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>3.01</td>
<td>2.99</td>
<td>6.0</td>
<td>3.34</td>
<td>2.99</td>
<td>6.33</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>2.41</td>
<td>0.16</td>
<td>2.57</td>
<td>2.68</td>
<td>0.16</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>6.88</td>
<td>2.14</td>
<td>9.02</td>
<td>7.64</td>
<td>2.14</td>
<td>9.78</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>0.52</td>
<td>2.52</td>
<td>3.04</td>
<td>0.58</td>
<td>2.52</td>
<td>3.10</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>0.52</td>
<td>0.52</td>
<td>0.52</td>
<td>0.52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>0.52</td>
<td>0.52</td>
<td>0.52</td>
<td>0.52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>0.52</td>
<td>4.14</td>
<td>4.66</td>
<td>0.58</td>
<td>4.54</td>
<td>4.71</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>6.88</td>
<td>0.44</td>
<td>7.32</td>
<td>7.64</td>
<td>0.44</td>
<td>8.08</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HONG KONG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>12.38</td>
<td>0.05</td>
<td>0.08</td>
<td>12.51</td>
<td>0.05</td>
<td>0.08</td>
<td>13.89</td>
</tr>
<tr>
<td>1.2</td>
<td>10.74</td>
<td>0.03</td>
<td>0.38</td>
<td>11.15</td>
<td>0.03</td>
<td>0.38</td>
<td>12.36</td>
</tr>
<tr>
<td>1.3</td>
<td>11.62</td>
<td>0.03</td>
<td>0.38</td>
<td>12.03</td>
<td>0.03</td>
<td>0.38</td>
<td>13.32</td>
</tr>
<tr>
<td>1.4</td>
<td>18.52</td>
<td>0.16</td>
<td>0.30</td>
<td>18.89</td>
<td>0.16</td>
<td>0.30</td>
<td>21.04</td>
</tr>
<tr>
<td>1.5</td>
<td>13.79</td>
<td>0.11</td>
<td>0.30</td>
<td>13.21</td>
<td>0.11</td>
<td>0.30</td>
<td>14.63</td>
</tr>
<tr>
<td>1.6</td>
<td>3.97</td>
<td>0.16</td>
<td>0.08</td>
<td>4.22</td>
<td>0.16</td>
<td>0.08</td>
<td>4.48</td>
</tr>
<tr>
<td>1.7</td>
<td>7.01</td>
<td>0.30</td>
<td>7.32</td>
<td>7.38</td>
<td>0.30</td>
<td>7.68</td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>2.63</td>
<td>0.25</td>
<td>2.88</td>
<td>2.93</td>
<td>0.25</td>
<td>3.18</td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>7.12</td>
<td>1.04</td>
<td>8.16</td>
<td>7.89</td>
<td>1.04</td>
<td>8.93</td>
<td></td>
</tr>
<tr>
<td><strong>HARBOUR</strong></td>
<td>134.25</td>
<td>2.27</td>
<td>136.52</td>
<td>163.29</td>
<td>2.27</td>
<td>165.56</td>
<td></td>
</tr>
<tr>
<td><strong>ABERDEEN</strong></td>
<td>11.97</td>
<td>14.55</td>
<td>11.97</td>
<td>14.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>460.43</td>
<td>60.83</td>
<td>1.52</td>
<td>522.78</td>
<td>526.96</td>
<td>60.83</td>
<td>1.52</td>
</tr>
</tbody>
</table>

**Note:** The values represent energy use in MJ x 10^5/day for the transport sector in Hong Kong for the specified periods.
TABLE 12
Seasonal Variation in Energy-Use by Energy Type and Defined Area for Point Losses, 1971
(MJ x 10^7/day)

<table>
<thead>
<tr>
<th>Defined Area</th>
<th>Incineration Power Utilities</th>
<th>Power Water Pumping Stations</th>
<th>Total Incineration Power Utilities</th>
<th>Power Water Pumping Stations</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mid-Winter (15th February)</td>
<td></td>
<td>Mid-Summer (15th July)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>KOWLOON</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>418.46</td>
<td>1.21</td>
<td>419.67</td>
<td>610.33</td>
<td>1.21</td>
</tr>
<tr>
<td>2.5</td>
<td>30.44</td>
<td>0.30</td>
<td>30.74</td>
<td>20.30</td>
<td>0.30</td>
</tr>
<tr>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td></td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NEW TERRITORIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>4.79</td>
<td>4.79</td>
<td>4.79</td>
<td>4.79</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>E</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>F</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>G</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>H</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>1.86</td>
<td>1.86</td>
<td>1.86</td>
<td>1.86</td>
</tr>
<tr>
<td>J</td>
<td></td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>K</td>
<td>2.82</td>
<td>2.82</td>
<td>2.82</td>
<td>2.82</td>
<td>2.82</td>
</tr>
<tr>
<td>L</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
</tr>
<tr>
<td>M</td>
<td>1.13</td>
<td>1.13</td>
<td>1.65</td>
<td>1.65</td>
<td>1.65</td>
</tr>
<tr>
<td>N</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
<td>0.74</td>
</tr>
<tr>
<td>O</td>
<td>3.48</td>
<td>3.48</td>
<td>3.48</td>
<td>3.48</td>
<td>3.48</td>
</tr>
<tr>
<td>P</td>
<td>349.67</td>
<td>349.67</td>
<td>509.81</td>
<td>509.81</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HONG KONG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>31.86</td>
<td>31.86</td>
<td>21.24</td>
<td>21.24</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>106.21</td>
<td>106.21</td>
<td>154.85</td>
<td>154.85</td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7</td>
<td>212.44</td>
<td>1.51</td>
<td>213.95</td>
<td>309.73</td>
<td>1.51</td>
</tr>
<tr>
<td>1.8</td>
<td></td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>1.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>62.50</td>
<td>1087.91</td>
<td>18.68</td>
<td>1169.09</td>
<td>41.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1586.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18.68</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1646.79</td>
</tr>
</tbody>
</table>
TABLE 13: Seasonal Variation in Energy-Use, Overall Total for each Defined Area, Hong Kong, 1971

<table>
<thead>
<tr>
<th>Defined Area</th>
<th>Mid-Winter</th>
<th>Mid-Summer</th>
<th>MJ x 10^5/day</th>
<th>Defined Area</th>
<th>Mid-Winter</th>
<th>Mid-Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KOWLOON</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>73.92</td>
<td>84.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>135.64</td>
<td>146.72</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>53.02</td>
<td>61.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>508.10</td>
<td>718.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>94.45</td>
<td>102.84</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>96.10</td>
<td>99.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>23.80</td>
<td>25.97</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td>165.54</td>
<td>181.68</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.9</td>
<td>205.34</td>
<td>257.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NEW TERRITORIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>10.14</td>
<td>11.91</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>23.00</td>
<td>25.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>7.72</td>
<td>8.86</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>1.20</td>
<td>1.56</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>3.28</td>
<td>3.84</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>8.86</td>
<td>9.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>184.25</td>
<td>241.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>355.89</td>
<td>518.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HONG KONG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>99.56</td>
<td>96.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>61.88</td>
<td>71.76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>68.72</td>
<td>77.94</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>60.26</td>
<td>63.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>194.15</td>
<td>260.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td>49.69</td>
<td>57.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7</td>
<td>250.59</td>
<td>352.32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>11.25</td>
<td>12.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9</td>
<td>13.97</td>
<td>15.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>VICTORIA HARBOUR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>11.97</td>
<td>14.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ABERDEEN HARBOUR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>3053.43</td>
<td>3854.91</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>February (mid-winter)</td>
<td>July (mid-summer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------</td>
<td>-------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incoming Solar Radiation (A)</td>
<td>Artificial Heat Generation (B)</td>
<td>Ratio (B)/(A)</td>
<td>Incoming Solar Radiation (A)</td>
<td>Artificial Heat Generation (B)</td>
<td>Ratio (B)/(A)</td>
</tr>
<tr>
<td>0100-0300</td>
<td>-</td>
<td>0.094</td>
<td>-</td>
<td>-</td>
<td>0.133</td>
<td>-</td>
</tr>
<tr>
<td>0300-0500</td>
<td>-</td>
<td>0.071</td>
<td>-</td>
<td>-</td>
<td>0.107</td>
<td>-</td>
</tr>
<tr>
<td>0500-0700</td>
<td>0.17</td>
<td>0.106</td>
<td>0.609</td>
<td>1.94</td>
<td>0.139</td>
<td>0.07161</td>
</tr>
<tr>
<td>0700-0900</td>
<td>4.85</td>
<td>0.209</td>
<td>0.043</td>
<td>17.76</td>
<td>0.257</td>
<td>0.01447</td>
</tr>
<tr>
<td>0900-1100</td>
<td>20.20</td>
<td>0.287</td>
<td>0.014</td>
<td>39.33</td>
<td>0.369</td>
<td>0.00938</td>
</tr>
<tr>
<td>1100-1300</td>
<td>33.93</td>
<td>0.323</td>
<td>0.01</td>
<td>51.97</td>
<td>0.420</td>
<td>0.00808</td>
</tr>
<tr>
<td>1300-1500</td>
<td>33.69</td>
<td>0.295</td>
<td>0.01</td>
<td>46.72</td>
<td>0.393</td>
<td>0.00841</td>
</tr>
<tr>
<td>1500-1700</td>
<td>22.12</td>
<td>0.296</td>
<td>0.01</td>
<td>33.01</td>
<td>0.390</td>
<td>0.01181</td>
</tr>
<tr>
<td>1700-1900</td>
<td>4.88</td>
<td>0.324</td>
<td>0.07</td>
<td>16.30</td>
<td>0.397</td>
<td>0.02436</td>
</tr>
<tr>
<td>1900-2100</td>
<td>-</td>
<td>0.331</td>
<td>-</td>
<td>1.47</td>
<td>0.376</td>
<td>0.25613</td>
</tr>
<tr>
<td>2100-2300</td>
<td>-</td>
<td>0.262</td>
<td>-</td>
<td>-</td>
<td>0.313</td>
<td>-</td>
</tr>
<tr>
<td>2300-0100</td>
<td>-</td>
<td>0.179</td>
<td>-</td>
<td>-</td>
<td>0.225</td>
<td>-</td>
</tr>
</tbody>
</table>

All day 119.84 2.78 0.023 208.50 3.52 0.017
<table>
<thead>
<tr>
<th>Time</th>
<th>February (mid-winter)</th>
<th>July (mid-summer)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incoming Solar</td>
<td>Artificial Heat</td>
</tr>
<tr>
<td></td>
<td>Radiation (A)</td>
<td>Generation (B)</td>
</tr>
<tr>
<td>0100-0300</td>
<td>-</td>
<td>9.71</td>
</tr>
<tr>
<td>0300-0500</td>
<td>-</td>
<td>8.06</td>
</tr>
<tr>
<td>0500-0700</td>
<td>0.17</td>
<td>9.32</td>
</tr>
<tr>
<td>0700-0900</td>
<td>4.85</td>
<td>15.90</td>
</tr>
<tr>
<td>0900-1100</td>
<td>20.20</td>
<td>25.85</td>
</tr>
<tr>
<td>1100-1300</td>
<td>33.93</td>
<td>29.31</td>
</tr>
<tr>
<td>1300-1500</td>
<td>33.69</td>
<td>27.04</td>
</tr>
<tr>
<td>1500-1700</td>
<td>22.12</td>
<td>27.43</td>
</tr>
<tr>
<td>1700-1900</td>
<td>4.88</td>
<td>29.98</td>
</tr>
<tr>
<td>1900-2100</td>
<td>-</td>
<td>29.49</td>
</tr>
<tr>
<td>2100-2300</td>
<td>-</td>
<td>24.23</td>
</tr>
<tr>
<td>2300-0100</td>
<td>-</td>
<td>16.46</td>
</tr>
<tr>
<td><strong>DAILY</strong></td>
<td><strong>119.84</strong></td>
<td><strong>252.78</strong></td>
</tr>
</tbody>
</table>
TABLE 16: Incoming Solar Radiation and Artificial Heat Generation (MJ x 10^5/sq. km.) in Kwun Tong (2.9) for two-hourly Periods in February and July 1971, with their ratios

<table>
<thead>
<tr>
<th>Time</th>
<th>February (mid-winter)</th>
<th></th>
<th>July (mid-summer)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incoming Solar Radiation (A)</td>
<td>Artificial Heat Generation (B)</td>
<td>Ratio (B)/(A)</td>
<td>Incoming Solar Radiation (A)</td>
</tr>
<tr>
<td>0100-0300</td>
<td>-</td>
<td>0.48</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0300-0500</td>
<td>-</td>
<td>0.34</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0500-0700</td>
<td>0.17</td>
<td>0.45</td>
<td>2.65</td>
<td>1.94</td>
</tr>
<tr>
<td>0700-0900</td>
<td>4.85</td>
<td>1.17</td>
<td>0.24</td>
<td>17.76</td>
</tr>
<tr>
<td>0900-1100</td>
<td>20.20</td>
<td>1.62</td>
<td>0.08</td>
<td>39.33</td>
</tr>
<tr>
<td>1100-1300</td>
<td>33.93</td>
<td>1.87</td>
<td>0.06</td>
<td>51.97</td>
</tr>
<tr>
<td>1300-1500</td>
<td>33.69</td>
<td>1.71</td>
<td>0.05</td>
<td>46.72</td>
</tr>
<tr>
<td>1500-1700</td>
<td>22.1</td>
<td>1.55</td>
<td>0.07</td>
<td>33.01</td>
</tr>
<tr>
<td>1700-1900</td>
<td>48.8</td>
<td>1.86</td>
<td>0.38</td>
<td>16.30</td>
</tr>
<tr>
<td>1900-2100</td>
<td>-</td>
<td>1.99</td>
<td>-</td>
<td>1.47</td>
</tr>
<tr>
<td>2100-2300</td>
<td>-</td>
<td>1.55</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2300-0100</td>
<td>-</td>
<td>1.08</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DAILY</td>
<td>119.84</td>
<td>15.73</td>
<td>0.13</td>
<td>208.50</td>
</tr>
</tbody>
</table>
### Table 17: Incoming Solar Radiation and Artificial Heat Generation (MJ x 10^5/sq. km.) in Tsuen Wan (P) for two-hourly periods in February and July 1971, with their ratios

<table>
<thead>
<tr>
<th>Time</th>
<th>Incoming Solar Radiation (A)</th>
<th>Artificial Heat Generation (B)</th>
<th>Ratio (B)/(A)</th>
<th>Incoming Solar Radiation (A)</th>
<th>Artificial Heat Generation (B)</th>
<th>Ratio (B)/(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0100-0300</td>
<td>-</td>
<td>0.39</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0300-0500</td>
<td>-</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0500-0700</td>
<td>0.17</td>
<td>0.35</td>
<td>2.06</td>
<td>1.94</td>
<td>0.48</td>
<td>0.25</td>
</tr>
<tr>
<td>0700-0900</td>
<td>4.85</td>
<td>0.81</td>
<td>0.17</td>
<td>17.76</td>
<td>1.05</td>
<td>0.06</td>
</tr>
<tr>
<td>0900-1100</td>
<td>20.20</td>
<td>1.19</td>
<td>0.06</td>
<td>39.33</td>
<td>1.58</td>
<td>0.04</td>
</tr>
<tr>
<td>1100-1300</td>
<td>33.93</td>
<td>1.39</td>
<td>0.04</td>
<td>51.97</td>
<td>1.86</td>
<td>0.03</td>
</tr>
<tr>
<td>1300-1500</td>
<td>33.69</td>
<td>1.29</td>
<td>0.03</td>
<td>56.72</td>
<td>1.75</td>
<td>0.03</td>
</tr>
<tr>
<td>1500-1700</td>
<td>22.12</td>
<td>1.17</td>
<td>0.05</td>
<td>33.01</td>
<td>1.58</td>
<td>0.04</td>
</tr>
<tr>
<td>1700-1900</td>
<td>4.88</td>
<td>1.39</td>
<td>0.28</td>
<td>16.30</td>
<td>1.79</td>
<td>0.11</td>
</tr>
<tr>
<td>1900-2100</td>
<td>-</td>
<td>1.50</td>
<td>-</td>
<td>1.47</td>
<td>1.85</td>
<td>1.26</td>
</tr>
<tr>
<td>2100-2300</td>
<td>-</td>
<td>1.18</td>
<td>-</td>
<td>-</td>
<td>1.50</td>
<td>-</td>
</tr>
<tr>
<td>2300-0100</td>
<td>-</td>
<td>0.82</td>
<td>-</td>
<td>-</td>
<td>1.08</td>
<td>-</td>
</tr>
</tbody>
</table>

**Daily**

| 119.84 | 11.80 | 0.10 | 208.50 | 15.50 | 0.07 |
Figure 2
SPATIAL DISTRIBUTION OF ARTIFICIAL HEAT GENERATION IN THE NEW TERRITORIES, HONG KONG, 1971.

LEGEND:
Energy in MJ x 10^8/sq.km.
Refer to spatial distribution of energy map for Hong Kong & Kowloon, 1971.

10 km.
5

HONG KONG ISLAND
URBAN AREA

KOWLOON
URBAN AREA
Figures 3-6: The temporal variation in energy use by sector of activity, including losses, for Hong Kong in summer and in winter, and Hung Hom in summer and winter, respectively.
Figures 7-10: The temporal variation in energy-use by sector of activity, including losses, for Kwun Tong in summer and in winter, and for Tsuen Wan in summer and in winter, respectively.
Figs. 11-14. The seasonal pattern of temporal variation in total energy-use in Hong Kong, Hung Hom, Kwun Tong and Tsuen Wan, respectively.
CHAPTER V

ENERGY IN THE HONG KONG FOOD SYSTEM
INTRODUCTION

Proposals to alleviate the world food problems (President's Sci. Adv. Comm. 1967, F.A.O., 1970) have consistently emphasised the importance of increasing mechanization, the use of artificial fertilizers, herbicides, pesticides and intensive irrigation systems. These reports have discussed at length how to overcome the limiting factors of space, water resources, technical understanding and finance. However, throughout these most important documents the vastly expanded energy requirements of an agricultural system including all of the above inputs have received no more than cursory attention.

Clearly each step in the proposed modernization of agriculture in the developing countries, whether it be the introduction of tractor power or the systematic application of insecticides, involves a substantial expansion in the energy support base of the food system. As with almost all other processes of production in the industrialized world, an increased reliance on extrasomatic energy* in the food system was not viewed with concern until it became obvious that energy is not yet an unlimited resource and that it is just as effective a limiting factor as (in this case) finance, water resources or technical understanding. Nevertheless, despite a new-found understanding of the

*Extrasomatic energy: "that energy which flows through or is utilised by a human community and which is not utilised through metabolic processes within a living organism." In this research 'extrasomatic energy' only includes fuels in current use.

Somatic energy: "that energy which is utilised, through the metabolic processes, within a living organism".
precariousness of continued energy supplies the solution to the world food problem is portrayed as one which is inherently energy-expensive.

Unlike the energy-efficient food production systems described by Rappoport (1971) and Lee (1969) for neolithic and hunter-gatherer groups, the new agricultural technology of the industrialised world is high-yielding only at the expense of large extrasomatic energy inputs to the food production process. It is, in fact, relatively inefficient in energy input-output terms (Hipsley, 1967; Odum, 1971 and Perelman, 1972).

The transactional models of input-output economics developed by Leontief (1966) provide a framework for quantifying the flow and exchange of energy within an ecosystem as well as for the production of a particular commodity by industry. Several authors have adopted this methodology to analyse the impact of changes in technology on the energy requirements of energy-intensive industrial sectors of nations of the western world, and to describe the impact of rising fuel prices on the economy (Herendeen, 1973; Chapman, 1974 and Wright, 1975). Their research also provides an energy equivalent value for a number of commodities essential to western agriculture. These values complement data gathered by Leach and Slesser (1973) on the energy equivalents of network inputs to food producing processes. The compilation of such data has greatly assisted analyses of the energy requirements of production of particular crops (e.g. corn in the U.S. Pimentel et al, 1973 and potatoes in the U.K., Leach, 1974), and the energy
requirements of national food systems (e.g. for the U.S.,
Steinhart and Steinhart, 1974, Hirst, 1974; for Israel,
Stanhill, 1974; for the U.K., Blaxter, 1975 and for
Australia, Gifford and Millington, 1975).

Research on the energy requirements of food production
and on energy distribution in national food systems has
shown that, while the process is marginally efficient for
'pre-farm gate' production, the ratio of energy input to
output is much greater than unity when account is taken of
the energy inputs necessary to bring food to the consumer's
table. In other words, food processing, storage and
especially costs of transportation are very energy-expensive.

Research into the energetic efficiency* of corn
production in the United States by Pimentel et al. (1973)
has shown a return of 3 units of somatic energy for an
investment of 1 unit of mostly extrasomatic energy. This
is notably inferior to the efficiencies reported by
Rappoport (1971) and others for neolithic groups, of the
order of one unit of energy invested for about 15 units
returned.

The yields of more primitive agriculture are often up
to 6 times less per unit area than the yields obtained by
using modern agricultural techniques. However, yield does
not increase in direct proportion to energy subsidy and the
return per unit of extrasomatic energy invested tends to get
smaller as the total amount of energy invested increases

*For convenience, the concept of 'efficiency' in this paper is
narrowly related to the ratio of 'input' to 'output' of energy
in food systems whereby if output of energy exceeds input the
process is described as 'efficient' and if input 'exceeds'
output, the process is described as 'inefficient'.

past a certain optimal level. This has been tentatively outlined by Heichel (1973) but follows a more fundamental principle evinced by Adams (1962) which finds its origin in the second law of thermodynamics. It is important to define in what way the additional energy cost of western agriculture is contributing to increased yield and therefore what low-energy alternatives are available which do not cause a significant reduction in yield.

Contributions to an understanding of the energy requirements of western food systems have importance not only in terms of the already experienced shortages of extrasomatic energy in the western world but, as Odum (1971) recognised, because the so-called 'Green Revolution' has involved exporting western agricultural technology to the developing world without underpinning the concomitant dependence on high energy subsidies inherent in the new high-yielding mode of production.

The study of energy use in the Hong Kong food system attempts to provide information on the impact of western technology on the energetic efficiency of the food system in the environment of a developing country. The analysis, using an energy accounting methodology, examines the energy requirements of crop production and distribution in Hong Kong. An attempt is also made to identify trends in energy-use by analysing the energy requirements of vegetable production using the most advanced agricultural technology in use in Hong Kong and comparing this with an example of the energy requirements of traditional Chinese agriculture.

Hong Kong is a developing country with a food production
system which is in transition between traditional Chinese and western agricultural technology. By examining relationships between the new energy expensive inputs, yield and system-energy demand, it is possible to identify the relative importance of each energy-expensive input, and to explore feasible low-energy alternatives within the local food production system.

The setting of Hong Kong

Hong Kong (lat. 22°N) is located on the south coast of China, extending into the South China Sea. Its population in March 1971 was about 3.9 million people. Hong Kong's land area including the New Territories is 1,046 km². There are 253 islands, the largest ones of agricultural importance are Lantau Island and Lamma Island. The terrain is mountainous and rugged with very little flat land available for settlement and agriculture. Only some 124 square kilometres can be regarded as arable land.

In 1971, 12,103 hectares were under agricultural production, including orchards and fallow. Despite this small area, Hong Kong produces about 40% of its animal protein, 5% of its plant protein and 5% of its total somatic energy requirements (Newcombe, in preparation).

A number of factors operate to make Hong Kong suitable for this study. Firstly, the colony is a discrete geographical, political, economic and demographic entity. Secondly, excellent records have been kept for lengthy periods by most government departments in Hong Kong. Thirdly, in recent years, agriculture in Hong Kong has undergone certain trends in the application of western technology which are in
train in many countries in Asia.

Energy network inputs

In this paper an attempt is made to allocate an energy value to as many as possible of the major inputs to the processes of production and distribution of plant nutrients in Hong Kong. This, of course, involves identifying both the direct energy costs and also the energy required to produce each commodity which forms part of the material inputs to the production process. For example, an energy equivalent value is allocated to the construction and maintenance of a vehicle, as well as ascribing an energy value to the fuel used by the vehicle. However, an exhaustive analysis of all the energy inputs remains difficult and is, perhaps, unnecessary. The objective of this research is to provide a reasonably accurate index of the comparative energy costs and benefits of one form of food system versus another. Where the amounts of energy involved were considered unlikely to be significant in relation to already known energy costs, detailed analyses were not undertaken. For example, the energy costs of building construction or the construction costs of the intricate network of concrete water reticulation channels which permeate agricultural lands in Hong Kong, have not been considered, mainly because their longevity reduces their per annum energy cost to minimal proportions.

In effect this method of analysis encompasses an objective referred to by Chapman (1974) which is "to follow each network of inputs back from the final product until it is found that the addition of the next input makes an
acceptably small difference to the total energy cost".

The way in which the energy equivalents of each of the inputs are calculated is contained in detail in the footnotes to each table.

This analysis of energy requirements of plant production in Hong Kong is confined to major crops of rice, vegetables (mainly *Brassica* spp.) and field crops (largely sweet potatoes). In fact this excludes only orchard and abandoned or fallow land, reducing the land area under consideration from 12,103 hectares to 8,380 hectares.

It must also be made clear from the outset that comparisons of the energetic efficiency of food are significantly affected by the wide variation in the energy content of particular crops. Leafy green vegetables have an energy content per unit wet weight 20 times less than rice and other grains. Because it is common in Hong Kong to produce 6 to 8 crops of vegetables per year compared with one crop of rice, the actual variation in energy content per annum of different crops may be reduced to a factor of about three.

All energy inputs have been calculated for conditions which applied in 1971, although reference will be made later to more recent years. The unit of energy used is the joule.

\[
1 \text{ Megajoule} = 10^3 \text{ Kilojoules} = 10^6 \text{ Joules} = 947.82 \text{ BTU} = 238.85 \text{ Kcal} = 0.2778 \text{ Kwh.}
\]

The analysis of inputs has been divided for the purposes of discussion into 'pre-farm gate' inputs and
'post-farm gate' inputs. All inputs are schematically represented in Figure 1.

Pre-farm gate production

A list of the inputs showing their energy value is contained in Table 1 (and represented in Figure 1). As the footnotes to Table 1 indicate, the introduction of mechanisation is comparatively recent and not widespread. Because of the small farm size, averaging only a fraction of a hectare, large farm machinery is not practical. Small mechanical cultivators are now becoming popular, but there were only 200 of them in use in 1971. Very intensive sprinkler irrigation systems covered only 40 of the 8380 hectares. These facts serve to explain why machinery is a negligible energy input and irrigation is only 14% of the total in 1971.

Fertilizers make up 35% of the energy inputs. Artificial fertilizers are applied almost entirely to vegetables of which there are 6 to 8 crops per year. This means that 2.8 tonnes of artificial inorganic fertilizer is applied per hectare per year. Due largely to intensive cultivation of every portion of available land, these average fertilizer application rates are 35 times the rates for the U.S., 5 times the rates for New Zealand, and 107 times the rates for Australian application for 1968 (FAO, 1971).

Transportation represents a major energy cost despite the very small distances between Hong Kong agricultural zones and urban centres. About 90% of this energy is used to bring the fertilizers and insecticides from distant points of production in the world to Hong Kong. Despite the
adoption of a number of high energy inputs, Hong Kong agriculture remains moderately labour intensive with 2.4 farm labourers per hectare. The similarity of the machinery and hand tool inputs also testify to this fact.

The total yield of the specified crops in 1971 has been calculated from our research on nutrient flow in Hong Kong. When compared with the energy inputs in Table 1, a ratio of energy invested to energy returned in food of about 0.8 to 1 results. The ratio of energy invested to energy returned pre-farm gate in Australia is also about 0.8 to 1 (Gifford, 1974 and Gifford and Millington, 1975). This comparison indicates that although Hong Kong is still in transition towards a fully mechanised western agriculture, the sophisticated inputs that have already been adopted, such as artificial fertilizers, when applied to intensive farming, easily counter-balance the energy costs of machine intensive agriculture in Australia. However, in analysing the inputs to a total production system, it is evident that the energy costs of some of the advanced technology are hidden.

**Maximum energy costs**

Because the mechanical cultivators, sprinkler irrigation systems and so on, are very new features of the Hong Kong food system their full impact on energetic efficiency and energy demand has yet to be experienced. In 1971 only 30-40 hectares of crop land in Hong Kong was being farmed using such technology. However, the Department of Agriculture and Fisheries is encouraging the introduction of this technology because of the labour savings and yield
increases that might be achieved by its use. It is important, then, to appreciate the demand on energy resources which might occur as a result of a significant transition to this higher technology agriculture. Table 2 is an analysis of the energy requirements of intensive vegetable farming using the most sophisticated technology now being utilised in Hong Kong agriculture. It is immediately apparent that vegetable production by this mode is energetically very inefficient. An input of about 7.39 units of extrasomatic energy and 0.21 units of somatic energy are required to produce one unit of somatic energy at the farm gate.

Major contributors to this imbalance include intensive irrigation, machinery and artificial fertilizers. Between them they make up 92% of the total energy inputs compared with less than 50% on average, in the food system in 1971 (see Table 1).

It has been emphasised previously that Hong Kong is in transition between the use of traditional agricultural technology and western agricultural technology. A comparison of the data presented in Table 1 with that in Table 2 testifies that this is so. However, it is necessary to establish the energy requirements of traditional agriculture in order to understand how far Hong Kong's mode of food production has moved towards a high-energy agriculture.

**Energy subsidy in traditional Chinese agriculture**

Knowledge of western agricultural technology had not penetrated rural China of the mid-nineteen thirties. It was in this period, 1935-7, that Fei and Chang (1945) undertook a detailed study of the rural economy of two southern Chinese villages, Lutsun and Yunnan. From their careful documentation
of every aspect of farmers and farming it has been possible to construct the energy relations for double-cropped production, i.e. rice and beans, for an average hectare of land using traditional chemical agriculture.

Table 3 indicates the energy value of the inputs. Calculations supporting these values are contained in the accompanying footnotes. These calculations indicate that the traditional system is highly energetically efficient, returning about 34 units of energy for one invested. Significantly, only 1% of the energy input is from extrasomatic sources, emphasising the lack of mechanisation and artificial chemical supports. The higher yield (which is still an average one) compared with Hong Kong (Table 1 and 2) can be attributed to the differences in the crops produced.

Post-farm gate production

The post-farm gate sector has grown to be the most energy expensive part of the food system in the industrialized world. For the U.S., Hirst (1974) and Steinhart and Steinhart (1974) show that between 76% and 82% of the energy inputs to the food system are used in post-farm gate activities. Similarly, Gifford and Millington (1975) attribute 90% of the energy requirements of the food system to post-farm gate activities in Australia. Although crop production remains energetically efficient, despite large extrasomatic energy investments, the western food systems viewed as a whole are only 15 to 20% efficient.

The major energy costs are incurred in food processing
packaging, transportation, commercial and domestic cooking and refrigeration. This study will consider post-farm gate energy input up to and including retail outlets. Table 4 indicates that while the categories of inputs are familiar, and even in the same proportion to one another as those in western food systems, they are only slightly larger than the pre-farm gate inputs (Table 1).

Table 4 also indicates that transportation and packaging are the most energy-expensive processes in the section of the post-farm gate activities of the food system considered here. Overall, about one unit of energy is used to make the same amount of food energy available at retail outlets, compared with 1.8 units to take a unit of food energy through the same stage in the Australian food system (Gifford and Millington, 1975).

There are many features of the Hong Kong food distribution system which contribute to this situation. Firstly, transportation costs are comparatively small, a fact which relates to the small area of Hong Kong.

Secondly, the Hong Kong food system is very dynamic. The Chinese population consistently demand food as fresh as it is possible to have it. This means that the food system has only a minimal storage component.

Thirdly, packaging is often no more than a piece of seagrass tied around the food purchased to assist in its handling and is unrelated to its protection or preservation. However a shift to plastic containers is rapidly increasing the energy cost of this simple process.

Finally, the commodities which are dealt with in this
analysis, namely rice and vegetables, reach the market fresh without undergoing any factory processing. The same is true of poultry and fish produced in Hong Kong. The incapacity of Hong Kong's small land area to provide all its population's food requirements, and the inability of the countries within the region to continue to meet the ever-increasing demand for fresh foodstuffs, is forcing the growing Hong Kong population to accept preserved and frozen foodstuffs. This impasse makes it difficult to avoid a shift towards a more energy-intensive food system.

Trends and alternatives: Pre-farm gate

In comparison to traditional Chinese agriculture (see Table 3), the major feature of change in the past forty years has been a rapid shift from the somatic energy of labour to the use of extrasomatic energy for artificial material inputs and to a certain extent for machines (see Table 2). Similarly, practices which conserve nutrients and energy are progressively abandoned.

Table 1, 2 and 3 indicate the nature of the transition from traditional to western agriculture. It is now possible to comment on the implementation of each energy intensive input, its potential impact and the apparent alternatives. Table 2 indicates that fully automated sprinkler irrigation systems are the most energy expensive of the new technologies likely to be introduced. Footnote 1.6 shows that, due to small land area over which they were installed in 1971, these had little impact on the overall energy cost of crop production. However in the 4 years, 1971-75, the number of
these systems, covering \( \frac{1}{5} \)th of a hectare each, has doubled (J.E.J. Revell, Agriculture and Fisheries, Hong Kong, personal communication, 1974). Even though irrigation energy costs remain small in comparison to the pre-farm gate costs of the total system, a doubling time of four years will rapidly increase total agricultural energy requirements.

What must be evaluated is the relative worth of extensive reticulated sprinkler irrigation systems, as opposed to traditional, water conserving, bucket and furrow irrigation when applied in small plot agriculture. Where labour is abundant it is not a labour-saving device that is required but a labour-using device. In this situation, where the size of the average plot, for geographic and other reasons, is less than \( \frac{1}{3} \)rd hectare, the value of mechanised application of water to crops is questionable. On the other hand, it is desirable to ensure a regular water supply to each plot to facilitate manual bucket or furrow irrigation.

The applications of artificial fertilizer to vegetable crop land vary from 0 to 8.95 tonnes per hectare with an average application rate of 2.77 tonnes per hectare. The introduction of artificial fertilizers and the concomitant decline in the application of natural fertilizer has been rapid and dramatic. In 1957 Blackie reported that 89.7 tonnes of fertilizers were applied to multiple cropped vegetable production land in Hong Kong. Of this only 1%, or 0.9 tonnes, was chemical fertilizer. Of the remainder 86%, or 77.1 tonnes, was nightsoil, 8%, or 7.2 tonnes, was fishmeal and 4%, or 3.6 tonnes, was animal manure or compost.
This rate of application is not unprecedented. Carlson and Menzies (1971) reports applications of sewage effluents over long periods in Europe of about 90 tonnes per hectare and Bowerman (1959, cited in Mey, 1972) has recommended application rates of manure enriched composts of 185 tonnes per hectare. In 1967 natural fertilizers were still being applied at the rate of 5.4 tonnes per hectare but by 1971 this rate had dropped to 2.5 tonnes per hectare (Director, Agriculture and Fisheries, 1973). In 14 years the application of artificial fertilizers has at least trebled and that of natural fertilizers has declined to negligible proportions. The same source indicates that retained imports of artificial fertilizer are increasing at a rate of 10% per year in recent years.

The implications of these trends in fertilizer consumption are twofold. Firstly, nightsoil, animal manure and compost which were formerly an essential feature of nutrient recycling in Hong Kong are now classed as pollutants. Borgstrom (1973) noted that this has become a common feature of industrialization throughout the world. It has been estimated that in 1971 there were 1770 tonnes of animal sewage generated each day in Hong Kong (Director, Agriculture and Fisheries, 1973). In 1973 the poultry population alone generated this amount of excrement, quite apart from the excrement of 400,000-500,000 pigs (Binnie and Partners, 1975). If this were applied to cropland at the same rate that nightsoil and animal manure were applied a decade earlier in Hong Kong (Blackie, 1957) its production would neatly satisfy demand. Instead it collects on the banks of
waterways, blocks water flow, creates public health problems, and has been the subject of government sponsored consultants reports (Isaac, 1974; Binnie and Partners, 1975). Nightsoil, formerly applied to agricultural land, but restricted because of dangers to human health now known to be avoidable (Sebastion, 1972), threatens public health elsewhere in the Hong Kong ecosystem and is also the subject of consultants reports to government (Watson, 1971, 1973).

Secondly, both Ehrlich and Ehrlich (1970) and Commoner (1972) have cited evidence showing that application rates of inorganic fertilizers have been increased five-fold in 19 years for some soils in the U.S. in order to maintain the same yield. The clear, albeit challengeable, implication of the data these authors present is that somehow artificial fertilizers create their own demand, being required in ever-increasing amounts in order to obtain the same crop yield.

Only a fraction of the phosphorous and nitrogen applied as fertilizer is actually collected by plants (Commoner, 1972). At very high rates of nitrogen application, as in Hong Kong, there is certainly a potential for a significant portion of nitrogen as nitrates to leach out of the soil into groundwater (Smith, in Commoner, 1968). Where groundwater contributes to the potable water supply of the area, the nitrate content presents a danger to human health (Kohl et al, 1973). In addition, the replacement of organic fertilizers with inorganic fertilizers decreases the humus content of the soil and impairs the capacity of the soil to retain nutrients (e.g. see Powell, 1970). There is evidence that the naturally occurring plant nutrients are
quickly leached from soils when inorganic fertilizers are applied. Albrecht (1966) has cited soil half-lives for nitrogen of 25 years with comparatively low inorganic nitrogen application. Clearly soil type and climate has a significant bearing on the impact of artificial fertilizers on soil structure and plant production. Generally, however, it seems likely that continued monitoring for acidity and trace element toxicity is necessary with inorganic fertilizer application. Similarly, a reliance on artificial fertilizers is constructed because of a reduction in naturally occurring soil fertility. Any such reliance is dangerous when the continued supply of artificial fertilizers is not guaranteed.

A clear and acceptable alternative for coping with these difficult problems would be to recycle the nutrients that now constitute pollutants and stop the rapid increase in the use of inorganic fertilizers. The Hong Kong government has begun experiments aimed at recycling poultry manure onto farms and forest land. Early results of collection and drying experiments are encouraging (J. E. J. Revell, Agriculture and Fisheries, Hong Kong, personal communication, 1975). Already fresh-water fish farmers are turning to poultry manure as a viable alternative to superphosphate which is increasingly expensive and often unprocurable. Consultants have recommended a composting plant for recycling organic urban refuse which has become another major problem in Hong Kong (Maunsell, 1974). Enriched compost, animal manure or nightsoil, carefully monitored for trace elements from urban-industrial sources, could reduce the need for, or even
replace, inorganic fertilizers. Essentially it must follow that as far as plant growth is concerned, the availability of nutrients is important and not the form in which they are available. Experiments have shown that even unenriched compost contributes to plant growth as much as inorganic fertilizers (Tietzen and Hart, 1969) as well as increasing water retention properties of the soil (Terman, 1970).

The additional energy spent to transport 60-90 tonnes/ha. of organic fertilizers to vegetable land is considerably less than the saving subsequently earned by only transporting a third or less of the current amount of artificial fertilizers to Hong Kong (see Table 5). The energy cost might be negligible if vehicles carrying vegetables to wholesale markets carried bagged and sterile compost in the opposite direction. Any recycling of nutrients would also result in significant, though hidden, savings in financial and energy costs of the massive waste disposal operations in Hong Kong.

Insecticides incur a relatively small energy cost in relation to total energy requirements, but their limitation is important because a dependency has developed on their use which can be reduced and because they have a potential environmental impact beyond that intended by their application. Steinhart and Steinhart (1974) commented that a 'treat where necessary' pesticide application would bring a 35% to 50% reduction in pesticide use. Electrostatic spray equipment developed by R. Coffee (University of Hong Kong, personal communication, 1975) ensures very specific localised application and significantly reduces the insecticide required.
Labour saving devices in irrigation, cultivation and transportation must be critically evaluated before implementation because they do not in themselves enhance plant growth. They simply replace somatic energy with extrasomatic energy. In developing countries there is no shortage of labour. Replacing a labourer with a mechanised process simply relocates him to an urban environment where he adds to the already intolerable load on housing, health and welfare facilities and where his capacity to, at least, produce his own subsistence diet is lost. Drakakis-Smith (1974) has indicated that the current demand for housing in South-East Asian cities cannot be met by the year 2000, let alone the additional demand which will arise during the coming 25 years. The possibility of increasing food productivity comes not so much through introducing mechanisation in order to increase work capacity but rather, as Myrdal (1974) has argued, through more efficient use of the excess labour which already exists in rural areas. Furthermore, Johnston and Cownie (1969) convincingly argue that where farm labour is abundant and increasing, farm mechanisation is unlikely to be economic from a societal viewpoint, despite increased private productivity, if the social costs of increasing underemployment and unemployment are taken into account.

The use of electricity instead of liquified petroleum gas, town gas, diesel oil or kerosene, can mean the expenditure of three times more energy to do the same task when the efficiency of fuel production is taken into account. In some mechanised tasks electricity is only marginally more
energy-expensive than the direct use of other fuels because of the superior efficiency of the electrical appliance in translating the available energy into work. However, if diesel fuel were used for high-pressure irrigation systems in Hong Kong, a saving of more than half of the current energy costs would result.

Table 5 summarises these energy-saving alternatives for crop production in Hong Kong and discusses savings in the post-farm gate sector as well. Little change in crop yield would be anticipated if any or all of these potential alternatives were implemented. An overall reduction of 40-50% of the energy requirements of pre-farm gate production seems possible.

Trends and alternatives: Post-farm-gate

The energy overheads of distributing the food produced in Hong Kong are comparatively small, though still open to reduction. The direct result of an inability to produce fresh food in Hong Kong and the region is a proliferation of the packaged, preserved and frozen foodstuffs which epitomise the most energy-expensive sector of the western food systems. Plastic-covered and sealed lettuces from California are now common in hawker stalls! By maximising food production, Hong Kong could simultaneously achieve greater self sufficiency and a higher energetic efficiency.

There will, of course, continue to be imported goods regardless of increases in local production. Unfortunately, the many well dispersed stores in Hong Kong which dispense bulk grains, pulses and nuts and dried products are coming under increasing economic pressure from supermarkets which
dispense the same goods with attractive but excessive packaging. Supermarkets did not exist in the 1960's in Hong Kong. By 1971 they numbered 25 and in 1975 there were 100 supermarkets in the urban area alone. It would be profitable for the Hong Kong government to develop a packaging policy to ensure the appropriate mix of reusable or readily recyclable materials (either as such or by extracting their energy through pyrolysis). Documentation which enables the formulation of such a packaging strategy is now available (Berry and Makino, 1974).

Regarding only the energy costs of distributing and marketing locally produced crops, there has been a rapid change from newspaper to plastic bags for crude packaging. In the mid-1960's plastic bags were not used by hawkers for packaging vegetables. By 1971-72 the weight of plastic bags used by vegetable hawkers was 28% of combined papers and plastics, however this represented 70% of the combined energy costs. Not only is plastic up to 6 times more energy expensive to produce (Chapman, 1975), but within the Hong Kong system it is not as recyclable as paper which is exhaustively picked from refuse and sold for export to Taiwan (Maunsell, 1974). A reversion to the exclusive use of paper would save more than half the energy invested in packaging, even disregarding the continued re-use of paper.

Post-farm gate transportation energy could also be reduced considerably by the more efficient use of existing cargo transport modes. From earlier research (Newcombe, 1975 b) it is evident that, in direct energy costs, trains are 11 times less expensive than 5 tonne goods vehicles,
30 times less expensive than 1 tonne goods vehicles and about 3 times less expensive than motorised cargo boats. Although pushbikes are 19 times more expensive than trains as cargo carriers, the direct energy they use is not in short supply and varying types of light and heavy duty cycles are obvious alternatives in a compact society like Hong Kong. Currently 80% of vegetables are delivered from wholesale to retail outlets by large goods vehicles (McGee, 1973), usually loaded to only a fraction of their capacity and scheduling practically no back-loading (personal communication, Traffic Survey Division, Public Works Department). Clearly an optimisation of transport forms can occur which can reduce the energy overheads of distribution.

A reduction in energy costs in the food system would conserve valuable resources, reduce environmental impact and serve to regain the stability which is a feature of low energy systems and which is eroded when we become subject to what can be called the 'ever expanding networks of dependence' that come with a high energy alternative.

Expanding networks of dependency

An important feature of the transition from traditional to western, from low-energy to high-energy agriculture is the extension of the agricultural ecosystem. In traditional agriculture documented in Table 3, the only input at any distance from the village (apart from the sun) was the energy invested in steel production for hand-tools. This input, though important to the efficiency of production, needed only to be intermittent, since lengthy gaps in
supply could be afforded without great difficulty.

In existing agriculture in Hong Kong, agricultural production is reliant upon inputs which come both from within the Asian region and from the most distant parts of the globe, particularly from the industrialised west. For example, most of the fertilizer which is used in Hong Kong is produced in West Germany (Census and Statistics, 1971) and travels more than 24,000 kms to Hong Kong. Not only has the catchment area for inputs to agricultural production in Hong Kong been extended from the local community to the world, but the number of stages passed through to make the inputs available in Hong Kong are numerous. Furthermore, each one of these stages is itself dependent on energy intensive processes. Again using artificial fertilizer as an example, energy is required to build factories, to produce chemical feedstock, to fuel the production process, to power conveyance to ship, and to power the ship to Hong Kong, bunker by bunker.

Figure 1, which is adapted from Odum (1967), indicates the relationship between the extrasomatic energy of fossil fuel and agricultural production. It provides a graphic illustration of the flow of extrasomatic energy through widely dispersed human settlements, before each input is in the form required for agricultural production in Hong Kong.

Food production in the traditional system is threatened only by the vicissitudes of weather. In the expanded network of inputs to Hong Kong agriculture at each of the many stages in production of all of the required inputs, a shortage of extrasomatic energy can become a limiting factor for food production. Increases in yield have been traded both for
a critical dependence on non-renewable resources and a loss in resilience and stability in the total food system. Asian farmers who followed the example set by the International Rice Research Institute by planting fertilizer sensitive grain in the 1973-74 season sometimes produced less grain per hectare than with traditional varieties. They could not get fertilizer to apply to their crops because the Japanese fertilizer factories had been closed by the shortage of fuel oil caused, in turn, by the energy crisis of that time (Awano, 1974).

It seems to follow that a food system which requires a carefully co-ordinated network of inputs from throughout the globe is inherently less reliable than one, the inputs of which are fewer, more local and more widely available.

SUMMARY AND CONCLUSIONS

The pre-farm gate stage of crop production in Hong Kong remains efficient with the investment of 0.8 units of energy for a return of one unit of somatic energy in food. This ratio of energy input-output is not significantly different from that found for the pre-farm gate stage of sophisticated agricultural systems in the western world, e.g. Israel, 0.94 to 1 (Stanhill, 1974) and Australia, 0.8-0.9 to 1 (Gifford and Millington, 1975). Moreover, the tendency in Hong Kong crop production is towards much higher energy subsidies, leading to gross energetic inefficiency. Practices in vegetable farming current in a small section of Hong Kong agriculture show an investment of 7.7 units of energy for 1 returned as food. Clearly
this efficiency is somewhat related to the nature of the crop being produced. However, data for vegetable production in California, where even more high-energy agricultural technology is in use, show a ratio of input to output of 2.3-4.1 to 1, for similar crop species, including post-farm gate transportation (Cervinka, et al 1974). It seems to follow that the more intensive the mode of agricultural production, the more energy-expensive it becomes per unit of food produced.

Since we are dealing here with the energetic efficiency of the production of vegetables which are inherently less energy-rich per unit wet weight than cereals, it is as well to note that vegetables contribute about 10% of the total protein and carbohydrates consumed by the Chinese in Hong Kong (Newcombe, in preparation) and that vegetables, as a major source of many nutrients, are particularly important components of the diet in countries where the world food problem is most felt (Latham, 1975; Dwyer and Mayer, 1975). In other words, the high energy cost of intensive vegetable farming, using western technology, cannot be dismissed as unimportant simply because the major thrust of research in the third world is towards improving cereal crop production. Indeed, if only 10% of the somatic energy consumed as grain were consumed as vegetables then the results of this study suggest that as much energy will be spent producing vegetables as will be expended in cereal production if western agricultural technology is being used. In this case energy conservation in vegetable production in
developing countries is not merely a side-issue.

The post-farm gate sector studied in Hong Kong, i.e. from farm-gate to retail outlet, is markedly less energy-expensive than the same sector of western food systems. In Hong Kong about the same amount of energy as is contained in the food being distributed is expended in this sector of the food system, compared with nearly double that amount in, for example, the Australian food system (Gifford and Millington, 1975).

The absence of elaborate food processing, packaging, storage and lengthy transportation is responsible for reduced costs in this stage of the Hong Kong food system.

Allowing for a four-fold difference in energy content of the crops being produced, a comparison between Tables 1 and 2, and Table 3, would infer that the number of units of energy required to produce one unit of somatic energy has increased from an average of 10 times to, in some parts of the present food system, 250 times during the past 40 years. Even these estimates are conservative for they disregard the enormous differences in post-farm gate distribution costs between old and new Hong Kong food systems (see Table 4). Nevertheless, the data clearly indicates a rapidly expanding extrasomatic energy demand per unit of agricultural land. This forewarns a period of increasing dependence on extrasomatic energy for food production, particularly in the developing world, where the focus of FAO and other agencies is on the modernisation of traditional agriculture to increase food production. Currently this modernisation means a transition from low-energy to high-energy agriculture. Hence a dilemma is posed by attempting to solve the shortage of one critical
resource, food, by advocating the widespread use of another already scarce resource, energy. With such a rapidly growing dependence on energy, it is understandable how even a small hesitation in the flow of energy can have significant repercussions for energy-intensive food systems. This consideration becomes critical when it is realised that already at least 400-500 million people are dependent for food supplies on high-energy agriculture (Borgstrom, 1973).

This paper illustrates some of the dangers in adopting high-energy food systems. It further indicates that conservation of energy can proceed in agriculture in much the same way as it has been possible, in recent times, for other areas of industrial activity (Berg, 1974).

It seems likely that a 40% to 50% reduction of energy inputs to the Hong Kong food system is immediately possible without significantly affecting crop yield. However, measures to reduce energy consumption in the food system by this much are unlikely to occur because there is no economic incentive to implement more than one or two of the necessary changes. The cost of transporting bulky organic fertilizers to farms and spreading it is probably more than the total cost of using inorganic fertilizer. However, if the hidden costs of disposing of organic materials as waste were calculated, perhaps the economic incentive for recycling them would be seen. Plastics are as cheap as paper for packaging, indeed polythene piping is likely to be introduced for irrigation systems in Hong Kong because it is more economic than galvanised iron piping. In the long term, given the certain exhaustion of the fossil fuels which form
the extrasomatic energy subsidy to the food system, the energy cost of a material will be more closely reflected in its ascribed market value. Then the economic incentives to reduce energy consumption in the food system will be clearly available (see Odum, 1973).

Finally, it is evident that high-energy agriculture has played a significant role in disrupting natural nutrient cycling processes, simultaneously adding to the pollution load of the Hong Kong ecosystem. Recycling animal and human wastes will redress this imbalance as well as reduce the energy requirements of the Hong Kong food system.
References


TABLE 1: FOOD PRODUCTION ENERGETICS IN HONG KONG, 1971
(for all Vegetable and Rice production)*

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ENERGY INPUTS (10^8 MJ/yr)</th>
<th>FOOTNOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicides, Insecticides, Fungicides</td>
<td>0.23</td>
<td>1.1</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>1.47</td>
<td>1.2</td>
</tr>
<tr>
<td>Machinery</td>
<td>0.02</td>
<td>1.3</td>
</tr>
<tr>
<td>Animal Labour</td>
<td>0.11</td>
<td>1.4</td>
</tr>
<tr>
<td>Human Labour</td>
<td>0.60</td>
<td>1.5</td>
</tr>
<tr>
<td>Irrigation</td>
<td>0.60</td>
<td>1.6</td>
</tr>
<tr>
<td>Agricultural administration, research and extension</td>
<td>0.21</td>
<td>1.7</td>
</tr>
<tr>
<td>Hand tools</td>
<td>0.01</td>
<td>1.8</td>
</tr>
<tr>
<td>Transportation to farm</td>
<td>0.79</td>
<td>1.9</td>
</tr>
<tr>
<td>Seeds</td>
<td>0.13</td>
<td>1.10</td>
</tr>
</tbody>
</table>

| Total Input                                                | 4.17                       |          |
| Gross Yield                                                | 5.43                       | 1.11     |
| Net Yield                                                  | 5.36                       | 1.12     |

Ratio Energy Input to Output 0.8:1

*Considering the 3771 ha of fresh water paddy rice, 3897 ha of vegetables and 712 ha of field crops (e.g. sweet potato) under production in 1971. The total land under crop production is therefore 8,380 ha.
Footnotes to Table 1

1.1: Total 1971 consumption was 120,375 l. insecticides, 38,520 l. herbicides for vegetables, and 12,530 l. insecticides for rice.
(pers. comm. E.H. Nichols, Agriculture and Fisheries, Hong Kong). Retained imports of fungicides 1971 were 58,549 Kg. (Census and Statistics, 1971). Converting to unit weight for combined total of 229,594 Kg. and using energy network input (E.N.I.) of 101.5 MJ/Kg. (Leach and Slesser, 1973) gives 0.23 x 10^8 MJ.

1.2: Total artificial fertilizer application for 1971 was 7,984 tonnes compound fertilizer, 943 tonnes calcium nitrates and 1858 tonnes sulphate of ammonia (Director, Agriculture and Fisheries, Hong Kong 1973). Allowing for the application of fertilizer to flower crops (pers. comm. H.C. Tsoi, Agriculture and Fisheries) total fertilizer applied to crops under consideration was 9,412 tonnes. Given energy equivalents for compound fertilizer, calcium nitrates and ammonium sulphates of 15.23, 21.33 and 14.20 MJ/Kg respectively (Leach and Slesser, 1973) the energy input is 1.47 x 10^8 MJ.

1.3: Machinery in 1971 was only small mechanical cultivators. There were about 200 operating on approximately 1/3 ha. each, no sharing. Given 50 Kg. weight of each and an E.N.I. of 86,788 MJ/tonne (Berry and Fels, 1974), and allowing for a 10 year life with 10% maintenance costs in energy inputs for that period, the energy input per annum is 0.001 x 10^8 MJ. Fuel consumed in 1971 was 63,644 l. (pers. comm. C.T. Wong, Agriculture and Fisheries, Hong Kong) at 36.8 MJ/l. is 0.023 x 10^8 MJ. Total machinery and fuel input is 0.02 x 10^8 MJ.

1.4: The remaining draught animal population of Hong Kong 1971 was 11,515 Brown Cattle and 1080 Water Buffalo (pers. comm. C.T. Wong, Agriculture and Fisheries) of which only about a third would actually be worked as draught animals. According to Blackie (1957) paddy rice production requires about 30 days animal labour per ha. crop. In 1971, 3771 ha. were under paddy rice production, 763 ha. were cropped twice. Thus 136,020 animal labour days were spent in 1971. Taking 83.73 MJ/day for a work period of 10 hours at a ratio of 8:1 over basal metabolism (Brody, 1964) and assuming that draught animals eat residue under contemporary farm management, we have 136,020 x 83.73 = 0.11 x 10^8 MJ.
Farming people engaged in vegetable and rice farming in 1971 numbered 20,206 (Census and Statistics, Hong Kong, 1972a) and 184 were engaged in the agriculture side of the Agriculture and Fisheries department. Given that in Hong Kong 1 man-day is required to transport 1 tonne, 20 kms, then from 1.9 about 30 people are employed full-time moving commodities from ship to farm. Farmers work an average of 8 hours/day each day of the year (Census and Statistics 1972a). Using Stevenson (1925) for average weights of southern Chinese and a 65%-35%, male-female, labour force at moderate work rates (Thomas and Corden, 1970) we arrive at an average energy consumption of about 10 MJ/person/day or given a ratio of 6:1 over basal metabolism, a mean investment of 8 MJ for the work period. Thus $8 \times 20,420 \times 365 = 0.60 \times 10^8$ MJ/yr input.

Irrigation in Hong Kong mostly consists of furrow and bucket systems, both labour intensive. General pumping to provide water for these purposes was carried out by about 2,500 diesel pumps (pers.comm. C.T.Wong, Agriculture and Fisheries, H.K.). Given 14,234 MJ energy equivalents per pump (Steinhart and Steinhart, 1974) and assuming a 10 year life plus 10% of initial energy costs for maintenance we have $0.04 \times 10^8$ MJ/yr. Closely reticulated high pressure systems covered only 40 ha's in 1971. These systems were driven by about 3x10 HP pumps per ha. of negligible establishment and maintenance energy costs. For the reticulations calculating the energy equivalents of the galvanized iron only at 3,000 m per ha. for 40 ha. and 2.5 Kg/m with an energy equivalent of 23.76 MJ/Kg (Wright, 1975) we have $3000 \times 40 \times 2.5 \times 23.76 = 0.07 \times 10^8$ MJ. Given a 10 year life and 10% maintenance the energy cost is $0.006 \times 10^8$ MJ/yr. Fuel costs of the low pressure diesel systems for 1,136,500 litres/yr (pers.comm. C.T.Wong) at 36.8 MJ/litre give $0.42 \times 10^8$ MJ/yr or $0.51 \times 10^8$ MJ/yr taking refinery efficiency into account. Electricity costs, pre-refining for high pressure reticulation are $0.04 \times 10^8$ MJ/yr (see 2.5). Total irrigation costs are approximately $0.60 \times 10^8$ MJ/yr.
Administration, research and agricultural extension work is cited as energy input in so far as transport and direct energy overheads are concerned. Total physical plant is not evaluated. There were about 29 tonnes of vehicles being used in relation to crop production in the Agriculture and Fisheries Department, 1971. Given a 10 year life and allowing 10% maintenance costs per annum with an energy equivalent of 86,788 MJ/tonne (Berry and Fels, 1974) we have \(0.0023 \times 10^8\) MJ/yr invested. Knowing approximate mileage and consumption of the 9 lorries, 9 cars and 22 motorbikes (Statement DSM/WP/3/75, Agriculture and Fisheries) an average pre-refinery fuel investment of \(0.01 \times 10^8\) MJ is calculated, half of which is apportioned to post-farm gate activities. Electricity overhead of the Agriculture and Fisheries Department were estimated at 10% of China Light and Power company sales to government in Kowloon and the New Territories. Half is allocated to post-farm gate activities. Allowing for generation, distribution and refinery efficiencies (factor of 4.45) this is \(0.2 \times 10^8\) MJ/yr giving a total overhead here of \(0.21 \times 10^8\) MJ/yr.

1.8: Hand tools such as hoes, rakes, spades, and ploughs for draught animals, have been estimated to be about 35 Kgs. of steel per ha. of such intensively cultivated land. Thus 8380 ha. will require about 293 tonnes of steel in such implements. Given a life of 10 years and an E.N.I. of 23.76 MJ/Kg. (Wright, 1975) or \(0.01 \times 10^8\) MJ per annum.

1.9: Taken as the transport of materials used in Hong Kong agriculture from their point of production to the farm. Per tonne km. costs for sea transport were established by examining fuel consumption data from ships calling at Hong Kong from Department of Oil Supplies records, and cross referencing with the cargoes carried by these ships with Marine Department records, Hong Kong. The mean distance travelled by the commodity was calculated using trade statistics (Census and Statistics Department 1972). General cargo transport costs were computed as 0.25 MJ/tonne km. By far the largest imported commodities for Agriculture are fertilizers and insecticides, herbicides etc. 10,783 tonnes of fertilizer was carried an average distance of 23,298 km. giving an expenditure of \(0.63 \times 10^8\) MJ or \(0.76 \times 10^8\) MJ taking refinery efficiency into account, and 230 tonnes of insecticides etc. travelled 15,256 km. expending about \(0.01 \times 10^8\) MJ. The ship to shore trip averaging 3.96 km. is of negligible energy cost. The shore
to farm distance averages 20 km. at 9.35 MJ/tonne km. (see 4.2 and Newcombe, 1975b) in goods vehicles expending $0.02 \times 10^8$ MJ.

Total energy input, $0.79 \times 10^8$ MJ.

1.10:

About 80% of the vegetable seeds are produced in China, and 20% in Hong Kong. It is assumed that where seeds are not commonly eaten they have replaced foodstuffs which had to be forgone in order to yield seeds and are thus taken as the same energy value as this food. Also there must be an investment of energy in the seeds production. This is assumed to be about 80% of the somatic energy value of seeds in line with the findings summarised in Table 1. The energy invested in Chinese produced vegetable seeds is assumed to be the same as in Table 3, i.e. $\frac{1}{32}$ of the somatic energy of the seed. The Chinese seed is transported about 140 km. to Hong Kong by river barge at negligible energy expenditure. From Blackie (1957) 6.43 kg. of vegetable seed are required per ha. per year, giving a total of 25,058 kgs, and 94 kgs. of rice seed/ha/yr, or 426, 196 kg. (allowing for small double cropping). Given 2000 KJ/100 gm. vegetable seed, and 1495/100 gm. for rice we have $0.07 \times 10^8$ MJ/yr. as somatic energy inputs plus about $0.06 \times 10^8$ MJ/yr production costs. Total seed costs are about $0.13 \times 10^8$ MJ/yr.

1.11:

Gross yield has been established from an analysis of nutrient flow in Hong Kong (Newcombe, in preparation). Local production in the relevant categories yielded $5.36 \times 10^8$ MJ for 1971. To this is added $0.07 \times 10^8$ MJ of the energy value of seeds as per 1.10. Thus gross yield is $5.43 \times 10^8$ MJ.

1.12:

Net yield is gross yield minus seedstock or $5.36 \times 10^8$ MJ/yr
(Note: On farm consumption equivalent to $0.20 \times 10^8$ MJ/yr and animal feed equivalent to $0.13 \times 10^8$ MJ/yr are not deducted in the calculation of net yield since the fate of foods produced is unrelated to the energetic efficiency per se).
TABLE 2: FOOD PRODUCTION ENERGETICS, HONG KONG 1971

(Vegetable production on 1 hectare of land utilizing the most modern farming technology currently available)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ENERGY INPUTS $(10^3 \text{MJ/ha})$</th>
<th>FOOTNOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicides, Insecticides</td>
<td>4.43</td>
<td>2.1</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>136.65</td>
<td>2.2</td>
</tr>
<tr>
<td>Machinery (1 rotary hoe)</td>
<td>30.30</td>
<td>2.3</td>
</tr>
<tr>
<td>Human Labour (3 people)</td>
<td>8.81</td>
<td>2.4</td>
</tr>
<tr>
<td>Irrigation</td>
<td>114.29</td>
<td>2.5</td>
</tr>
<tr>
<td>Administration, research and extension</td>
<td>2.51</td>
<td>2.6</td>
</tr>
<tr>
<td>Hand tools</td>
<td>0.12</td>
<td>2.7</td>
</tr>
<tr>
<td>Transportation</td>
<td>9.43</td>
<td>2.8</td>
</tr>
<tr>
<td>Seeds</td>
<td>0.23</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>TOTAL INPUT</strong></td>
<td><strong>306.77</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Gross Yield</strong></td>
<td><strong>40.06</strong></td>
<td>2.10</td>
</tr>
<tr>
<td><strong>Net Yield</strong></td>
<td><strong>39.83</strong></td>
<td>2.11</td>
</tr>
<tr>
<td><strong>RATIO ENERGY INPUT TO OUTPUT</strong></td>
<td><strong>7.7 : 1</strong></td>
<td></td>
</tr>
</tbody>
</table>
Footnotes to Table 2

2.1: Per hectare application rates are 31 litres insecticide and 10 litres herbicides (pers. comm. E.H. Nichols, Agriculture and Fisheries, Hong Kong). Using an energy equivalent of 101.5 MJ/Kg. (Leach and Slesser, 1973) the energy input is $4.43 \times 10^3$ MJ.

2.2: The highest rate of application of artificial fertilizers in a survey of their use by Agriculture and Fisheries (pers. comm. H.C. Tsoi) was 8,972 Kgms. ha/yr which corresponds to the application rate recommended by the soils division of the department. This is mostly compound fertilizer taken at 15.23 MJ/Kg. (Leach and Slesser, 1973) giving an energy cost of $136.65 \times 10^3$ MJ.

2.3: Converting data in Footnote 1.3 to per ha. per annum figures gives $0.02 \times 10^8$ MJ/66 = $30.30 \times 10^3$ MJ/ha/yr.

2.4: Taking the reduced labour requirements of mechanised vegetable production as 1 man per one third ha., thus 3 men per ha. and using footnote 1.5 we have $8.81 \times 10^3$ MJ/ha/yr.

2.5: The piping and maintenance costs per ha. can be computed from footnote 1.6, giving $15.0 \times 10^3$ MJ/ha/yr. The production and maintenance costs of, on average, three 10HP electric pumps per hectare are $4.70 \times 10^3$ MJ/ha/yr. At $1/3$ ha. in size each system runs for about 25 minutes per day, i.e. 75 minutes per ha/day delivering about 5mm water per hectare. There are about 65 days when precipitation exceeds 2mm in Hong Kong, thus 300 days on which the intensive systems are utilized. These 10HP duty pumps use 53.10 MJ/hour of direct electric energy or 236 MJ/hour indirect (considering refining, conversion and transmission losses). At 1.25 hours/day/ha, 300 days/yr the energy cost is $88.50 \times 10^3$ MJ/ha/yr. A proportion of the low pressure diesel power system which provides water to the site must also be included. i.e. $0.51 \times 10^8$ MJ + 8380 ha = $6.09 \times 10^3$ MJ/ha/yr. The overall irrigation costs are $114.29 \times 10^3$ MJ/ha/yr.

2.6: The proportionate overhead per hectare on footnote 1.7 is $2.51 \times 10^3$ MJ/ha/yr.
2.7: From footnote 1.8 taking the per ha. rates to be 
\[0.01 \times 10^8 / 8380 = \frac{0.12 \times 10^3}{MJ/ha/yr} \]

2.8: From footnote 1.9 the proportionate overhead per ha. of \(9.43 \times 10^3\) MJ is computed.

2.9: Computed from footnote 1.10, vegetable seeds energy value and cost of production is \(0.23 \times 10^3\) MJ/ha/yr.

2.10: Peak productivity per ha. for mixed Brassica spp. cropped 6-8 times per ha/per year is about 53,100 Kg (pers. comm. C.T. Wong, Agriculture and Fisheries) or \(39.83 \times 10^3\) MJ/ha/yr, using 75 KJ/100 gm leafy green vegetables (Thomas and Corden, 1970), plus \(0.23 \times 10^3\) MJ for seeds gives gross productivity of \(40.06 \times 10^3\) MJ/ha/yr.

2.11: Net productivity is gross productivity minus seedstock or \(39.83 \times 10^3\) MJ/ha/yr. (see 1.12 for notes on net yield).
TABLE 3: FARMING ENERGETICS IN CHINA 1935-37*
(for a double-cropped hectare for rice and broad beans)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ENERGY INPUTS</th>
<th>FOOTNOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Labour</td>
<td>6.62</td>
<td>3.1</td>
</tr>
<tr>
<td>Animal Labour</td>
<td>1.00</td>
<td>3.2</td>
</tr>
<tr>
<td>Tools</td>
<td>0.06</td>
<td>3.3</td>
</tr>
<tr>
<td>Seeds</td>
<td>0.47</td>
<td>3.4</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Total Inputs</strong></td>
<td><strong>8.15</strong></td>
<td></td>
</tr>
<tr>
<td>Gross Yield</td>
<td>276.00</td>
<td>3.6</td>
</tr>
<tr>
<td>Net Yield</td>
<td>275.53</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Ratio Energy Input to Output</strong></td>
<td><strong>1 : 33.8</strong></td>
<td></td>
</tr>
</tbody>
</table>

* Calculated using:
Footnotes to Table 3

3.1 Traditional Chinese agricultural unit of 1 Kung (230 sq. metres) double-cropped, thus used all year round, requires 10.3 units of female labour, 8.5 units of male labour and 1.5 units of mixed labour. (Fei and Chang, 1945. p.33). A unit is defined as an 8 hour work-day. From Stevenson (1925) and Thomas and Corden (1970) a daily expenditure of 10 MJ was calculated of which 7.5 MJ was invested in work, assuming an expenditure 6 times greater than basal activity for the work period. There are about 43.5 Kung in a hectare. Thus $43.5 \times 7.5 \times 20.3 = 6.62 \times 10^3$ MJ/ha/yr. male labour.

3.2: According to Fei and Chang (1945. p.92) it requires 6 days to plough a hectare and it must be ploughed twice, thus giving 12 days of animal labour per year. Using Brody (1964) the input by a buffalo per 10 hours of moderate work, assuming a ratio of 8:1 over basal metabolism, would be about 83.7MJ; which for 12 days is about $1.00 \times 10^3$ MJ/ha/yr.

3.3: Hand tools and ploughs are assumed to constitute about 25 Kgs of steel per ha. Given a life of 10 years and an E.N.I. of 23.76 MJ/Kg (Wright, 1975), we have $0.06 \times 10^3$ MJ/ha/yr.

3.4: Seeds are given by Fei and Chang (1945, p.70) as 0.5 Kg/Kung for rice and 0.75 Kg/Kung for broad beans, thus 21.75 kg/ha of rice seed per year and 32.63 Kg/ha of broad bean seed per year. The energy content of these edible seeds is calculated using 1495 KJ/100 gms for rice, and 440 KJ/100 gms for broad beans, as $0.47 \times 10^3$ MJ/ha/yr.

3.5: There are no inputs of artificial fertilizer, insecticide and so on. Fertilizers are basically pig, buffalo, horse and human excreta. The manure is gathered from roads, inkeepers stalls, and styes, or drains into the production area from the human settlement. Often fertilizer in this form is bartered for straw from rice production. The labour to gather and distribute fertilizer is included in 3.1.
3.6:
Gross yield is 16,478 Kg/ha of unhusked rice per year; 6,748 Kg/ha per broad bean crop and 1,741 Kg/ha of green beans. This is a medium yield, related to soil type, care of crop and so on. The highest yield would be 25% greater, and the lowest yield 40% less (Fei and Chang, 1945, p. 70-71). This yield gives a total energy value of $275.53 \times 10^3$ MJ/ha/yr. Including the energy content of seeds, the gross yield becomes $276.00 \times 10^3$ MJ/ha/yr.

3.7:
Net yield at the farm-gate is taken as gross yield minus seed energy value, i.e. $275.53 \times 10^3$ MJ/ha/yr. (Note that in this calculation the on-farm consumption of somatic energy by buffalo, estimated at $2.18 \times 10^3$ MJ/ha/yr, and by humans, estimated at $8.83 \times 10^3$ MJ/ha/yr, is not deducted for the calculation of net yield since the ultimate use of foodstuffs produced is not the concern of this study).


<table>
<thead>
<tr>
<th>INPUTS</th>
<th>ENERGY EQUIVALENT MJ x 10^8</th>
<th>FOOTNOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>0.16</td>
<td>4.1</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.74</td>
<td>4.2</td>
</tr>
<tr>
<td>Marketing</td>
<td>negligible</td>
<td>4.3</td>
</tr>
<tr>
<td>Packaging</td>
<td>3.82</td>
<td>4.4</td>
</tr>
<tr>
<td>Administration and research</td>
<td>0.21</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Total Inputs</strong></td>
<td><strong>4.93</strong></td>
<td></td>
</tr>
<tr>
<td>Somatic energy of food for distribution</td>
<td>5.36</td>
<td>4.6</td>
</tr>
<tr>
<td>Somatic energy of food losses in distribution</td>
<td>0.54</td>
<td>4.7</td>
</tr>
<tr>
<td>Net somatic energy of food distributed</td>
<td>4.82</td>
<td></td>
</tr>
<tr>
<td>Ratio of energy input to somatic energy distributed</td>
<td>1.02 : 1</td>
<td></td>
</tr>
</tbody>
</table>
Footnotes to Table 4

4.1: Hawker stalls are the major retail outlets for local crops followed by fresh provision stalls and stalls in retail markets. The vegetables come through wholesale markets controlled by the Vegetable Marketing Organisation (V.M.O.) or are black-marketed direct to hawkers. A small proportion goes direct to restaurants. The major labour component is that of hawkers in retail activities. McGee (1973) gives a hawker population of 34,212 for Kowloon and Hong Kong in 1971. His data allows a further computation of 673 for non-urban areas. According to Lu and Tsoi, (1973) 33.4% of Hawkers sell uncooked food other than fruit which can be assumed to be vegetables. Fresh vegetables marketed in Hong Kong are 45% of total sold, and since Hawker stalls are a standard size, 4' x 5', this serves to estimate the hawkers involved in selling local vegetables at 5,080. There are about 160 people selling vegetables in fresh provision stalls (calculated from Urban Services Department records), and about 500 selling vegetables in market stalls. The V.M.O. employs 200 people and the post-farm gate section of agriculture and fisheries about 300. 200 people are employed on goods vehicles involved in crop distribution. Allowing for rice distribution and marketing and black-market labour, another 200 people, the total estimated labour input is 6,640. As the bulk are middle-aged hawkers, 50% women (McGee, 1973) and involved in light work only, there is an allocation of 6.62 MJ per work period (10 hrs) per day. This gives
\[ 365 \times 6,640 \times 6.62 = 0.16 \times 10^8 \text{ MJ/yr} \]

4.2: On average 585 tonnes of locally produced crops are transported and distributed within Hong Kong daily. Taking the location of major production areas into account each unit of food travels about 30 km. The goods vehicles travel half the distance empty and are usually only 65% full (pers. comm. Traffic and Transport Survey Division, P.W.D. Hong Kong), giving a daily energy cost of 9.35 MJ tonne\(^{-1}\) km\(^{-1}\). This gives
\[ 585 \times 30 \times 9.35 \times 365 = 0.60 \times 10^8 \text{ MJ/yr} \] or at pre-refinery efficiency (82.7%) is 0.72 \times 10^8 \text{ MJ/yr}. Production and maintenance energy costs of 100 vehicles weighing 192.78 tonnes, using 86,788 MJ/tonne (Berry and Fels, 1973) and assuming a
10 year life and 10% per annum maintenance is \(0.02 \times 10^8\) MJ. This gives a total of \(0.74 \times 10^8\) MJ yr\(^{-1}\).

4.3: The only marketing overheads are those of electricity costs for lighting and equipment in V.M.O. markets and urban services markets where vegetables are sold. This is \(0.002 \times 10^8\) MJ yr\(^{-1}\) (pers. comm. Anson Choy, Urban Services Department).

4.4: Packaging is restricted to loose wrapping of goods for the customers convenience. Cane baskets, old newspapers, seagrass and plastic bags are used. Paper and plastic are the energy expensive materials. The 850 tonnes of seagrass used for packing local crops in 1971 is produced in China and transported to Hong Kong at negligible energy cost. Cane baskets are re-used many times. From our field surveys on hawkers use of packaging, it is evident that 1 Kg. of plastic bags are used for every 130 Kgs. of vegetables and 1 Kg. of paper for every 50 Kgs. of vegetables. For 213,525 tonnes of vegetables marketed this derives about 4,270 tonnes of paper and 1643 tonnes of plastic. Energy equivalents assigned are 27 MJ/Kg per paper and 162 MJ/Kg for plastic (Chapman, 1975) giving a total of \(3.82 \times 10^8\) MJ/yr.

4.5: Half of administration and research direct energy costs and vehicle use costs are allocated to post-farm-gate distribution activities. This is \(0.21 \times 10^8\) MJ/yr (see 1.7).

4.6: As in 1.12

4.7: Net distributed food refers to losses at wholesale and retail outlets which total 10.1% of local crop production (pers. comm. N.K. Lee, Agriculture and Fisheries). This gives \(4.82 \times 10^8\) MJ/yr available at retail outlets.
### TABLE 5: SUMMARY OF POTENTIAL REDUCTIONS IN THE ENERGY REQUIREMENTS OF THE HONG KONG FOOD SYSTEM

<table>
<thead>
<tr>
<th>ITEM</th>
<th>% REDUCTION</th>
<th>REDUCED ENERGY INPUTS</th>
<th>FOOTNOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a) PRE-FARM GATE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbicides, Insecticides</td>
<td>65-50</td>
<td>0.12-0.15</td>
<td>5.1</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>90-33</td>
<td>0.15-0.98</td>
<td>5.2</td>
</tr>
<tr>
<td>Machinery</td>
<td></td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Animal labour</td>
<td></td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Human labour</td>
<td></td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>5</td>
<td>0.57</td>
<td>5.3</td>
</tr>
<tr>
<td>Agricultural admin. etc.</td>
<td></td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>Hand tools</td>
<td></td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>90-21</td>
<td>0.08-0.62</td>
<td>5.4</td>
</tr>
<tr>
<td>Seeds</td>
<td></td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>52-18%</td>
<td>2.01-3.40</td>
<td></td>
</tr>
<tr>
<td><strong>b) POST-FARM GATE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td></td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Marketing</td>
<td></td>
<td>negligible</td>
<td></td>
</tr>
<tr>
<td>Packaging</td>
<td>60</td>
<td>1.53</td>
<td>5.5</td>
</tr>
<tr>
<td>Administration etc.</td>
<td></td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>48-33</td>
<td>0.38-0.49</td>
<td>5.6</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>54-51%</td>
<td>2.28-2.39</td>
<td></td>
</tr>
<tr>
<td><strong>OVERALL TOTAL</strong></td>
<td>53-36%</td>
<td>4.29-5.79</td>
<td></td>
</tr>
</tbody>
</table>

(footnote a) PRE-FARM GATE (cf. Table 1)

(footnote b) POST-FARM GATE (cf. Table 4)
Footnotes to Table 5

5.1: Following 'treat where necessary' policy from Steinhart and Steinhart (1974) supported by new electrostatic spray equipment reducing volume of pesticides required which has been developed in Hong Kong by R. Coffee (personal communication, 1975).

5.2: The reductions present a range of those possible allowing for continued utilisation of inorganic fertilizers as an enrichment where quick release of nutrients such as nitrogen is advantageous. Additional transport costs for distributing voluminous organic materials is dealt with in 5.4.

5.3: This 5% reduction is possible by using only high-pressure diesel pumps rather than electric pumps for the installed sprinkler systems, calculating the direct and indirect energy costs of both systems shows diesel pumps to use only 43% of the energy used by electric systems (see Footnotes 1.6 and 2.5). Comparison provided by Southern Cross Pumps, Sydney (I. Hutchison, personal communication, 1975).

5.4: This range of reduction possible relates to at best reducing overseas shipping costs by 90% and backloading all vegetable marketing vehicles with organic fertilizers, through to reducing overseas shipping costs by one third and incurring full transport costs within Hong Kong for distributing organic materials (see footnotes 1.9). Additional land transport costs in Hong Kong are estimated at $0.37 \times 10^8$ MJ/yr, allowing for 70 tonnes/hectare of organic fertilizers.

5.5: Completely removing plastics as packaging and replacing them by paper gives total paper of approximate weight 5,900 tonnes/yr, or $1.59 \times 10^8$ MJ/yr, cf. $3.82 \times 10^8$ MJ with plastic and paper (see footnote 4.4).

5.6: By using heavy duty bicycles to deliver vegetables from wholesale outlets to hawker stalls, i.e. 100 Kgs/day/hawker, energy costs of goods vehicles can be reduced by more than a third. By careful supervision of load factors of goods vehicles from farm to markets a further minimum reduction of 15% in direct energy costs is possible (see footnote 4.2).
Figure 1: Diagrammatic representation of energy flow in Hong Kong agriculture. Symbols adapted from Odum (1967). Note that the somatic energy input of seeds contains some extrasomatic energy as per footnote 1.10. Solar energy input over 8380 ha. was calculated from data provided by the Royal Observatory of Hong Kong (P.C. Chin, personal communication, 1974).
Introduction

Urbanisation has proceeded apace in the 20th century and projections for the year 2000 indicate that 63% of the population of less developed countries will reside in urban settlements (United Nations, 1969). Early in the 21st century, urban settlements will constitute the most common environment for human habitation. The task of sustaining life-supporting systems in urban environments presents unique problems, not the least of which is to ensure a continued flow of essential nutrients to expanding urban populations. Up until the 20th century most of mankind remained in close proximity to the sources of nutrients essential to his survival. Before long the great majority of the world's population will be reliant for nutrients on intricate and extensive networks of supply encompassing not only the local region but areas of high agricultural productivity in distant parts of the world. This situation already prevails for populations in the developed world, and with the rapid rural-urban migration taking place in the Third World (Davis, 1965), the tenuous, though comforting, hold on nutrient production experienced by subsistence farmers is being broken.

Effectively, urban settlements are vast loci where the consumption of energy and key materials such as nutrients exceeds their production. Hence an understanding of the patterns of consumption and disposal of energy and materials in urban settlements is of obvious importance to modern man.
The work presented in this paper, as part of the Hong Kong Human Ecology Programme, documents the supply of nutrients to the urban settlement of Hong Kong and discusses questions related to the origin and ultimate fate of nutrients entering the city ecosystem. We have also examined the potential for nutrient conservation and recycling, paying particular attention to the likely impact of Western influences on the forage area requirement for nutrient production and the process of nutrient cycling in Hong Kong, a city of which the system ecology is strongly influenced by Chinese cultural traditions. An examination of questions of nutrition in an urban population is a natural concomitant of a study dealing with overall patterns of nutrient flow and is presented elsewhere (Newcombe, in preparation).

The setting of Hong Kong

Hong Kong (latitude 22°N) is located on the south coast of China, extending into the South China Sea. Its population

1. The Hong Kong Human Ecology Programme is co-ordinated by the Urban Biology Group at the Australian National University. Field work was based in the Centre of Asian Studies, University of Hong Kong and the Social Research Centre of the Chinese University of Hong Kong, supported by UNEP/UNESCO funds (MAB Project 11) also received funds from the Nuffield Foundation and co-operation from the Hong Kong Government. Further information can be obtained from the Director, S.V. Boyden.

2. The original definition given by Tansley (1935) is adopted here, whereby an ecosystem is an open-ended, not necessarily self-sustaining portion of a larger system with which there may be a constant exchange of organic and inorganic materials, organisms and so on.
in March 1971 was about 3.9 million people. Hong Kong's land area, including the New Territories, is 1,046 km$^2$.

There are 253 islands, the largest ones being Hong Kong Island, Lantau Island and Lamma Island. The terrain is mountainous and rugged with very little land available for settlement and agriculture. Only some 124 square kilometres can be regarded as arable land. In fact, in 1971, only 12,103 hectares were used for agricultural production, including fallow.

It is important in the context of the present study to note that Hong Kong is a major fishing port. Hong Kong's fishing fleet is composed of 5,200 vessels, ranging from junks to trawlers, which range as far as the Paracel Islands 400 miles to the south to maintain a regular input of fresh marine produce to the Hong Kong population.

**Analysing nutrient flow**

The British colony of Hong Kong is, in effect, a city state. Concurrently, therefore, a study of nutrient flow in Hong Kong is a study of nutrient flow in a contemporary urban settlement. Government records of trade, local production and so on provide excellent basic data for determining overall patterns of nutrient flow and have been employed here to estimate an input-output balance of nutrients for Hong Kong in the calendar year 1971. This study of nutrient flow deals primarily with nutrients in the Hong Kong food system, although reference will be made to nutrient flow outside the food system.

The procedure adopted to analyse the flow of nutrients was straightforward. All food items listed as imports, exports
re-exports and those produced locally (Census and Statistics, 1971, Director of Agriculture and Fisheries, 1972) were grouped into generally recognised categories of foodstuffs, and computations were made to represent their content in terms of the major food components, namely animal and plant protein, fats, carbohydrates, somatic energy¹, calcium, iron, thiamine, ascorbic acid and food water. Food composition tables used to present Hong Kong foodstuffs in terms of their nutrient content were compiled from a wide range of tabulations useful for analysing foodstuffs common in the region (McCance and Widdowson, 1960; Tung, et al, 1961; Platt, 1962; Watt and Merrill, 1963; D.A.B.M., 1964; Thomas and Corden, 1970; Anon. no date) or were estimated in consultation with members of the Commonwealth Department of Health, Australia (M. Corden and E. Hipsley, personal communication, 1974). In estimating the loss of human food in the flow of nutrients, as many of the potentially important parts of food wastage were taken into account as possible. For example, food wastes from marketing and processing operations and nutrients in domestic and commercial refuse were analysed in considerable detail. Nutrients held in stocks of human food in Hong Kong were also included in the analysis. Here it was found that the amounts and kinds of foods held in reserves and storage, including those required by legislation, did not change significantly during the period. In addition they constituted a negligible proportion of the total flow of nutrients.

¹. Somatic energy: "that energy which is utilised, through the metabolic processes, within a living organism." The term most commonly applies to the energy in food. Extrasomatic energy: "that energy which flows through or is utilised by a human community and which is not utilised through metabolic processes with a living organism." Research 'extrasomatic energy' only includes fuels in current use.
Utilising the above information a balance of nutrients retained in the Hong Kong food system as food for human consumption was derived from the sum of imports and local production, minus the sum of exports, re-exports and estimated or 'known' losses. Nutrients in animal feedstuffs and fertilisers were not accounted for in drawing up this balance. The balance of nutrients obtained in this manner is essentially the apparent consumption of food by the human population.

**Nutrient supply**

Figure 1 is a diagrammatic representation of nutrient flow in the Hong Kong food system. It shows that the sources of nutrients entering the Hong Kong ecosystem include imported human and animal food, and fertilisers. From this input of nutrients are derived food stocks, human and animal feed and fertiliser exports, nutrient supplements to local agricultural production and, of course food wastes. The movement of nutrients in the Hong Kong ecosystem is complex, with some part of the initial input of nutrients being recycled as either animal feed or fertilisers. Needless to say, although the manner in which the data is presented gives the impression of a static balance, the flow of nutrients is dynamic.

The overall picture is that, while local production makes an important contribution to local nutrient consumption, Hong Kong is nevertheless heavily reliant on imported nutrients. There is little throughput of nutrients in the form of exports of human food or animal feed of fertiliser. Losses within the food system are large and a proportion of the losses from
food formerly fit for human consumption is recycled as animal feed or fertilisers.

An important anomaly in the presentation of data is that local agricultural statistics include in local production statistics marine products harvested from the South China Sea, well outside Hong Kong territorial waters. For the purpose of constructing a nutrient balance, we have continued to treat such nutrients as being locally produced, but we refer, on occasions, to the more strict definition which encompasses only those nutrients produced within the territory of Hong Kong. Virtually none of the marine products included under local production are in fact produced within Hong Kong territory.

This broad perspective is confirmed in the detail of the tabulations presented here. Tables I to V present nutrients in the major sectors of nutrient flow in Hong Kong, being imports, local production, exports, re-exports and known losses respectively. Each of these tables contributes to the balance of nutrients available for human consumption, or apparent consumption, in Hong Kong in 1971, as shown in Table VI. Table VII presents retained local production, retained imports and losses as a percentage of the retained input of particular nutrients and energy to Hong Kong. Apart from such major nutrients as protein, fats and carbohydrates, calcium is considered here because elsewhere we have shown that it is in unusually short supply in the Hong Kong diet. (Newcombe, in preparation). The impression gained from these figures, that fats and calcium produced in
Hong Kong are a significant proportion of the total is correct, however, 67% of the animal protein listed under local production is, in fact, imported from the South China Sea. So in effect only 13%, or $14.1 \times 10^6$ kg of animal protein is locally produced, while 28% is imported by the large commercial fishing fleet based in Hong Kong. Of this $14.1 \times 10^6$ kg of animal protein produced in Hong Kong territory, $6.33 \times 10^6$ kg is from fresh water fish, $5.04 \times 10^6$ kg from poultry and eggs, $2.65 \times 10^6$ kg from pork, $0.03 \times 10^6$ kg from beef, and $0.02 \times 10^6$ kg from milk.

These figures demonstrate the relationship between the data on nutrient losses in Table V, other major nutrient inputs to the Hong Kong ecosystem, such as fertilisers and animal feeds and local production, exports and so on. From the above data on the sources of animal protein produced within Hong Kong territory, we can see that $7.7 \times 10^6$ kg of animal protein are derived from pig and poultry products. In Hong Kong the pig and poultry population are fed on both recycled feed and imported feed. Table V shows that $7.8 \times 10^6$ kg of plant and animal protein from commercial food refuse are recycled for animal feed, largely for pigs. 10%, or about $1.0 \times 10^6$ kg of domestic refuse (see Table v) is also estimated to be recycled as animal feed (Binnie, 1974). Imported animal feedstuffs include cereal concentrates such as brans, oil-cakes and various meals. Using trade information (Census and Statistics, 1972), and
appropriate conversion factors to calculate digestible protein content (Morrison, 1956), it appears that imported animal feeds contain roughly \(1.7 \times 10^6\) kg of digestible protein. Recycled and imported animal feed together provide \(2.65 \times 10^6\) kg of digestible protein. The implication here is that the conversion efficiency of feedstuff protein to animal protein by the pig and poultry population is twenty per cent, and that there are additional sources of animal feed such as domestic refuse, unrecorded wastes from local crop production and so on. These assumptions appear reasonable considering, firstly, that the conversion efficiency of feed protein to animal protein is generally accepted as being between 15% and 19% (Godden, 1948), and secondly, that the Agriculture and Fisheries authorities in Hong Kong suggest that they have underestimated the amount of food wastes recycled as pig food (Agriculture and Fisheries, 1975).

Feed protein for the local bovine population comes mainly from crop residue and free range grazing over approximately 3600 ha (C.T. Wong, Agriculture and Fisheries Department, personal communication, 1974). Milk cows in Hong Kong consume a tiny amount of imported feedstuffs and they graze over about 50 ha of pasture land.

The other major source of animal protein produced within Hong Kong territory is fresh water fish. During the five-year period 1970-74, the land area occupied by fish ponds increased from 940 ha to 1370 ha (Director, Agriculture & Fisheries Department, 1974). This expanding industry does not require imported feeds, or a share of recycled food wastes. However, as will be discussed later, the nutrients required for local
fish culture form a vital part of nutrient flow in the Hong Kong ecosystem.

Although some food wastes are recycled as animal feed, losses of food for human consumption are considerable and more detailed discussion of food losses is warranted.

Losses of Nutrients

The losses of nutrients considered here are those from food available for human consumption. Table V contains data on these nutrients under the heading 'known nutrient wastes'. Clearly it is difficult to account for all losses of nutrients from human food. Nevertheless, the data shown in Table VII indicate that the nutrient losses we have been able to record form a considerable proportion of the nutrients in food available for consumption in Hong Kong. From these records, 18% of plant protein and 14-16% of other important nutrients retained in the Hong Kong ecosystem as human food are ultimately unavailable for human consumption. These losses, with the exception of animal protein, represent 16-22% of apparent consumption (see Table VII). In contrast to large losses of other nutrients only about 7% of animal protein is lost from human food. This is all the more exceptional because out of the total of animal and plant protein lost, animal protein makes up only 32%, whereas it comprises 64% of the total protein available for human consumption. Presumably there are strong economic incentives which ensure that the generally more expensive animal protein is subjected to greater
care and supervision aimed at preventing losses during the food preparation and marketing processes.

There are at least two reasons for concern at such large losses of nutrients in the Hong Kong food system. Any large scale loss of nutrients adds to the already considerable burden of world food production, or, in the least, negates part of that effort to produce enough food. Similarly, each unit of nutrient lost also represents the loss of the extrasomatic energy, water, labour, time and so on, invested in its production.

Secondly, the loss of nutrients already in short supply in the local diet may lead to, or further aggravate, problems of a nutritional health nature. Calcium, for which the recorded losses are 16% of the total retained input in human food, is in this category of nutrients in Hong Kong.

Our figures on nutrients lost in the Hong Kong food system are clearly underestimates. While these figures corroborate the prediction, by the Presidents' Science Advisory Committee (1967), that 15% of foodstuffs are lost in contemporary urban food systems, the likelihood is that actual losses exceed 20% of the retained input of most nutrients.

More careful scrutiny of the points of major nutrient losses, as shown in Table V, gives further cause for concern. Taking protein as the example, about 90% of the losses are in food wastes from domestic homes, restaurants and hotels. In other words, so long as a state of reasonable affluence prevails, it will be difficult to encourage consumers to be more frugal in purchasing and preparing their nutrient requirements. However, by way of compensation, much of the food waste listed
in Table V enters a somewhat unique system of nutrient recycling of considerable importance to the functioning of the Hong Kong ecosystem.

Recycling: Practice and Potential

At least $130 \times 10^6$ kg of food wastes from restaurants and food processing plants are transported daily to the pig farms of the New Territories in Hong Kong. This recycling measure substantially maintains a pig population of about 400,000, provides a source of income and employment for thousands of small farmers. At the same time it overcomes the potentially severe problem of disposing of $130 \times 10^6$ kg of swill, for whereas most domestic and trade refuse in Hong Kong is incinerated, or used as landfill, wet food wastes are unsuitable for either of these disposal methods. No composting plant was in operation in 1971, although composting will become important in the near future. The Hong Kong Department of Agriculture and Fisheries has only recently experimented with bioconversion plants which produce methane and fertilizer. Therefore if Hong Kong were without a large pig population, the disposal of $130 \times 10^6$ kg of swill would pose a difficult problem.

However, it takes careful management to maintain a large pig population in a confined area such as Hong Kong, without generating a sewage pollution problem. Consultant engineers, hired by the Hong Kong Government to examine the problem of animal wastes in water catchment zones, have recommended either pumping pig sewage out to sea, or, preferably, eliminating pigs altogether (Binnie, 1974). In effect, they are suggesting either an expensive process to dispose of a highly valuable resource, or the replacement of the pig sewage disposal
problem in the New Territories with a pig swill disposal problem in the urban centre of Hong Kong. Disposing of pig swill would also mean the loss of the high quality human food produced from the food waste.

Sewage production by pigs in 1971 was about 1280 tonnes per day (Director, Agriculture and Fisheries, 1973). If handled properly, this so-called waste could generate up to $33 \times 10^8$ MJ of extrasomatic energy and more than 100,000 tonnes of valuable fertilizer per annum. The methane which could be generated from the 1880 tonnes of pig and poultry manure produced daily is equivalent to 4% of Hong Kong's total energy requirements (Newcombe, 1975a). Similarly, if all the pig and poultry manure produced in Hong Kong were applied to crop land at the same rate as it was 15-20 years ago in Hong Kong it would satisfy the total demand for fertilizer (Newcombe 1975b).

The poultry manure, of which there is about 600 tonnes produced each day, is even more valuable as a resource than is pig manure. Poultry manure is easier to handle, it is a high grade fertilizer for crop land and fish ponds and it can be fed to pigs as a protein feedstuff. Because poultry manure is a solid more than a liquid waste, it does not present the same water pollution problems as pig manure which, with the water used to flush it from production sites, readily flows into waterways.

Experiments aimed at drying poultry manure quickly have met with some success by the Agriculture and Fisheries Department in Hong Kong (J.E.J. Revell, personal communication, 1975). The Agriculture and Fisheries Department intends to spread poultry manure on forest land as a fertilizer and also to experiment with it as a pig food. In 1971 about 10% of poultry
manure was used to fertilise vegetable crops and fishponds (Binnie, 1974). In 1975 fresh water fish farmers were purchasing all available poultry manure as a result of the increasing expense and general shortage of the usual fertiliser. This use of poultry manure by fish farms is really an extension of an older tradition whereby ducks are reared in association with fish farming, their droppings directly fertilising the fish ponds. Ducks are one fifth of the Hong Kong poultry population and an association between duck and fresh water fish farming is frequent.

Table V shows that domestic refuse constitutes a significant point for nutrient loss in Hong Kong. Currently very few of the nutrients in refuse are recycled, either as foodstuffs or fertiliser. However, composting plants to process approximately 15%, or 600 tonnes of urban refuse per day, will be in operation by 1979-80 (H.S. Grewal, Colonial Secretariat, personal communication, 1975). Clearly, more than 80% of the nutrients from food refuse will still be lost, but if composting proves successful as a disposal method in Hong Kong, the proportions may change in the future.

Finally, the most significant of nutrient flows currently regarded as waste is sewage. An estimated 3,900 tonnes of human sewage is produced daily, 80% of which drains into Victoria Harbour between Hong Kong Island and the mainland. To regard human sewage as no more than a waste which creates a disposal problem is a viewpoint commonly held by engineers, urban planners and policy makers in the Western world. However, this attitude is relatively new to Hong Kong and quite alien to the Chinese in the Hong Kong population.
During the late 1950s, human sewage was applied to agricultural land in Hong Kong at the rate of up to 77 tonnes per hectare (Blackie, 1957). By 1971 virtually no human sewage was applied to Hong Kong cropland (Newcombe, 1975a) whereas in the Peoples Republic of China, all available sewage, human and animal, is recycled into agricultural production (Sebastion, 1974, Sprague, 1975). It is important to see this trend away from applying organic matter to cropland as motivated largely by a change in attitudes towards agriculture, for in practice the trend is completely reversible. In this case, as with other forms of nutrient waste, there is good potential for recycling and conservation. Obviously the task appears more difficult and complex the larger each particular urban settlement becomes. Indeed, Borgstrom (1973) has postulated that with urbanisation there is an inevitable breach in the flow of mineral nutrients. His postulate can be examined in the context of the following brief analysis of the flow of phosphorus in the Hong Kong food system.

The example of phosphorus

The flow of phosphorus in the Hong Kong food system is depicted in Figure 2. The amounts of phosphorus involved in each part of the food system are marked on the flow chart in units of kilogrammes of the element phosphorus per day. The total input of phosphorus is 12,803 kg/day. The major components of this input are human food, 42%, imported animal feed, 25%, imported fertilisers, 10% and local production 10%. Similarly, the fate of the phosphorus input is very largely to be lost in
human and animal sewage. 35% of the phosphorus is disposed of in human sewage and 24% in animal sewage. 14% is in soil and water reserves, 10% is exported as human and animal food. Only 13% of the total phosphorus input is recycled, 10% as fertiliser from waste food and sewage, and 3% in waste human food fed to animals. In effect, some 3.6 x 10^6 kg of P are immobilised in, or discarded from, the Hong Kong ecosystem each year, often eutrophicating freshwater and marine ecosystems in the process. In addition, we have estimated that a further 1.6 x 10^6 kg of phosphorus contained in detergents, textile chemicals and other industrial agents are discarded into Hong Kong marine environments each year.*

The data on phosphorus flow have been obtained from a number of sources. Imports, local production, exports, re-exports and food wastes data on phosphorous in human food are derived from Tables I to V. Phosphorus in food wastes has been recycled as described for all nutrients in the previous section. A large proportion of the phosphorus recycled from food wastes comes from bonemeal. The food waste, namely bones and minimal scrap meat was not included amongst the food wastes listed in Table V. Local fertiliser factories produce some 4,000 tonnes of bonemeal each year. The phosphorus content of abattoir wastes which are listed in Table V are included in the estimate of 1074 kg P/day given in Figure 2 as recycled food wastes.

*i.e. 405 tonnes P/yr from textile wastes (calculated from data from Mr. Short, J.D. & D.M. Watsons, Consultant Engineers, personal communication, 1975), 430 tonnes P/yr from detergents (calculated from Census and Statistics, 1971, Devey and Harkness, 1973), and 1125 tonnes from P containing chemicals imported to Hong Kong (calculated from Census and Statistics, 1971).
Data on the import and export of fertilisers and animal feedstuffs (Census and Statistics, 1971; Director, Agriculture and Fisheries, 1973) were converted to phosphorus content, using appropriate conversion factors (Spector, 1956, 188-9, 191). The phosphorus content of animal sewage produced in 1971 (Director, Agriculture and Fisheries, 1973) was calculated using data from analyses of pig and poultry manure conducted by the Agriculture and Fisheries Department (Y.C. Lim, personal communication, 1974) and of cattle manure conducted by Hart and Turner (1965).

The phosphorus content of human sewage in Hong Kong was obtained by taking the apparent consumption of phosphorus presented in Table VI and deducting an amount representing the phosphorus requirement of the increased human biomass given population growth rates (after Aston et al, 1973). The increase in soil and water reserves of phosphorus is assumed to be the difference between the input and output of phosphorus after all other likely fates are examined.

Recycling of phosphorus occurs very much in the ways we have described for nutrients in general. There are a number of recent changes in Hong Kong which aid, specifically, the recycling of phosphorus. As mentioned, there has been a reversion to the practise of fertilising fish ponds with poultry manure. The incentive for this move was provided by the scarcity and increased cost of the alternative, superphosphate. Currently as much as 50% of available poultry manure, representing an additional 725 P/day, compared to 1971, is being recycled.

Similarly, the new capacity to produce compost from urban waste, and the potential use of sewage sludge rich in
phosphorous from advanced treatment works for fertiliser (Watsons, 1974), substantially improve the outlook for phosphorous recycling. Phosphorous rich sludge could also be retrieved from the methane digestors which the Department of Agriculture and Fisheries are experimenting with (J.E.J. Revell, personal communication, 1975). However, the use of these kinds of fertiliser is apparently unlikely in any substantial way in the near future (E.H. Nichols, Agriculture and Fisheries, personal communication, 1975).

For the moment there are no proposals to recycle the bulk of human sewage which we have observed to be the largest source of phosphorous currently lost from the Hong Kong food system. The potential for applying human sewage, at the stage of primary treatment, to agricultural land is much diminished by the lack of available land and the prospect of increasing population generating even more sewage. This does not mean that human sewage reduced to ash, or composted with urban refuse, and thereby much reduced in volume, could not largely be recycled within Hong Kong. For this to happen incentives must be developed which make investment in, and deployment of, suitable technology a feasible proposition. Such incentives might include taxing phosphatic fertilisers imported for local primary production. The hidden cost of both cleaning up, or disregarding pollution caused by human and animal sewage are not included when accounting agricultural productivity. If they were there is no doubt that proposals of direct economic, tax or subsidy, incentives to use organic waste would appear more attractive.

Presently, however, the recycling which does occur, and which might increase in the future, is as much fortuitous as it is related to the desire to conserve phosphorous itself.
There can be no doubting the economic and ecological profitability of recycling nutrients, such as phosphorus, from within the urban ecosystem. Nevertheless, there are other external areas in which the conduct of the urban population has a considerable bearing on resource consumption and conservation. The basic composition of the average diet chosen by an urban population influences the size of the forage area of the urban settlement and the amount of resources devoted to feed each individual in the population.

**The influence of diet on forage area**

Table VIII provides a comparison between the daily supply of nutrients, including wastes, to the urban settlements of Hong Kong and Sydney, Australia. The Hong Kong data is derived from Tables I to V. Exports and re-exports of nutrients have not been included in the total supply as they have been regarded as a direct throughput for the Hong Kong ecosystem to other populations. The Australian data is calculated from apparent consumption data documented by the Australian Bureau of Statistics (1971) and related to a population the size of Hong Kong in 1971 (3,939,153). Sydney is given as the Australian city because estimated figures based on the Sydney population and information relating the actual supply of various nutrient categories to Sydney had previously been shown to compare well (Aston et al, 1973).

The purpose of Table VIII, for this study, is twofold. Firstly, it provides a comparison between the nutrient intake of a city where the population has adopted a typical western diet, and a city where the population is following a traditional non-western pattern of food consumption, at least in so far as major foods are concerned. The Asian
diet as reflected by the consumption patterns of the comparatively affluent Chinese of Hong Kong is high in grain products, poultry, fish and egg consumption, and low in milk and milk products, fats and oils (e.g. butter), and sugars when compared with the western diet presented by Sydney. Other important differences between the Sydney and Hong Kong diets, not immediately evident from Table VIII, are that in Sydney, beef and mutton rather than pork, wheat and flour rather than rice, potatoes and root crops rather than leafy greens, and apples, pears and bananas rather than oranges and citrus fruits, are dominant in their respective food categories.

Secondly, Table VIII provides data fundamental for the calculation of estimated forage areas of both Sydney and Hong Kong, as presented in Table IX. Before discussing the results presented in Table IX it is very important to stress the limitations and qualifications which apply to the calculations performed to obtain those results. The basis of the calculations are presented in detailed footnotes attached to Table IX. Energy of the foodstuffs in each category has been used to estimate the respective and total forage areas. Precise estimates of forage area would be very detailed and complex, requiring information on specific farming techniques, yields of various feedstuffs and concentrates, efficiencies of the various animal converters, losses of each category of foodstuffs prior to entering the urban settlement ecosystems, all for each country exporting food and for the particular year in which it was produced. Therefore, for the purposes of this study, assumptions have been made about the yields per unit area for crops, the type of feedstuffs consumed by animals, and the efficiency with which they convert gross energy into somatic energy of the human food they produce.
It is especially difficult to estimate the area utilised by grazing animals, so for convenience, the assumption has been made that they are all grain fed. Australia and China are major exporters of grain, meat, vegetables and milk products to Hong Kong, therefore average yields for Australian and Chinese produce are used to calculate forage area wherever applicable.

Information is not available in the present study, which would allow the calculation of oceanic forage area. Indeed, accurate data on the productivity of oceans which might allow estimations of forage area per unit marine food is not readily accessible for any oceanic region (excepting for sedentary molluscs and so on). Thus we have restricted our analysis to estimating the land area required to provide food for each urban population. This restriction is important in so far as the Hong Kong population consumes twenty times more marine products than a Sydney population of equivalent size.

It is obvious, then, that notional, rather than actual forage area size is the outcome of such calculations. So, with a knowledge of the factors which could not be considered, the likelihood is that the forage areas on land, cited for each category of nutrients, and particularly the total forage area for each settlement, are underestimated.

The data presented in Table IX are also biased to underestimate the forage area of Sydney compared to Hong Kong. Whereas care has been taken to document all major identifiable points of nutrient loss in the Hong Kong ecosystem, and to include this data as part of the total daily supply of nutrients to the city, the same is not true for Sydney.
To quote the Australian data source 'in many cases, allowance is not made for wastage before the foodstuffs are consumed' (Australian Bureau of Statistics, 1971).

Taking into consideration these qualifications, Table IX shows that the overall land forage area for Sydney, adjusted to Hong Kong's population size, is more than double that for Hong Kong. Each Hong Kong citizen requires on average about 0.57 ha to provide nutrients, compared with 1.12 ha for the average Sydney resident. The larger forage area demands of Sydney residents result from a high consumption of butter, milk and milk products and the use of ruminants to provide meat and offal requirements.

In the light of discussion on recycling of nutrients in Hong Kong it becomes clear that feeding food wastes to pigs and poultry, rather than grain, considerably reduces the demand for forage area, as well as performing a vital nutrient recycling function. Currently such practices are more likely to be a feature of urban ecosystems in the developing world than in the developed world where legislation aimed at preventing the transmission of disease frequently prevents the use of waste human foodstuffs for animal production.

General Discussion and Conclusions

The discussion on forage area requirements of Hong Kong and Sydney highlights an important distinction between the kinds of plants and animals which the two populations rely on for their essential nutrients. In general terms, Hong Kong depends on species that are more efficient converters of available energy into the somatic energy of food acceptable for human consumption.
than are the species which provide food for the Sydney population. It is likely that this difference is not merely coincidental but has arisen over thousands of years from pressures on available land resources exerted by an ever-increasing Chinese population. Whyte (1972) writes of two major changes in the Chinese diet in response to the pressure of increasing population and decreasing land resources; from the 4th to the 1st century B.C., beef and mutton were foregone in favour of pork, and from the 3rd to the 6th century, rice replaced wheat and pulses as staples in the south and vegetables and fish compensated for reduced mineral, vitamin and protein content. When beef was replaced by pork, milk and milk products disappeared from the diet, and cattle were used only for draught. Any beef consumed by rural Chinese today comes mostly from draught animals which traditionally consume crop residue and forage in areas peripheral to cropland, roadways and so on (Fei and Chang, 1945; Buck, 1956). Of course wheat continues to dominate grain production in Northern China (Wortman, 1975).

The particular combination of food-producing animals maintained in Hong Kong also ensures good potential for recycling nutrients. There can be little doubt that pigs were an acceptable alternative to beef for the Chinese of two thousand years ago because they could convert all manner of foodstuffs, including food wastes into high quality human food and could easily cohabit with man. Indeed, pigs were frequently kept in the same room as an entire Chinese family, even in the extraordinarily crowded conditions of Hong Kong in the 1860's (Endacott, 1958). Poultry also require little space and are able to convert human food wastes, husks and
so on into high quality food with reasonable efficiency.
As outlined in the discussion on recycling, given intermediate
technology to convert animal sewage into extrasomatic energy,
fertilizers and other products, the emphasis on pig, poultry
and fresh-water fish farming could be integrated to provide
a valuable resource-conserving system closely
associated with urban settlements. In Hong Kong this system
has clearly enabled considerable food production, essentially
within the urban settlement itself. The point is illustrated
by again comparing Hong Kong with Sydney. The total land
area of Hong Kong is one quarter the size of the Sydney Statistical Division and yet contains 35% more people and produces up
to 10% of its total animal protein and 5% of its total plant
protein requirements. There are other proposals, such
as to locate market gardens on large building complexes
(Page, 1973), which could contribute to the development of
an integrated system to cycle essential nutrients and to
conserve space, energy and other valuable resources in the
urban environment.

Nevertheless, as the example of phosphorus flow
in Hong Kong shows, urbanization has had a seriously disruptive
influence on nutrient cycling. It would be possible to
decrease the rate of dissipation of mineral nutrients but
it would require careful planning for which few incentives
currently exist. Urban settlements are essentially large
feedlots for human beings, involving the same immense
concentration of organics and mineral nutrients as feedlots
for beef, pigs, dairy cattle and sheep.

Western influences in the management of the Hong
Kong ecosystem only tend to exacerbate the problem of
nutrient loss. Animal and human sewage generated in Hong Kong have more often been regarded as wastes posing an engineering problem of disposal rather than resources posing a biological problem of utilization (Binnie, 1974). Initiatives by engineers to recover fertilizer or potable water from human sewage have been largely ignored (E. Short, J.D. & D.M. Watsons, personal communication, 1975). Human and animal sewage fertilizer has been replaced by chemical fertilizers in the past 15 years (Newcombe, 1975a), whereas in China, Taiwan and Japan organics are highly valued fertilizers in addition to large inorganic fertilizer supplements (Buck et al, 1966, Sprague, 1975). As we have documented, the breach in nutrient cycling resulting from these developments is considerable.

Throughout Asia, including Hong Kong, beef is being promoted as a prestige food, as opposed to pork and poultry, giving rise to what the popular press has called the 'pinko-gray revolution' (S.C.M.P. 1974). Any shift in meat consumption toward beef and away from traditional meats in Hong Kong will tend to increase forage area demand and eventually decrease the capacity of the existing food system to recycle food wastes back into human food.

The importance of milk products, frequently stressed by nutritionists (Kon, 1959), and exaggerated by multinational corporations (Muller, 1975), is questionable. Breast feeding is abandoned in favour of cows milk, fresh or powdered, often leading to increased costs, malnutrition and infection (Jelliffe and Jelliffe, 1975). According to Hong Kong paediatricians there is evidence of malnutrition in children
whose mothers consistently mismanage the preparation of appropriate mixtures of powdered milk and water (G. Kneebone, personal communication, 1975). Clearly, any nutritional justification for increasing milk consumption is subject to criticism. In addition, a considerably increased forage area would be required to support milk consumption at a level approaching that of western populations. These criticisms apply equally well to milk products including butter.

It should be noted here that food policy makers have recently attached less importance to land as an agricultural resource, placing emphasis instead on fertilisers, irrigation and machinery as agents to increase yield (U.S. Department of Agriculture, 1975). For example, in regard to milk production, it has been shown that protein production per hectare on some experimental farms is of the same order as grain production (Duckham and Masefield, 1970). However, land saved by the use of high yielding technology is, to a certain extent, required elsewhere to provide the vastly increased extrasomatic energy, materials and water requirements of the new production techniques. The availability of land remains critical to agricultural production, and any change in the combination of plant and animal producers which increases forage area and/or energy and key materials demand, which cannot be justified on nutritional grounds, or which disrupts established patterns of nutrient consumption must be viewed with concern.

Losses of nutrients, likely to exceed 20% of the retained input of particular nutrients to the Hong Kong ecosystem, add to the already considerable burden of losses at the point of production, and en route to urban settlements.
Borgstrom (1974) suggests that half of the rice crop is lost through weeds, diseases and pests and that 30% to 50% is lost post harvest and prior to consumption. It follows that as the urban population grows, the forage area grows and the distance over which fresh food must travel increases. Therefore, unless a conscious effort is made to concentrate the production of fresh foods close to, and within the urban settlement, losses of fresh food are likely to increase in Hong Kong, and, in addition, greater extrasomatic energy costs will be incurred in transporting, packaging, processing, and refrigerating foodstuffs.

The apparent consumption of major nutrients by the Hong Kong population, with the notable exceptions of fats and calcium, is the same or higher than the United States, United Kingdom, New Zealand and Australia (Newcombe, in preparation). Therefore this marked difference between Hong Kong and Sydney in land required for forage area offers some guidelines for establishing food production policies for developing urban settlements. Perhaps through pressure on land resources, Hong Kong has sought to obtain about 25% of its animal protein from the ocean, compared with 2.5% in the case of Sydney. Currently only 5% of the world's food comes from the ocean (Pimental et al, 1975), but this will undoubtedly increase in the future. Not only will we have to learn more about the ocean's productivity, and how to harvest it without irrevocable damage, but steps will have to be taken to protect the rights of those countries who have already come to depend on the ocean for a major proportion of their essential food nutrients.

Rather than unthinkingly imposing Western values on foods and nutrition it seems logical
that any combination of plant and animal producers, which has been selected by agriculturalists over thousands of years has some virtue both in terms of providing an adequate diet and for nutrient conservation. For example, farmers in Southern China have, for hundreds of years, recycled human food wastes as animal feeds, and human sewage as fertilizer. They have used small animals with high conversion efficiency to optimise the production of animal protein from feed protein. These kinds of resource-conserving measures are only now being stressed by western authors (Borgstrom, 1973; Dwyer and Mayer, 1975). The integrative pattern of Chinese agriculture, evident in part in Hong Kong, can be enhanced to maximise the conservation and recycling of resources in and around contemporary urban settlements.
REFERENCES

Anon, no date. Chinese food and nutrition for University students. Held by the Census and Statistics Department, Consumer Price Index Division, Hong Kong.


Census and Statistics Department, 1971. Hong Kong trade statistics, December. Hong Kong Government Printer, Hong Kong.
Daftar Analisa Bahan Mokanan (D.A.B.M.), 1967. Indonesia


Godden, W., 1948. The relative efficiency of conversion of feeding stuff by farm animals. Agric. Prog. 23(2):1-10.


<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PROTEIN</th>
<th>PLANT</th>
<th>FAT</th>
<th>CHO'S</th>
<th>SOMATIC ENERGY</th>
<th>CALCIUM</th>
<th>P</th>
<th>IRON</th>
<th>THIAMINE</th>
<th>ASCORBIC ACID</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANIMAL Kg x 10^6</td>
<td>PLANT Kg x 10^6</td>
<td>FAT Kg x 10^6</td>
<td>CHO'S Kg x 10^6</td>
<td>SOMATIC ENERGY M J x 10^6</td>
<td>CALCIUM Kg</td>
<td>P Kg</td>
<td>IRON Kg</td>
<td>THIAMINE Kg</td>
<td>ASCORBIC ACID Kg</td>
<td>WATER Kg x 10^6</td>
</tr>
<tr>
<td>Milk and Milk Products</td>
<td>4.03</td>
<td>3.62</td>
<td>10.78</td>
<td>367.14</td>
<td>124221</td>
<td>41188</td>
<td>177</td>
<td>22</td>
<td></td>
<td>3898</td>
<td>15.28</td>
</tr>
<tr>
<td>Meat and Offal</td>
<td>23.52</td>
<td>60.11</td>
<td>2.39</td>
<td>3082.07</td>
<td>16745</td>
<td>298571</td>
<td>3464</td>
<td>920</td>
<td></td>
<td>3204</td>
<td>90.82</td>
</tr>
<tr>
<td>Poultry and Fish</td>
<td>27.98</td>
<td>5.65</td>
<td>1.96</td>
<td>1335.95</td>
<td>141096</td>
<td>324049</td>
<td>2790</td>
<td>150</td>
<td></td>
<td>6525</td>
<td>85.95</td>
</tr>
<tr>
<td>Eggs &amp; Egg Products</td>
<td>6.88</td>
<td>6.48</td>
<td>0.48</td>
<td>373.47</td>
<td>30737</td>
<td>124124</td>
<td>1321</td>
<td>58</td>
<td></td>
<td>-</td>
<td>40.22</td>
</tr>
<tr>
<td>Oils &amp; Fats (inc. butter)</td>
<td>0.03</td>
<td>3.15</td>
<td>0.02</td>
<td>118.33</td>
<td>640</td>
<td>602</td>
<td>4</td>
<td>1</td>
<td></td>
<td>-</td>
<td>0.60</td>
</tr>
<tr>
<td>Sugar and Syrups</td>
<td>0.15</td>
<td>-</td>
<td>97.27</td>
<td>1588.81</td>
<td>21028</td>
<td>3463</td>
<td>1806</td>
<td>15</td>
<td></td>
<td>1</td>
<td>41.94</td>
</tr>
<tr>
<td>Pulse and Nuts</td>
<td>2.75</td>
<td>5.59</td>
<td>4.00</td>
<td>401.03</td>
<td>7918</td>
<td>51585</td>
<td>380</td>
<td>100</td>
<td></td>
<td>446</td>
<td>6.70</td>
</tr>
<tr>
<td>Vegetables</td>
<td>14.93</td>
<td>1.72</td>
<td>78.41</td>
<td>1592.32</td>
<td>126898</td>
<td>356396</td>
<td>8322</td>
<td>509</td>
<td></td>
<td>44437</td>
<td>228.37</td>
</tr>
<tr>
<td>Fruit &amp; Fruit Products</td>
<td>1.79</td>
<td>1.86</td>
<td>40.72</td>
<td>592.27</td>
<td>57983</td>
<td>38159</td>
<td>1157</td>
<td>138</td>
<td></td>
<td>32409</td>
<td>231.15</td>
</tr>
<tr>
<td>Grain Products</td>
<td>53.45</td>
<td>8.42</td>
<td>627.43</td>
<td>11728.26</td>
<td>159479</td>
<td>640059</td>
<td>11213</td>
<td>549</td>
<td></td>
<td>-</td>
<td>94.22</td>
</tr>
<tr>
<td>Beverages</td>
<td>4.33</td>
<td>3.73</td>
<td>11.16</td>
<td>501.45</td>
<td>34798</td>
<td>88875</td>
<td>2256</td>
<td>4</td>
<td></td>
<td>16014</td>
<td>2.85</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1.11</td>
<td>3.42</td>
<td>2.86</td>
<td>307.72</td>
<td>27168</td>
<td>17190</td>
<td>176</td>
<td>18</td>
<td></td>
<td>914</td>
<td>11.24</td>
</tr>
</tbody>
</table>

**TOTAL:** 62.44 78.51 103.75 877.48 21988.82 748711 1984261 33066 2484 107848 849.34

Source: Census and Statistics (1971)
<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PROTEIN</th>
<th>PLANT</th>
<th>FAT</th>
<th>CHO'S</th>
<th>ENERGY</th>
<th>CALCIUM</th>
<th>P</th>
<th>IRON</th>
<th>THIAMINE</th>
<th>ASCORBIC ACID</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANIMAL Kgx10^6</td>
<td>PLANT Kgx10^6</td>
<td>FAT Kgx10^6</td>
<td>CHO'S Kgx10^6</td>
<td>MJx10^6</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kgx10^6</td>
</tr>
<tr>
<td>Milk and Milk Products</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
<td>1.89</td>
<td>772</td>
<td>644</td>
<td>1</td>
<td>*</td>
<td>7</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>Meat and Offal</td>
<td>2.68</td>
<td>9.89</td>
<td>0.01</td>
<td>424.64</td>
<td>1632</td>
<td>38436</td>
<td>418</td>
<td>2</td>
<td>46</td>
<td>10.13</td>
<td></td>
</tr>
<tr>
<td>Poultry and Fish</td>
<td>39.36</td>
<td>3.94</td>
<td>0.30</td>
<td>859.77</td>
<td>204400</td>
<td>386395</td>
<td>3873</td>
<td>159</td>
<td>321</td>
<td>134.99</td>
<td></td>
</tr>
<tr>
<td>Eggs and Egg Products</td>
<td>0.96</td>
<td>0.88</td>
<td>0.05</td>
<td>51.02</td>
<td>4112</td>
<td>16599</td>
<td>183</td>
<td>8</td>
<td>5.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>4.25</td>
<td>0.71</td>
<td>9.20</td>
<td>217.58</td>
<td>184859</td>
<td>8597</td>
<td>2653</td>
<td>140</td>
<td>123298</td>
<td>163.63</td>
<td></td>
</tr>
<tr>
<td>Fruit &amp; Fruit Products</td>
<td>0.02</td>
<td>0.36</td>
<td>5.01</td>
<td>735</td>
<td>491</td>
<td>10</td>
<td>2</td>
<td>1118</td>
<td>2.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grain Products</td>
<td>1.38</td>
<td>0.12</td>
<td>17.26</td>
<td>318.44</td>
<td>3621</td>
<td>23643</td>
<td>149</td>
<td>17</td>
<td>2.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>43.02</strong></td>
<td><strong>5.65</strong></td>
<td><strong>15.57</strong></td>
<td><strong>27.21</strong></td>
<td><strong>1878.35</strong></td>
<td><strong>400131</strong></td>
<td><strong>474805</strong></td>
<td><strong>7287</strong></td>
<td><strong>328</strong></td>
<td><strong>124790</strong></td>
<td><strong>320.06</strong></td>
</tr>
</tbody>
</table>

* Negligible

Source: Director, Agriculture and Fisheries (1972). Local production here includes marine products harvested outside Hong Kong territory.
<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>WATER Kg x106</th>
<th>ASCORBIC ACID Kg</th>
<th>THIAMINE Kg</th>
<th>IRON Kg</th>
<th>CALCIUM Kg</th>
<th>POTASSIUM Kg</th>
<th>CHOLES + FAT Kg x106</th>
<th>ANIMAL PROTEIN Kg x106</th>
<th>PLANT PROTEIN Kg x106</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat and Offal</td>
<td>- 0.02</td>
<td>0.66</td>
<td>14</td>
<td>28</td>
<td>2</td>
<td>-</td>
<td>0.01</td>
<td>1.26</td>
<td>- 0.01</td>
</tr>
<tr>
<td>Poultry and Fish</td>
<td>1.03</td>
<td>0.30</td>
<td>32</td>
<td>124</td>
<td>1</td>
<td>-</td>
<td>0.29</td>
<td>0.13</td>
<td>0.01</td>
</tr>
<tr>
<td>Jamaica Fruits and Proteins</td>
<td>1.50</td>
<td>0.37</td>
<td>32.00</td>
<td>108</td>
<td>351</td>
<td>368</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Vegetables</td>
<td>26.21</td>
<td>0.78</td>
<td>10.13</td>
<td>242.04</td>
<td>9142</td>
<td>48791</td>
<td>0.09</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Grain Products</td>
<td>9.83</td>
<td>0.38</td>
<td>10.05</td>
<td>216</td>
<td>1924</td>
<td>13568</td>
<td>0.36</td>
<td>0.13</td>
<td>0.11</td>
</tr>
<tr>
<td>Beverages</td>
<td>216</td>
<td>1.11</td>
<td>209.60</td>
<td>8040</td>
<td>630</td>
<td>4</td>
<td>2</td>
<td>1.15</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.27</td>
<td>2.26</td>
<td>14.22</td>
<td>549.52</td>
<td>125294</td>
<td>12509</td>
<td>2</td>
<td>1684</td>
<td>11.78</td>
</tr>
</tbody>
</table>

Source: Census and Statistics (1971)

* Negligible
<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PROTEIN</th>
<th>PLANT</th>
<th>FAT</th>
<th>CHO'S ENERGY</th>
<th>CALCIUM</th>
<th>P</th>
<th>IRON</th>
<th>THIAMINE</th>
<th>ASCORBIC ACID</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANIMAL Kgx10⁶</td>
<td>PLANT Kgx10⁶</td>
<td>FAT Kgx10⁶</td>
<td>CHO'S MJx10⁶</td>
<td>CALCIUM Kg</td>
<td>P Kg</td>
<td>IRON Kg</td>
<td>THIAMINE Kg</td>
<td>ASCORBIC ACID Kg</td>
<td>WATER Kgx10⁶</td>
</tr>
<tr>
<td>Milk and Milk Products</td>
<td>0.31</td>
<td>0.30</td>
<td>0.79</td>
<td>32.16</td>
<td>11970</td>
<td>5538</td>
<td>24</td>
<td>6</td>
<td>574</td>
<td>0.35</td>
</tr>
<tr>
<td>Meat and Offal</td>
<td>0.24</td>
<td>0.64</td>
<td>0.03</td>
<td>15.82</td>
<td>233</td>
<td>1382</td>
<td>35</td>
<td>1</td>
<td>43</td>
<td>0.93</td>
</tr>
<tr>
<td>Poultry and Fish</td>
<td>0.93</td>
<td>0.09</td>
<td>0.01</td>
<td>20.95</td>
<td>10492</td>
<td>12130</td>
<td>122</td>
<td>2</td>
<td>13</td>
<td>1.58</td>
</tr>
<tr>
<td>Eggs and Egg Products</td>
<td>0.08</td>
<td>0.08</td>
<td>0.01</td>
<td>4.27</td>
<td>390</td>
<td>1569</td>
<td>17</td>
<td>1</td>
<td>-</td>
<td>0.49</td>
</tr>
<tr>
<td>Oils and Fats (inc butter)</td>
<td>-</td>
<td>0.05</td>
<td>-</td>
<td>2.06</td>
<td>11</td>
<td>11</td>
<td>*</td>
<td>*</td>
<td>-</td>
<td>0.01</td>
</tr>
<tr>
<td>Sugar and Syrups</td>
<td>-</td>
<td>-</td>
<td>38.14</td>
<td>622.93</td>
<td>1515</td>
<td>354</td>
<td>114</td>
<td>1</td>
<td>*</td>
<td>2.22</td>
</tr>
<tr>
<td>Pulse and Nuts</td>
<td>0.99</td>
<td>1.74</td>
<td>0.93</td>
<td>103.11</td>
<td>2386</td>
<td>17970</td>
<td>127</td>
<td>32</td>
<td>48</td>
<td>0.86</td>
</tr>
<tr>
<td>Vegetables</td>
<td>4.64</td>
<td>0.35</td>
<td>21.59</td>
<td>299.62</td>
<td>26801</td>
<td>93149</td>
<td>1971</td>
<td>33</td>
<td>12576</td>
<td>31.83</td>
</tr>
<tr>
<td>Fruits and Fruit Products</td>
<td>0.13</td>
<td>0.08</td>
<td>4.99</td>
<td>83.72</td>
<td>3918</td>
<td>4196</td>
<td>115</td>
<td>11</td>
<td>2322</td>
<td>25.85</td>
</tr>
<tr>
<td>Grain Products</td>
<td>1.63</td>
<td>0.24</td>
<td>17.94</td>
<td>339.07</td>
<td>4562</td>
<td>24448</td>
<td>216</td>
<td>24</td>
<td>-</td>
<td>2.78</td>
</tr>
<tr>
<td>Beverages</td>
<td>3.00</td>
<td>3.31</td>
<td>6.71</td>
<td>288.82</td>
<td>28476</td>
<td>42648</td>
<td>1140</td>
<td>*</td>
<td>2894</td>
<td>1.03</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>0.01</td>
<td>0.19</td>
<td>0.05</td>
<td>21.64</td>
<td>1898</td>
<td>463</td>
<td>5</td>
<td>*</td>
<td>46</td>
<td>0.33</td>
</tr>
</tbody>
</table>

TOTAL: 1.56 10.40 7.07 91.19 1834.17 92922 203858 3886 111 18515 68.26

*Negligible

Source: Census and Statistics (1971). Re-exports are exports of goods previously imported.
<table>
<thead>
<tr>
<th>FOOT- NOTE</th>
<th>CATEGORY</th>
<th>PROTEIN ANIMAL Kg x 10^6</th>
<th>PROTEIN PLANT Kg x 10^6</th>
<th>FAT Kg x 10^6</th>
<th>CHO'S Kg x 10^6</th>
<th>SOMATIC ENERGY MJ x 10^6</th>
<th>CALCIUM Kg</th>
<th>IRON Kg</th>
<th>THIAMINE Vitamin B</th>
<th>ASCORBIC ACID Vitamin C Kg</th>
<th>WATER Kg x 10^6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Domestic Refuse</td>
<td>4.6</td>
<td>5.23</td>
<td>7.08</td>
<td>50.65</td>
<td>1271.71</td>
<td>76,828</td>
<td>137,557</td>
<td>1778</td>
<td>194</td>
<td>40,956</td>
</tr>
<tr>
<td>2</td>
<td>Condemned Food</td>
<td>0.04</td>
<td>0.03</td>
<td>0.06</td>
<td>3.03</td>
<td>107</td>
<td>452</td>
<td>5</td>
<td>*</td>
<td>1</td>
<td>0.19</td>
</tr>
<tr>
<td>3</td>
<td>Abattoir Wastes</td>
<td>0.44</td>
<td>1.42</td>
<td>-</td>
<td>60.87</td>
<td>2,319</td>
<td>55,417</td>
<td>598</td>
<td>195</td>
<td>-</td>
<td>1.44</td>
</tr>
<tr>
<td>4</td>
<td>Market Wastes</td>
<td>0.18</td>
<td>1.28</td>
<td>0.36</td>
<td>14.75</td>
<td>246.19</td>
<td>43,544</td>
<td>30,911</td>
<td>1032</td>
<td>96</td>
<td>44,246</td>
</tr>
<tr>
<td>5</td>
<td>Restaurant and stall wastes for pig</td>
<td>1.75</td>
<td>6.03</td>
<td>6.30</td>
<td>60.66</td>
<td>1373.86</td>
<td>25,859</td>
<td>130,222</td>
<td>1438</td>
<td>200</td>
<td>4,750</td>
</tr>
<tr>
<td></td>
<td>food destroyed following inspection</td>
<td>TOTAL KNOWN WASTE:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>in 1971.</td>
<td>7.01</td>
<td>12.54</td>
<td>15.19</td>
<td>126.12</td>
<td>2955.66</td>
<td>148,657</td>
<td>354,559</td>
<td>4851</td>
<td>685</td>
<td>89,953</td>
</tr>
</tbody>
</table>

*Negligible

FOOTNOTES:

1. Personal communication, R. Grieve, Maunsell Consultants, Asia, Hong Kong, 1974. Analysis revealed approximately 0.22 lbs food matter per day, ranging from less than 1/4" to more than 1" in size, and approximately 20% as animal matter, 80% vegetable matter for which food composition formula was devised in accordance with main food types present.

2. Personal communication, Un Wai-Kwok, Urban Services Department, Hong Kong, 1974. Detailed analysis of food destroyed following inspection in 1971.

3. Personal communication, Chan Kin Wang, Kennedy Town Abattoir, and Ho Man Chan, Cheung Sha Wan Abattoir, 1974. Very small private abattoirs in the New Territories were assumed to have negligible wastes by comparison.

4. Personal communication, Yu Hon Ping, Li King Hung and Yuen Wai-Keung, Urban Services Department, Hong Kong, 1974 regarding Kennedy Town Markets, regarding vegetable wastes. N.K. Lee, Agriculture and Fisheries Department, Hong Kong, 1974, and Ip Yauk-Lam, The Association of Dealers in Fruit, Vegetables, Beef, Mutton, Poultry, Pork and Fish, Hong Kong and Union Egg Corporation Ltd., 1974, regarding vegetable, poultry, fish, fruit and egg wastes in Hong Kong.

5. Estimated from 'pig Manure Treatment and Disposal' Bulletin No. 3 February, 1975, Agriculture and Fisheries Department, Hong Kong and personal communication J.E.J. Revell, Agriculture and Fisheries Department, Hong Kong, 1975.
### TABLE VI

**NUTRIENT BALANCE FOR HONG KONG, 1971**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PROTEIN</th>
<th>PLANT</th>
<th>FAT</th>
<th>CHO'S</th>
<th>ENERGY</th>
<th>CALCIUM</th>
<th>P</th>
<th>IRON</th>
<th>THIAMINE</th>
<th>ASCORBIC ACID</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kg x 10^6</td>
<td>Kg x 10^6</td>
<td>Kg x 10^6</td>
<td>Kg x 10^6</td>
<td>MJ x 10^6</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
</tr>
<tr>
<td><strong>IMPORTS</strong></td>
<td>62.44</td>
<td>78.51</td>
<td>103.75</td>
<td>877.48</td>
<td>21988.82</td>
<td>748711</td>
<td>1984261</td>
<td>33066</td>
<td>2484</td>
<td>107848</td>
<td>849.34</td>
</tr>
<tr>
<td><strong>LOCAL PRODUCTION</strong></td>
<td>43.02</td>
<td>5.65</td>
<td>15.57</td>
<td>27.21</td>
<td>1878.35</td>
<td>400131</td>
<td>474805</td>
<td>7287</td>
<td>328</td>
<td>124790</td>
<td>320.06</td>
</tr>
<tr>
<td><strong>TOTAL INPUT</strong></td>
<td>105.46</td>
<td>84.16</td>
<td>119.32</td>
<td>904.69</td>
<td>23867.17</td>
<td>1148842</td>
<td>2459066</td>
<td>40353</td>
<td>2812</td>
<td>232638</td>
<td>1169.40</td>
</tr>
<tr>
<td><strong>EXPORT</strong></td>
<td>1.27</td>
<td>2.26</td>
<td>1.15</td>
<td>14.22</td>
<td>549.52</td>
<td>125294</td>
<td>91509</td>
<td>790</td>
<td>42</td>
<td>1684</td>
<td>11.78</td>
</tr>
<tr>
<td><strong>RE-EXPORT</strong></td>
<td>1.56</td>
<td>10.40</td>
<td>7.07</td>
<td>91.19</td>
<td>1834.17</td>
<td>92922</td>
<td>203858</td>
<td>3886</td>
<td>111</td>
<td>18515</td>
<td>68.26</td>
</tr>
<tr>
<td><strong>KNOWN WASTES</strong></td>
<td>7.01</td>
<td>12.54</td>
<td>15.19</td>
<td>126.12</td>
<td>2955.66</td>
<td>148657</td>
<td>354559</td>
<td>4851</td>
<td>685</td>
<td>89953</td>
<td>250.10</td>
</tr>
<tr>
<td><strong>TOTAL OUTPUT</strong></td>
<td>9.84</td>
<td>25.20</td>
<td>23.41</td>
<td>231.53</td>
<td>5339.35</td>
<td>366873</td>
<td>649926</td>
<td>9527</td>
<td>838</td>
<td>110152</td>
<td>330.14</td>
</tr>
<tr>
<td><strong>APPARENT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CONSUMPTION</strong></td>
<td>95.62</td>
<td>58.96</td>
<td>95.91</td>
<td>673.16</td>
<td>18527.82</td>
<td>781969</td>
<td>1809140</td>
<td>30826</td>
<td>1974</td>
<td>122486</td>
<td>839.26</td>
</tr>
</tbody>
</table>

Source: Tables I, II, III, IV and V
TABLE VII

NET LOCAL PRODUCTION, NET IMPORTS AND LOSSES* AS A PERCENTAGE OF

NET INPUT OF PARTICULAR NUTRIENTS AND ENERGY TO HONG KONG

<table>
<thead>
<tr>
<th>FOOD COMPONENT</th>
<th>NET LOCAL PRODUCTION</th>
<th>NET IMPORTS</th>
<th>LOSSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal PROTEIN</td>
<td>40.6</td>
<td>59.4</td>
<td>6.9</td>
</tr>
<tr>
<td>Plant</td>
<td>4.6</td>
<td>95.4</td>
<td>17.5</td>
</tr>
<tr>
<td>FAT</td>
<td>13</td>
<td>87.0</td>
<td>13.7</td>
</tr>
<tr>
<td>CHO'S</td>
<td>1.6</td>
<td>98.4</td>
<td>15.8</td>
</tr>
<tr>
<td>ENERGY</td>
<td>4.7</td>
<td>95.3</td>
<td>13.8</td>
</tr>
<tr>
<td>Ca</td>
<td>29.4</td>
<td>70.6</td>
<td>15.9</td>
</tr>
</tbody>
</table>

* LOSSES (see Table V) is calculated as a percentage of Net Inputs as the sum of Net Local Production and Net Imports (see Appendix 1)
### TABLE VIII: COMPARATIVE DATA ON ESTIMATED DAILY SUPPLY OF NUTRIENTS TO HONG KONG AND SYDNEY

#### a) Hong Kong 1971 (population, 3,939,153)

<table>
<thead>
<tr>
<th>Food Commodity</th>
<th>Energy $\times 10^6$ (MJ)</th>
<th>Protein $\times 10^4$ (Kg)</th>
<th>Fat $\times 10^4$ (Kg)</th>
<th>Carbohydrates $\times 10^4$ (Kg)</th>
<th>Calcium $\times 10^4$ (Kg)</th>
<th>Iron (Kg)</th>
<th>Phosphorous $\times 10^2$ (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk and milk products</td>
<td>0.92</td>
<td>1.03</td>
<td>0.92</td>
<td>2.76</td>
<td>3.09</td>
<td>0.42</td>
<td>0.99</td>
</tr>
<tr>
<td>Meats and offal</td>
<td>9.57</td>
<td>7.16</td>
<td>19.00</td>
<td>0.65</td>
<td>0.49</td>
<td>10.53</td>
<td>9.19</td>
</tr>
<tr>
<td>Poultry and fish</td>
<td>5.88</td>
<td>17.99</td>
<td>2.58</td>
<td>0.61</td>
<td>6.47</td>
<td>17.59</td>
<td>18.56</td>
</tr>
<tr>
<td>Eggs and egg products</td>
<td>1.16</td>
<td>2.15</td>
<td>2.00</td>
<td>0.14</td>
<td>0.95</td>
<td>4.07</td>
<td>3.85</td>
</tr>
<tr>
<td>Oils and fats</td>
<td>0.32</td>
<td>0.01</td>
<td>0.85</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Sugar and syrups</td>
<td>2.65</td>
<td>0.04</td>
<td>16.21</td>
<td>0.53</td>
<td>4.64</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Pulse and nuts</td>
<td>0.82</td>
<td>0.47</td>
<td>1.06</td>
<td>0.84</td>
<td>0.14</td>
<td>1.89</td>
<td>0.92</td>
</tr>
<tr>
<td>Vegetables</td>
<td>4.05</td>
<td>3.91</td>
<td>0.53</td>
<td>17.69</td>
<td>7.71</td>
<td>23.67</td>
<td>7.12</td>
</tr>
<tr>
<td>Fruit and fruit products</td>
<td>1.32</td>
<td>0.46</td>
<td>0.48</td>
<td>9.52</td>
<td>1.49</td>
<td>2.86</td>
<td>0.93</td>
</tr>
<tr>
<td>Grain products</td>
<td>31.43</td>
<td>14.17</td>
<td>2.06</td>
<td>168.88</td>
<td>4.09</td>
<td>30.05</td>
<td>16.16</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>58.12</strong></td>
<td><strong>47.39</strong></td>
<td><strong>29.48</strong></td>
<td><strong>217.31</strong></td>
<td><strong>24.40</strong></td>
<td><strong>95.73</strong></td>
<td><strong>57.82</strong></td>
</tr>
</tbody>
</table>

#### b) Sydney (standardised to Hong Kong's population to allow comparison), 1970.

<table>
<thead>
<tr>
<th>Food Commodity</th>
<th>Energy $\times 10^6$ (MJ)</th>
<th>Protein $\times 10^4$ (Kg)</th>
<th>Fat $\times 10^4$ (Kg)</th>
<th>Carbohydrates $\times 10^4$ (Kg)</th>
<th>Calcium $\times 10^4$ (Kg)</th>
<th>Iron (Kg)</th>
<th>Phosphorous $\times 10^2$ (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk products</td>
<td>6.50</td>
<td>8.74</td>
<td>8.22</td>
<td>10.95</td>
<td>30.21</td>
<td>2.36</td>
<td>8.55</td>
</tr>
<tr>
<td>Meats and offal</td>
<td>9.53</td>
<td>12.25</td>
<td>19.11</td>
<td>0.20</td>
<td>0.77</td>
<td>18.51</td>
<td>17.05</td>
</tr>
<tr>
<td>Poultry, fish and rabbits</td>
<td>0.91</td>
<td>2.99</td>
<td>0.90</td>
<td>-</td>
<td>0.42</td>
<td>2.75</td>
<td>4.97</td>
</tr>
<tr>
<td>Eggs and egg products</td>
<td>0.79</td>
<td>1.49</td>
<td>1.38</td>
<td>0.07</td>
<td>0.64</td>
<td>2.75</td>
<td>2.94</td>
</tr>
<tr>
<td>Oils and fats</td>
<td>5.52</td>
<td>0.07</td>
<td>14.80</td>
<td>0.12</td>
<td>0.26</td>
<td>-</td>
<td>0.16</td>
</tr>
<tr>
<td>Sugars</td>
<td>8.68</td>
<td>-</td>
<td>-</td>
<td>53.05</td>
<td>0.10</td>
<td>0.39</td>
<td>0.84</td>
</tr>
<tr>
<td>Pulse and nuts</td>
<td>1.21</td>
<td>0.99</td>
<td>2.16</td>
<td>1.57</td>
<td>0.33</td>
<td>3.15</td>
<td>1.59</td>
</tr>
<tr>
<td>Vegetables</td>
<td>2.67</td>
<td>2.12</td>
<td>0.16</td>
<td>14.69</td>
<td>2.20</td>
<td>8.26</td>
<td>8.22</td>
</tr>
<tr>
<td>Fruit and fruit products</td>
<td>1.40</td>
<td>0.39</td>
<td>0.04</td>
<td>8.95</td>
<td>1.17</td>
<td>2.75</td>
<td>1.96</td>
</tr>
<tr>
<td>Grain products</td>
<td>14.02</td>
<td>10.00</td>
<td>1.49</td>
<td>72.95</td>
<td>1.87</td>
<td>16.93</td>
<td>20.15</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>51.23</strong></td>
<td><strong>39.04</strong></td>
<td><strong>48.26</strong></td>
<td><strong>162.55</strong></td>
<td><strong>37.97</strong></td>
<td><strong>57.85</strong></td>
<td><strong>66.50</strong></td>
</tr>
</tbody>
</table>

**Note:** Beverages and miscellaneous categories have been excluded from the analysis for the appropriate figures are unavailable for Sydney. They comprise about 1% of the Hong Kong daily nutrient supply.

**Source:** Hong Kong data, Table VI; Sydney date derived from Australian Bureau of Statistics (1971)
**TABLE IX CRUDE CALCULATION OF FORAGE AREAS FOR SYDNEY AND HONG KONG**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>SYDNEY ha</th>
<th>ha/cap</th>
<th>HONG KONG ha</th>
<th>ha/cap</th>
<th>DIFFERENCE IN REQUIREMENTS ha</th>
<th>ha/cap</th>
<th>Footnote No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk and milk products</td>
<td>486,163</td>
<td>0.12</td>
<td>68,811</td>
<td>0.02</td>
<td>417,352</td>
<td>0.10</td>
<td>9.1</td>
</tr>
<tr>
<td>Meats and offal</td>
<td>2,406,565</td>
<td>0.61</td>
<td>943,003</td>
<td>0.24</td>
<td>1,463,562</td>
<td>0.37</td>
<td>9.2</td>
</tr>
<tr>
<td>Poultry</td>
<td>254,028</td>
<td>0.06</td>
<td>554,770</td>
<td>0.14</td>
<td>-300,742</td>
<td>-0.08</td>
<td>9.3</td>
</tr>
<tr>
<td>Eggs and egg products</td>
<td>199,495</td>
<td>0.05</td>
<td>293,300</td>
<td>0.07</td>
<td>-93,805</td>
<td>-0.02</td>
<td>9.4</td>
</tr>
<tr>
<td>Oils and fats</td>
<td>812,960</td>
<td>0.21</td>
<td>47,128</td>
<td>0.01</td>
<td>765,832</td>
<td>0.20</td>
<td>9.5</td>
</tr>
<tr>
<td>Sugar and syrups</td>
<td>17,642</td>
<td>0.004</td>
<td>5,386</td>
<td>0.001</td>
<td>12,256</td>
<td>0.003</td>
<td>9.6</td>
</tr>
<tr>
<td>Pulse and nuts</td>
<td>19,206</td>
<td>0.005</td>
<td>13,015</td>
<td>0.003</td>
<td>6,191</td>
<td>0.002</td>
<td>9.7</td>
</tr>
<tr>
<td>Vegetables</td>
<td>23,628</td>
<td>0.006</td>
<td>41,752</td>
<td>0.011</td>
<td>-18,124</td>
<td>-0.005</td>
<td>9.8</td>
</tr>
<tr>
<td>Fruit and fruit products</td>
<td>16,455</td>
<td>0.004</td>
<td>18,262</td>
<td>0.005</td>
<td>-1,807</td>
<td>-0.001</td>
<td>9.9</td>
</tr>
<tr>
<td>Grain products</td>
<td>213,005</td>
<td>0.05</td>
<td>290,212</td>
<td>0.07</td>
<td>-77,207</td>
<td>-0.02</td>
<td>9.10</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>4,449,147</td>
<td>1.12</td>
<td>2,273,639</td>
<td>0.57</td>
<td>2,175,508</td>
<td>0.55</td>
<td></td>
</tr>
</tbody>
</table>

*Fish products not included in forage area calculations, see text. Beverages and miscellaneous categories, together about 1% of total nutrients have also been excluded from calculations. Source: Table VIII*

**FOOTNOTES**

9.1 Using current forage area per capita for Australian milk and milk product production of 0.12 ha/caput (Aston, et al 1973) or in energy terms, 13.37 MJ/ha/day.

9.2 Hong Kong meat and offal consumption rounds off to 17% beef, 82% pork and 1% mutton, compared with 42% beef, 12% pork and 4% mutton for Sydney (Australian Bureau of Statistics, 1971, Census and Statistics, 1972). The arbitrary standard for the calculation of forage area is that all animals are fed grain. The yield of grain is taken as the equivalent of Australian wheat at 1330 kgm/ha or 56.5 MJ/ha/day. Given the different efficiencies of converting gross energy in feed for the respective meat animals (Morrison, 1945) the weighted average conversion efficiency for Sydney is 7% and for Hong Kong is 18%. Hence productivity is 10.17 MJ/ha/day for Hong Kong and 3.96 MJ/ha/day for Sydney.

9.3 Poultry products contribute 0.72 x 10^6 MJ/day in Sydney and 1.57 x 10^6 MJ/day in Hong Kong. Assuming they are fed grain as in 9.2 and given a 5% efficiency of conversion of gross energy (Morrison, 1945) their productivity is 2.83 MJ/ha/day.

9.4 As for 9.2 and 9.3 given a conversion efficiency of 7% and an energy production of 3.96 MJ/ha/day.

9.5 Oils and fats are very largely butter in both Sydney and Hong Kong so the production efficiencies of butter have been used to calculate forage area. About 21.30 lbs. of milk is required for 1 lb. of butter with a 49% loss of energy in the process. From 9.1 this infers a productivity of 6.79 MJ/ha/day.

9.6 Sugars and syrups is very largely refined sugar and has been taken as such. Data from the Commonwealth Sugar Refineries Ltd. Australia (P.E. Robinson, personal communication, 1975) on average yields of refined sugar per hectare in major producing countries, allowed an estimate of 49.2 MJ/ha/day.

9.7 Pulses and nuts are represented particularly by peanuts in both cities. An average Australian yield of peanuts (1.32 tonnes/ha in shell) has been adopted to estimate forage area (Australian Bureau of Statistics, 1974). This derives a productivity of 63 MJ/ha/day.

9.8 The relative consumption of all major vegetables was calculated for each city (Australian Bureau of Statistics, 1971, Census and Statistics, 1972). More detailed information was used for calculations but broadly categorised Hong Kong's consumption was roots and tubers 29%, leafy greens 60%, cucurbits 1% and tomatoes 1%. Australian average yields and Hong Kong average yields (Australian Bureau of Statistics, 1974, C.T. Wong, Agriculture and Fisheries, personal communication, 1975) given the proportion each vegetable made of the total, allowed the computation of productivity figures of 97 MJ/ha/day for Hong Kong and 113 MJ/ha/day for Sydney.

9.9 Fruit and fruit products data was handled as for vegetables (see 9.8). Information on yield of various fruit came from the Australian Bureau of Agricultural Economics (A. Holman, personal communication, 1975) and the Australian Bureau of Statistics (1974). Broad categorisation shows Hong Kong's consumption at about 49% citrus, apple, pear and bananas, 39% dried tree fruits and others 6%. Productivity figures derived from this data gave Hong Kong as 97.28 MJ/ha/day and Sydney as 85.08 MJ/ha/day.

9.10 Using the same approach as for 9.8 and 9.9, grain consumption patterns were calculated as Hong Kong, 26% maize and products, 25% wheat and like grains and products, and 49% rice and products and Sydney, wheat and products 90%, maize and others 7%, rice 3%. Yields adopted for calculation were wheat 1330 kgm/ha, maize 2400 kgm/ha and rice 3250 kgm/ha for China (Sprague 1975) and 6060 kgm/ha for Australia. Productivity calculated for Sydney grain supply was 65.82 MJ/ha/day and for Hong Kong 108.29 MJ/ha/day.
### APPENDIX 1

**CALCULATION OF RETAINED INPUTS OF PARTICULAR NUTRIENTS AND ENERGY TO HONG KONG**

(Per Capita Per Day)

<table>
<thead>
<tr>
<th>FOOD COMPONENT</th>
<th>RETAINED IMPORTS (ie. Imports minus Re-exports)</th>
<th>plus</th>
<th>RETAINED LOCAL PRODUCTION (ie. Local Production-Exports)</th>
<th>equals</th>
<th>RETAINED INPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROTEIN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal</td>
<td>42.3 gm</td>
<td>+</td>
<td>29.0 gm</td>
<td>=</td>
<td>71.3 gm</td>
</tr>
<tr>
<td>Plant</td>
<td>47.4 gm</td>
<td>+</td>
<td>2.3 gm</td>
<td>=</td>
<td>49.7 gm</td>
</tr>
<tr>
<td>FAT</td>
<td>67.3 gm</td>
<td>+</td>
<td>10.0 gm</td>
<td>=</td>
<td>77.3 gm</td>
</tr>
<tr>
<td>CHO'S</td>
<td>546.9 gm</td>
<td>+</td>
<td>9.0 gm</td>
<td>=</td>
<td>555.9 gm</td>
</tr>
<tr>
<td>ENERGY</td>
<td>14017.8 KJ</td>
<td>+</td>
<td>924.2 KJ</td>
<td>=</td>
<td>14942.0 KJ</td>
</tr>
<tr>
<td>Ca</td>
<td>456.5 mg</td>
<td>+</td>
<td>191.2 mg</td>
<td>=</td>
<td>647.7 mg</td>
</tr>
</tbody>
</table>
Figure 1: A schematic representation of nutrient flow in the Hong Kong food system.
PHOSPHOROUS FLOW IN THE HONG KONG FOOD SYSTEM, 1971.
(kg of P per day)

Figure 2: A schematic representation of the flow of mineral phosphorus in the Hong Kong food system in 1971.
CHAPTER VII

APPARENT CONSUMPTION AND SOCIO-ECONOMIC DISTRIBUTION OF NUTRIENTS IN HONG KONG
Introduction

Most nations in the developed world have the advantage of yearly statistics of the apparent consumption of nutrients when attempting to evaluate the nutritional status of their populations. Although these averaged input-output analyses of nutrient flow tell nutritionists little about the distribution of nutrients and the details of nutritional maladjustment, they do at least indicate whether essential nutrients are available to be distributed. Such data also facilitate the formation of policy on food production, for example, placing an emphasis on the production and or importation of particular foodstuffs rich in nutrients which are scarce in the food system.

Furthermore, developed nations can afford to invest substantial amounts of money in large in-depth surveys of nutrition, such as Nutritition Canada (DNHW, 1974) and the Health and Nutrition National Survey in the United States (DHEW, 1975).

National per capita consumption figures for nutrients in the less developed countries are rare. When available they frequently emphasise the obvious, that there is not enough food. Surveys of nutrition covering large samples of the population, matching clinical examinations with dietary intake studies, are mostly too expensive to undertake thereby leaving unexplored interesting trends or indications, seen in national overview statistics. Anthropologists and nutritionists working at the micro-level of the village community provide valuable
information gathered with patience and care over considerable time (e.g. Mazess and Baker, 1964). But such an approach is not a realistic option for administrators and policy makers in the Third World. They are responsible not only for small rural communities, but also for rapidly growing urban populations, including people far removed from even the tenuous security of a subsistence agricultural base.

With 38% of the world's population likely to be living in urban settlements by 2000 (United Nations, 1969), and with suggestions that urbanisation has had a serious impact on patterns of nutrition (Jelliffe, 1962, Horine, 1967, Masek, 1974, Jelliffe and Jelliffe, 1975) it is appropriate to examine patterns of nutrient consumption in a contemporary urban settlement in the developing world.

This study pieces together apparent consumption data for Hong Kong, a place which is simultaneously a nation state (Colony) and, by virtue of being largely metropolitan, an urban settlement. Therefore generalised apparent consumption statistics for the single urban settlement of Hong Kong are likely to be a better guide to the nutritional status of the population than if they related to the widely diverse environments usually encompassed by nation states. To test this assumption, and to provide new information, the nutrient input to a large sample of households in the Hong Kong population was surveyed and compared with national apparent consumption data. The socio-economic patterns of distribution of nutrients between these households has also been examined.
This research forms part of a large integrative study of the human ecology of a contemporary urban settlement*.

The Setting

Hong Kong is located on the South coast of China (lat. 22°S), extending into the South China Sea. Its population in March 1971 was 3.9 million people. Hong Kong's land area is 1,046 km². There are 253 islands, the larger ones being the populous Hong Kong Island and the rural Lantau and Lamma Islands. Urban areas with more than 88% of the Hong Kong population comprise 146 km² or 14% of the total land area of the Colony. Of the 1971 population, 94% were Southern Chinese, either native to Hong Kong or Kwantung province. A further 4% were from elsewhere in China, 1% from within Asia and 1% of mostly European origin.

Methodology

Apparent consumption statistics are not compiled by departments of the Hong Kong Government, thus it was necessary to construct them from raw data in trade and local production statistics. The first step was to construct an input-output balance of nutrient flow in Hong Kong. The calendar year 1971 was selected as the time period and data relating to imports, exports, re-exports and local production was gathered (Census and Statistics, 1971; Director, Agriculture and Fisheries, 1972).

*The Hong Kong Human Ecology Programme is co-ordinated by the Urban Biology Group at the Australian National University. Field work was based in the Centre of Asian Studies, University of Hong Kong and the Social Research Centre of the Chinese University of Hong Kong. The programme, supported by UNEP/UNESCO funds (MAB Project 11) also received funds from the Nuffield Foundation and co-operation from the Hong Kong Government. Further information can be obtained from the Director, S.V. Boyden.
Losses of nutrients in all parts of the Hong Kong food system were calculated where possible and will be presented in a study of nutrient flow in Hong Kong (Newcombe, in preparation). The stocks of food held in Hong Kong, including statutorily determined grain stocks, were minimal in relation to the total flow (F. Hsiung, Commerce and Industry Department and N.K. Lee, Agriculture and Fisheries Department, personal communication, 1974). The Hong Kong food system is quite dynamic and there is little long term storage. Even packaged goods outlets are few, for example, in 1971, only 25 supermarkets operated in Hong Kong. So, with a constant volume of stocks, a balance was drawn from the sum of local production and imports, minus the sum of exports, re-exports and known losses. Apparent consumption, in per capita per day terms, was arrived at by dividing the nutrient balance by population size.

The compilation of data involved the conversion of more than 230 kinds of foodstuffs into 10 component nutrients, including animal and plant protein, fats, carbohydrates, energy, calcium, phosphorus, iron, thiamine, ascorbic acid and food water. Initially foods were grouped into 12 categories, including milk and milk products, meats and offal, poultry and fish, eggs and egg products, beverages and miscellaneous (inseparable combinations of other categories, e.g. cooking additives and some sauces).

Food composition tables for the Hong Kong diet were drawn together from a wide range of existing tabulations (Anon. no date, McCance and Widdowson, 1960, Tung et al, 1961, Platt, 1962, Watt and Merrill, 1963, DABM, 1964, Thomas and Corden, 1970) or were estimated
in consultation with officers of the Commonwealth Department of Health, Australia (M. Corden and E. Hipsley, personal communication, 1974).

Data from the Hong Kong consumer price index (CPI) were transcribed to provide the nutrient intake to a sample of 1,400 households representing 80% of the Hong Kong population by income. Very low and very high income groups were excluded from the sample. Within these limitations the sample was drawn at random from household records collected during the 1971 Hong Kong census. The CPI is an ongoing analysis and, for the purposes of this study, data from all households (714) in the 1971 CPI and from one quarter (716) of the households selected at random within each monthly set for 1973, were utilised. Members of a household selected by the Department of Census and Statistics staff were paid to record their daily expenditure on food items as well as other consumer and service commodities, for the duration of one calendar month (always adjusted to 31 days). Officers of the Department scrutinised recording procedures, collected daily records throughout the period and tabulated them into a combined statement of expenditure for all items or groups of items at the end of the recording period. Socio-economic and demographic parameters were also recorded for each household, including housing type and tenure, gross floor area, income, occupations, age and sex for each member of the household. Unbeknown to the respondents the sum of their daily expenditure provided an additional parameter: total household expenditure.
Transcription of expenditure on food items to weight and composition of foodstuffs involved tabulation of the price per food item per month from the economic records of the Census and Statistics Department, all of which were cross-checked with prices paid per unit weight or volume often recorded on the daily record sheets by the householder. The level of detail describing purchased staple commodities, often dividing them into several categories, such as pork chop, rib pork, pork offal, frozen pork, roast pork and so on, meant that food composition formulae for each major food item could be accurately determined. The nutrient components of combined categories such as vegetables in tins, or dried fruits, were estimated using records of the type and frequency of purchases of foods within each category for the appropriate month, as supplied by the Department of Census and Statistics (A. Yau, personal communication, 1974). All such data were then manipulated to effect the conversion to nutrient intake per household, per capita consumption and per 'adult equivalent' consumption.

'Adult equivalents' in this study are male adult equivalents, taking an 18-35 year old male performing light work as a standard. Age distribution data from the 1971 Census (Census and Statistics, 1972) and proportionate dietary allowances of different age and sex groupings (Thomas and Corden, 1970) were used to calculate the total number of adult equivalents in the Hong Kong population in 1971. In carrying out this exercise it was assumed that the dietary requirements of other groups, by age and sex, as a proportion
of young adult male requirements, is the same for Chinese as for European populations. Socio-economic patterns of consumption were also derived from computerised sorting and statistical tests of relationships following the input of appropriate socio-economic parameters relating to each household.

**Apparent Consumption**

An input-output balance which yields data on apparent consumption of nutrients is illustrated by Figure 1. Two important and unanticipated features of the Hong Kong food system are the significance of local production and 'known losses' as a proportion of the sources of nutrients which contribute to the Hong Kong diet. While these two features are considered in more detail in a study dealing specifically with nutrient flow in Hong Kong (Newcombe, in preparation) it is important to note that considerable amounts of such essential constituents of the diet, as ascorbic acid and calcium are produced and, in large measure, lost in Hong Kong. The large proportion of total protein available from local sources reflects the capacity of an urban settlement, employing intensive agriculture, to contribute significantly to its nutrient supply from within the urban area and its periphery. However, 67% of the animal protein included under 'local production is derived from the marine fishing industry which has the South China Sea as catchment area.

The category of nutrient losses is referred to as 'known losses', for it is obviously impossible to detect all
losses of nutrients in an urban settlement. This category is the result of considerable research into losses of nutrients at major points in the food distribution system such as in abattoirs, domestic refuse, restaurants, and during marketing. Losses of nutrients during food preparation are considered later (see Figure 2). Because data on nutrient losses are necessarily incomplete, apparent consumption is, to that extent, slightly overestimated. However this overestimate is balanced, in part, by the unaccountable contribution to the diet made by foods gathered locally which are not recorded as 'local production', e.g. estuarine molluscs, fish poached from public reservoirs and so on.

Given that the losses category is inevitably an underestimate, the fact that it represents up to 18% of total input for some nutrients (from Figure 1) registers unfavourably against previously acceptable 'guesstimates' of about 15% for food wasted in contemporary food systems (Pres.Sci.Adv.Comm.,1967) The apparent consumption data provided in Figure 1 takes on more meaning when compared with similar data from other populations, and with estimates of an adequate supply of nutrients.

Comparative data

Table 1 compares Hong Kong with other populations in the Far East region, with respect to apparent consumption per capita per day of energy, total protein and animal protein. It is immediately clear that in terms of these food components Hong Kong is well supplied relative to the countries being compared. Hong Kong's total protein supply per capita is almost twice that of Pakistan, the Phillipines and India,
and is significantly higher than the other populations considered. The supply of animal protein to Hong Kong is 4 to 6 times greater than that of the Korean republic and India respectively. Moreover, it is almost double that of the increasingly affluent populations of Taiwan and Japan.

Table 2 shows that the per capita apparent consumption of protein, carbohydrates, energy, iron, ascorbic acid and thiamine is similar to populations in developed countries. However, the table also shows striking differences in the supply of fats and calcium. The apparent consumption of both these nutrients in Hong Kong is about half that observed in Australia, the United Kingdom or America. Nevertheless, consumption of fats in Hong Kong appear to be adequate, even for large-bodied Western populations. However, comparisons of apparent consumption data across countries, while interesting, tells us nothing of the adequacy of the supply of particular nutrients in the population under consideration.

Dietary adequacy of available nutrients

Using the age-structure data on the Hong Kong population (Census and Statistics, 1972) and the recommended intake for various age groups compiled by Passmore et al (1974), a theoretical recommended per capita per day nutrient intake was constructed for the 1971 Hong Kong population. The increased nutrient requirements of pregnant and lactating women were allowed for in this calculation. Figure 2 is a comparison of this theoretical construct and the apparent consumption data for Hong Kong. It reveals the adequacy, or otherwise of the supply of protein, energy, thiamine,
ascorbic acid, calcium and iron as a percentage of recommended intakes for the 1971 Hong Kong population. Allowances are made in the case of ascorbic acid and thiamine for losses incurred in cooking.

By these standards all nutrients except calcium are available in more than adequate amounts. Thiamine, iron and energy are available at levels which suggest that slight inequities in their distribution in the population could make their consumption marginal in terms of dietary requirements. However, the supply of nutrients bears no more than a statistical relationship to the adequacy of distribution amongst individuals. The distribution, rather than the apparent consumption of nutrients, is considered in more detail in the discussion of socio-economic variables in nutrition in Hong Kong.

From Figure 2 the supply of calcium is seen to be either adequate or inadequate depending on what end of the range of recommended intake is adopted. In either case, the availability of calcium appears marginal, particularly when it is considered that we are dealing with broad averages. Thus a more detailed discussion about the importance of the low calcium content of Hong Kong diets is warranted.

Calcium

Nutritionists still debate about the level of calcium consumption which should be recommended for a balanced diet. Recommended daily allowances vary from 450-550 mg per day by Passmore et al (1974) through to 800 mg per day by United States authorities (FNB, 1974) for an adult male. Following
a special report of FAO/WHO (1962), most countries in establishing dietary standards reduced their estimates of the recommended daily allowances for calcium. It had been shown much earlier than the release of this report that the higher recommended daily allowances of calcium did not appear to be warranted. Some populations had been shown to survive remarkably well on very small calcium intakes without the appearance of disease which could be related to calcium deficiency (Nichols and Nimalasuriya, 1939) and that, particularly in regard to adult males, such low levels of calcium intake could be tolerated as to make a discussion of calcium deficiency almost meaningless (Hegsted et al, 1952). In the words of Clements (1975), 'calcium has been described as a nutrient in search of a disease'. With so little evidence that calcium deficiency leads to identifiable diseases, FAO authorities commented recently that 'man can adapt himself successfully to much lower intakes of calcium than are sometimes believed necessary for health' (KON, 1972).

Nevertheless, while diseases arising solely from calcium deficiency have been hard to define, there is increasing evidence that supplements of calcium in the diet of elderly people are successful in the treatment of osteoporosis, and are also beneficial in the treatment of cardiovascular disease (Albanese et al, 1973). This latter finding is supported by epidemiological evidence that the incidence of cardiovascular disease is lower where the calcium content of drinking water is high (Schroeder, 1960, Morris et al, 1973 and Biorck et al, 1965). However, the calcium intake from drinking water is very small in comparison to the intake from food so the relationship between cardiovascular disease and the calcium content of drinking water
may be coincidental.

Severe calcium deficiency, in terms of the prevailing recommended allowances, has long been associated with the tropical regions of Asia. In addition, losses of calcium from the metabolism are thought to be higher in hot climates (Newman, 1953). Southern Chinese populations live in a hot climate and consume a calcium deficient diet. Maynard and Swen (1937), who directed an intensive survey of rural nutrition in China from 1929 to 1933, claimed that 'the outstanding finding from the analysis of the food composition data is the widespread and severe deficiency of calcium'. Judging from the historical perspective of rural nutrition in China provided by Whyte (1972), the circumstances which provided for the existence of a marked calcium deficiency as described by Maynard and Swen are likely to have prevailed for hundreds, perhaps thousands of years. Given this likelihood, both biological and cultural adaptation to low calcium intakes are a distinct possibility. Newman (1960) emphasises that biological adaptation to supposedly inadequate diets seems to have occurred repeatedly. He cites such obvious morphological adaptations as slow growth, late maturation and relatively small body size of adults. Anthropometric data gathered by Stevenson (1925) shows that southern Chinese in particular exhibit these same morphological features. Stevenson indicates that these people are significantly smaller than central Chinese populations, which are, in turn, significantly smaller than northern Chinese populations. Interestingly, this gradation closely follows one of increasing calcium content in the diet, as indicated by a map of calcium consumption by regions of China drawn up by Maynard and Swen (1937, p. 422) from the 1929-33 survey.
Kwantung province populations had the lowest average calcium consumption (329 mg/caput/day) of any in China at that time. 94% of the Hong Kong population are directly or indirectly from Kwantung province and Hong Kong Chinese have been shown, through recent extensive study, to exhibit small body size, slow growth rate, and late maturation (Lee et al, 1968; Field and Baber, 1973). Since it has not been possible to detect disease related to calcium deficiency, and as physiological mechanisms are known which cope with low calcium intake (see Clements, 1975), the possibility cannot be ignored that small body size and slow growth rates in the southern Chinese are successful biological adaptations to, among other things, low calcium availability.

Nevertheless, there remain two disconcerting aspects of low calcium intake evidenced in the contemporary Hong Kong diet. First, it is generally recognised (Passmore et al, 1974) that for women, calcium requirements are definitely higher during certain stages of pregnancy and during lactation. With such low average calcium content it is possible that during these sensitive periods sufficient calcium may not be available from dietary sources. However, there appears to have been a cultural development which may well have evolved to cope with the low calcium diet likely to have prevailed for perhaps hundreds of years. Pariser and Brown (1975) report that the Chinese often feed calcium-rich powdered deer antler to pregnant and nursing women. In 1971 retained imports of deer antlers to Hong Kong were about 90,000 kg. From our observation of the very numerous traditional Chinese medical stores in Hong Kong, deer antlers were commonly offered for sale. Assuming antlers are 40% calcium, 90,000 kg of
antlers contain more than enough calcium, if evenly distributed, to alleviate any calcium deficiency in the diet of pregnant or nursing mothers. However, an equitable distribution of calcium in the form of antler is very unlikely because of the expense involved. According to a cultural anthropologist in Hong Kong, Marjorie Topley, a single dose, recommended to be about 30 gms, cost US$17.00. Dr. Topley has also informed us that women believe that antlers have 'vitamins' and now find it easier to take their vitamins in pill form (personal communication, 1975).

The second cause for concern arises from the relationship between protein intake and calcium excretion by metabolic processes. It has been reported that high protein intake over a prolonged period can result in substantial losses of calcium from the metabolism (Johnson et al, 1970). Clements (1975) notes that 'most communities with a low calcium intake, and apparently satisfactory metabolism, also have a low protein intake'. This was true of China, and particularly of Kwantung province, in the 1930's when protein intake, though adequate, was 40% less than in Hong Kong in 1971 (Maynard and Swen, 1937). The high protein content of the Hong Kong diet is a result of a large increase in the consumption of animal products. The data Maynard and Swen gathered for China in 1929-33 showed that protein from animal products made up, on average, only 3% of all protein sources in the diet. Table 3 indicates that of the apparent consumption of protein in Hong Kong, 64% comes from animal products. A re-examination of Tables 1 and 2 in this context suggests that Hong Kong may be unique as one of the few populations in the world with high protein and low calcium
intakes, a situation which, if persisting, may lead to the development of senile osteoporosis (Clements, 1975).

**Apparent consumption compared with household intake**

As mentioned previously, one aim of this study is to examine the value of apparent consumption data calculated for an urban settlement as an indication of nutritional maladjustment in the urban population. The degree of corroboration between settlement-wide data and data extracted from an analysis of nutrient intake at the household level for middle and low socio-economic groups is shown in Table 4. Here the average male adult equivalent intake for the whole Hong Kong population is compared with that for the 714 sampled households in 1971, and the 716 sampled households in 1973. As the apparent consumption data include the nutrient consumption of upper socio-economic groups, tourists and so on, it might be expected to show generally higher levels of consumption for most food constituents. This has proven true for protein, carbohydrates, phosphorous, iron and energy intake, and there is little difference in the level of calcium and thiamine intake. However, the apparent consumption of fat and ascorbic acid is markedly less than is the case with the sampled households. Close examination of the data provides at least a
partial explanation of these anomalies. The diet of Chinese in the lower socio-economic groups consists, in large part, of rice, pork and leafy green vegetables. Beef, which is much more expensive than pork in Hong Kong, is consumed less by lower and middle socio-economic groups. Pork contains much more fat than the other meats available locally, and, moreover, the cheaper cuts of pork have the highest fat content. The emphasis in the diet of lower socio-economic groups on leafy greens, such as Chinese kale and cabbages accounts for the high ascorbic acid intake.

As an indicator of nutritional trouble spots in the diet, apparent consumption data, even at the level of an urban settlement must be regarded with caution. Nevertheless, the low calcium intake recorded by the apparent consumption calculations is confirmed by the average calcium intake of middle and lower socio-economic households. Also given the almost inevitable inequity in nutrient distribution amongst the population, the levels of protein, carbohydrate and energy consumption in the sampled households could reasonably be anticipated from apparent consumption statistics.

Quite apart from any sampling errors, unrecorded food consumption and so on, the adult equivalent values for nutrient intake in the sampled households are biased to overestimate nutritional well-being because of a cultural phenomenon: feasting at the time of Chinese New Year. Although the
nutrient intake figures recorded represent an estimate, in adult equivalent per day units, of all nutrients reaching the household, in fact, there is a vast increase in nutrient intake over a short period each year which does not augment deficiencies in the diet throughout the remainder of the year.

Table 5 shows that in the month in which Chinese New Year fell, January in 1971 and February in 1973, nutrient intake was sometimes doubled, and was always, at least, two standard deviations above the monthly mean intake. In effect, then, average nutrient intake is overestimated by up to one twelfth, or 8%.

Even though with some nutrients the average intake for the sampled households is lower than the apparent consumption figures, they provide no indication of malnutrition. However they are average figures and the actual distribution of nutrients in the population is best approximated by sorting nutrient intake by a number of socio-economic variables.

**Socio-economic variation in nutrient intake**

Six parameters have been used to identify the socio-economic variation in nutrient intake. They are family income (1973 only), family expenditure, housing type, effective floor area per capita, and direct and indirect energy use per capita. Effective floor
area per capita is defined here as 70% of total floor space. It is an index we have used in much of the population ecology section of the Hong Kong Human Ecology Programme, and it is essentially the floor area of the dwelling minus toilets, bathrooms, kitchens and other such service areas. Direct energy use is a measure of the extrasomatic energy use at the point of end-use in the home, in transportation, and so on. Indirect energy is a measure of the total energy required for the particular domestic or transport end-uses. For example, it includes the energy lost in generating electricity as well as the electricity actually used in say, water heating or cooking. Indirect energy use is likely to be a better measure of socio-economic status than direct energy use because the more sophisticated fuels generally cost more energy to produce and are more expensive to buy. In Hong Kong for example electricity costs upto four times more money per joule than kerosene. All energy values are derived from recent research on energy flow in the Hong Kong ecosystem (Newcombe, 1975a and b).

It was possible to split each variable examined into 8 or 9 classes enabling a reasonable separation of groups with differing nutrient intake characteristics. Nutrient intake was sorted into the given classes within each variable to illustrate the socio-economic variation in nutrient intake. Three important nutrients are
presented in these terms; animal protein, somatic energy and calcium. Calcium is selected out for attention because it appears to be in short supply in the Hong Kong diet.

With each variable the null hypothesis that there is no significant difference in nutrient intake amongst the sampled households, is tested. The major test is the 'analysis of variance' which also yields correlation factors. Regression formulas, showing the relationship between the independent and dependent variables, are also provided.

Tables 6 to 11 present the nutrient intake, sorted by the classes assigned to each variable, and the results of the analysis of variance and regression analysis calculations, for family expenditure, family income, effective floor area per capita, direct energy use, indirect energy use and housing type, respectively.

With the exception of housing type, there are highly significant differences in nutrient intake amongst the households as measured by each variable. In other words there is a high degree of socio-economically determined variation in nutrient intake. Invariably, the lower the socio-economic grouping by any of the more economic indices, the lower the nutrient intake.

While the differences in nutrient intake between the occupants of the major types of housing in Hong Kong is significant, it is not as good an indicator of socio-
economic variation as the other variables considered. Our experience, through other research in the Hong Kong Programme has shown us that there is great variation in housing conditions and income groups within the major categories of housing, and within tenement and apartment blocks in particular.

Generally speaking the variation in nutrient intake is greater for the 1971 sample than for the 1973 sample. This may be related to the fact that 1971 was the first year the Consumer Price Index was conducted in this way so that both the level of co-operation by householders and the amount and refinement of information collected was less than in 1973.

Of the solely economic variables considered, family expenditure is likely to be the most reliable because, firstly, the householder did not have access to the total monthly expenditure figure, arrived at by summing the daily expenditure sheets, filled in daily and collected at least weekly and secondly because family income in Hong Kong, as elsewhere, is frequently deliberately understated.

Even excluding 1971 data, the data on family expenditure (see Table 6) indicates that at least 56% (i.e. 70% of the 80% sample) of the population have an intake of energy and up to 12% have an intake of calcium less than recommended levels (Passmore et al., 1974). As anticipated, protein deficiency is unlikely to be widespread in the Hong Kong population, for even the
animal protein is, in most cases, at the recommended level for total protein intake.

**General discussion**

Apparent consumption data for the Hong Kong population shows, with the exception of fats and calcium, about the same level of intake of major nutrients as developed western nations. The intake of animal protein is particularly high, at 64% of total protein, compared with 69% of total protein in the United States (Pimental et al, 1975). A high level of animal protein consumption is characteristic of the whole population, including lower socio-economic groups. The exceptions of fats and calcium are of considerable interest. The low level of fats in the Hong Kong diet compared with western countries, even though there is a tendency for middle and lower socio-economic groups to consume above the average level of fat intake for Hong Kong as a whole is perhaps an advantage, as there is a strong statistical association between level of fat intake and coronary heart disease (Australian Academy of Science, 1975). On the other hand, the level of calcium in the diet is marginal even in terms of the considerably lower recommended intake of Passmore et al (1974). The results of this study largely confirm the results of a previous study by Crooke (1965) of nutrient intake in a sample of 240 individuals in the Hong Kong population; 205
children, mostly 13-15, and 35 adults. Crooke weighed daily food intake on two separate occasions. She reported average per capita per day intakes of 260 gm for calcium, 59 gm for protein and 59 gms for fat. With the exception of iron intake, which was only 7.5 mg per capita per day, the intake of other nutrients was similar to those reported here. By the recently revised FAO recommended allowances the calcium intake of these individuals was, at the most, 60% of recommended allowance, while protein was almost double the daily requirement.

It can be seen that low calcium intake has long been a characteristic of the Southern Chinese diet, and so it seems, of the Hong Kong diet. However, with the possible exception of senile osteoporosis and, in lower socio-economic groups, deficiencies in pregnant and lactating women, low calcium intake is unlikely to cause nutritional maladjustment. The possibility of long term genetic adaptation to low calcium intake, involving perhaps more efficient metabolic use of available calcium, cannot be ignored. However, non-genetic biological adaptation, such as slower growth rate, later maturation and smaller body size, is very likely. This latter kind of biological adaptation is also likely to be a response to low somatic energy intake which, from the socio-economic section of this study, appears to be quite prevalent in the Hong Kong population.
A wide socio-economic variation in nutrient intake is common amongst most populations of the civilised world, so the variation in nutrient intake amongst the Hong Kong population is not exceptional (see FAO, 1971). Nevertheless, the socio-economic data suggests that, against a standard of 10,300 KJ per adult male equivalent per day, 56% of the Hong Kong population has a less than adequate intake of somatic energy, in which case widespread nutritional maladjustment might be anticipated. However, this somatic energy standard is for a reference 65 kg. male, and although the research is dated, Stevenson (1925) found the average weight of the Southern Chinese male to be 51 kg. Mahadeva et al (1953) have shown that metabolic activity is proportional to weight, so the more appropriate standard is 8870 KJ per adult male per day. This standard suggests that 24% of the Hong Kong population has an inadequate intake of somatic energy. Even this standard has an inherent margin of safety, and we find it questionable that any more than 1-2% of the Hong Kong population are really deficient in energy intake (see Table 6), for the evidence of biological adaptation to low levels of energy intake is considerable. Apart from the fact that there is no clinical evidence of widespread malnutrition in Hong Kong (G. Kneebone, Paediatrics Department, University of Hong Kong, personal communication, 1975), extensive study of skeletal
maturation in Hong Kong children encompassing all socio-economic groups, has shown that the lower socio-economic groups grow more slowly, but over a longer period, compared with the middle, and likewise the middle compared with the higher socio-economic groups, however all eventually overtake acceptable standards of skeletal development (Low, et al, 1964). In fact, by the age of 18 there was no significant difference between the height and weight of Chinese from all socio-economic groups (Chang, et al, 1963).

We are, therefore, more inclined to conclude that there is successful biological and even cultural, adaptation to low levels of energy and calcium intake by the Hong Kong Chinese than to support the alternative conclusion - that there is widespread malnourishment. As Durnin et al (1973) have noted, there have been studies in a number of countries which have shown people to be active and healthy on levels of energy intake well below currently recommended standards, and there is considerable doubt about recommended levels of intake of other food components.

The problem of interpreting nutritional data such as those presented here is that, if it is assumed that they signal widespread malnutrition, then proposed corrective measures can, instead, cause serious maladjustment. For example, in many parts of the world, parents in lower socio-economic groups have been encouraged to feed powdered milk to their children to boost protein,
energy and calcium intake. This has frequently given rise to disease and malnutrition, because parents are unable to administer correct doses, because the essential immunity and nutrient balance provided by human milk is lost, and because an additional avenue for disease transmission is opened up (Jelliffe and Jelliffe, 1975). Also multinational corporations which sell milk products are said to have been responsible for miseducation of parents about the value of powdered milk and bottle feeding (Muller, 1975).

Powdered milk is now a common baby food in Hong Kong and nutritional problems associated with its use have already been detected, such as feeding children very dilute mixtures through misunderstanding directions provided on the various containers (G. Kneebone, personal communication, 1975).

Although we have taken every precaution to ensure that the data presented here reflects, as closely as possible, the actual nutrient intake of the sampled households, no amount of data manipulation would provide a measure of maladjustment caused by the treatment of foodstuffs in modern urban-centred food systems. For example, we have no measure of the impact of chemical preservatives added to food (Anon, 1975), or of dietary aflatoxins from toxigenic moulds in stored grains (Shank et al, 1972) on individual health and well-being. Yet these kinds of problems are growing in proportion to the growth of urban settlements, for with expanding urban populations, food must be carried over longer distances,
remaining stored, preserved, packaged or frozen for longer periods. Similarly, using currently available food composition tables, we cannot readily distinguish between the nature and quality of the carbohydrates and fats entering the diet. In Hong Kong it is abundantly clear from import-export data that the consumption of confectionery, refined sugar and refined carbohydrates has increased markedly in recent years (Census and Statistics, 1971, 1973), but the impact, if any, of these changes in diet on health, is unknown.

Finally, both apparent consumption statistics, and data transcribed from consumer price index analyses, have some value for nutritionists and food policy makers, particularly if care is taken to examine the socio-economic variation in nutrient intake. However, in Hong Kong, data derived from these sources provides evidence that could be used to support two essentially opposite positions. According to the first there is serious malnutrition in Hong Kong, and according to the second the diet is largely adequate, for as we have argued, it is likely that there is successful biological and cultural adaptation to the reported low levels of energy and calcium intake.

It is clear, however, that more detailed research needs to be carried out before firm conclusions can be drawn, and that the current methodological approach to studies of nutrition in urban populations, including that used in this study, does not deal effectively with many important problems generated by contemporary food systems.
REFERENCES

Albanese, A.A., Edelson, A.H., Woodhull, M.L.,
Effect of a calcium supplement on serum cholesterol,
calcium, phosphorous and bone density of 'normal',
8: 119-130.

Jr. 22nd Feb: 416-417.

Anon, no date. Chinese food and nutrition for university
students. Held by the Census and Statistics
Department, Consumer Price Index Division, Hong Kong.

Australian Academy of Science, 1975. Report of a
working group on coronary heart disease and diet.
Australian Academy of Science, Canberra. 72 pp.

relationships between water hardness and death rate

Brown, N.L. and Pariser, G.R., 1975. Food science in
developing countries. Science 188: 589-593.

Census and Statistics, 1971. Hong Kong Trade Statistics,
December 1971. Census and Statistics Department,
Government Press, Hong Kong.

Census and Statistics, 1972. Hong Kong Trade Statistics,
December, 1972. Census and Statistics Department,
Government Press, Hong Kong.


Food and Agriculture Organisation (FAO), 1971. The state of food and agriculture. FAO, Rome.


Newcombe, K., 1975b. Energy use in Hong Kong, Part II, sector end-use analysis. Urban Ecology 1:


TABLE I

Comparison of Apparent Consumption, per caput per day, of Somatic Energy and Protein Consumption within the Far East Region, including Hong Kong

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Somatic Energy KJ</th>
<th>Total Protein gms</th>
<th>Animal Protein gms</th>
</tr>
</thead>
<tbody>
<tr>
<td>China¹ (Taiwan)</td>
<td>1969</td>
<td>10,969</td>
<td>68.2</td>
<td>20.9</td>
</tr>
<tr>
<td>India¹</td>
<td>1969</td>
<td>8,122</td>
<td>47.9</td>
<td>5.6</td>
</tr>
<tr>
<td>Japan¹</td>
<td>1969</td>
<td>10,257</td>
<td>75.1</td>
<td>29.7</td>
</tr>
<tr>
<td>Pakistan¹</td>
<td>1969</td>
<td>9,839</td>
<td>53.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Phillipines¹</td>
<td>1969</td>
<td>8,334</td>
<td>51.6</td>
<td>20.0</td>
</tr>
<tr>
<td>Korea, Republic of</td>
<td>1969</td>
<td>10,509</td>
<td>69.0</td>
<td>8.3</td>
</tr>
<tr>
<td>Hong Kong²</td>
<td>1971</td>
<td>12,887</td>
<td>107.4</td>
<td>41.0</td>
</tr>
</tbody>
</table>

Sources: 1. F.A.O. (1971)
2. This study
<table>
<thead>
<tr>
<th>Energy</th>
<th>KJ</th>
<th>12,887</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 2**

COMPARATIVE APPARENT CONSUMPTION DATA FOR 1971

<table>
<thead>
<tr>
<th>PROTEIN (per capita per day)</th>
<th>gm</th>
<th>107.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>FATS</td>
<td>gm</td>
<td>66.7</td>
</tr>
<tr>
<td>CHO</td>
<td>gm</td>
<td>543.9</td>
</tr>
<tr>
<td>CALCIUM</td>
<td>mg</td>
<td>21.5</td>
</tr>
<tr>
<td>P</td>
<td>mg</td>
<td>1,008</td>
</tr>
<tr>
<td>ASCORBIC ACID</td>
<td>mg</td>
<td>98</td>
</tr>
<tr>
<td>THIAMINE</td>
<td>mg</td>
<td>85.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HONG KONG</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY</td>
<td>KJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AUSTRALIA*</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY</td>
<td>KJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NEW ZEALAND*</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY</td>
<td>KJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AMERICA*</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY</td>
<td>KJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>X.K.*</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY</td>
<td>KJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food items</th>
<th>Animal Protein</th>
<th>Plant Protein</th>
<th>Fat</th>
<th>CHO's</th>
<th>Energy</th>
<th>Ca.</th>
<th>P</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Milk and milk</td>
<td>(2.75)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>products</td>
<td>4.10</td>
<td>4.16</td>
<td>1.90</td>
<td>2.18</td>
<td>14.99</td>
<td>2.19</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>2. Meat and offal</td>
<td>(13.04)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19.42</td>
<td>52.26</td>
<td>0.45</td>
<td>16.51</td>
<td>1.87</td>
<td>12.47</td>
<td>7.94</td>
<td></td>
</tr>
<tr>
<td>3. Poultry and fish</td>
<td>(45.59)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>67.91</td>
<td>11.44</td>
<td>0.42</td>
<td>13.60</td>
<td>30.75</td>
<td>39.76</td>
<td>22.70</td>
<td></td>
</tr>
<tr>
<td>4. Eggs and egg</td>
<td>(5.72)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>products</td>
<td>8.52</td>
<td>9.00</td>
<td>0.10</td>
<td>2.71</td>
<td>4.62</td>
<td>8.50</td>
<td>5.41</td>
<td></td>
</tr>
<tr>
<td>5. Oils and fats</td>
<td>(0.03)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>3.84</td>
<td>0.01</td>
<td>0.75</td>
<td>0.08</td>
<td>0.04</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>6. Sugar and syrups</td>
<td>(0.11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.33</td>
<td>-</td>
<td>11.21</td>
<td>6.25</td>
<td>2.59</td>
<td>0.20</td>
<td>6.18</td>
<td></td>
</tr>
<tr>
<td>7. Pulse and nuts</td>
<td>(1.27)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.86</td>
<td>4.43</td>
<td>0.56</td>
<td>1.87</td>
<td>0.72</td>
<td>1.99</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>8. Vegetables</td>
<td>(4.53)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.79</td>
<td>1.45</td>
<td>6.75</td>
<td>5.67</td>
<td>21.98</td>
<td>8.29</td>
<td>16.79</td>
<td></td>
</tr>
<tr>
<td>9. Fruit and fruit</td>
<td>(0.86)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>products</td>
<td>2.63</td>
<td>1.90</td>
<td>4.09</td>
<td>1.77</td>
<td>4.83</td>
<td>1.40</td>
<td>2.52</td>
<td></td>
</tr>
<tr>
<td>(24.64)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Grain products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>74.96</td>
<td>7.19</td>
<td>73.41</td>
<td>46.89</td>
<td>15.23</td>
<td>21.97</td>
<td>32.70</td>
<td></td>
</tr>
<tr>
<td>11. Beverages</td>
<td>(0.92)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.79</td>
<td>0.50</td>
<td>0.78</td>
<td>1.31</td>
<td>0.77</td>
<td>2.68</td>
<td>3.85</td>
<td></td>
</tr>
<tr>
<td>12. Miscellaneous</td>
<td>(0.54)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.64</td>
<td>3.84</td>
<td>0.33</td>
<td>0.50</td>
<td>1.55</td>
<td>0.52</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PROTEIN</td>
<td>FAT</td>
<td>CHO's</td>
<td>KJ's</td>
<td>CALCIUM</td>
<td>P</td>
<td>IRON</td>
<td>THIAMINE</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------</td>
<td>------</td>
<td>-------</td>
<td>--------</td>
<td>---------</td>
<td>------</td>
<td>------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>ANIMAL (gm.)</td>
<td>PLANT (gm.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HONG KONG</td>
<td>83.21</td>
<td>45.95</td>
<td>78.40</td>
<td>533.44</td>
<td>14,999</td>
<td>667.9</td>
<td>1470</td>
<td>25.9</td>
</tr>
<tr>
<td>SAMPLED HOUSEHOLDS</td>
<td>54.3</td>
<td>43.5</td>
<td>101.67</td>
<td>399.0</td>
<td>11,208.84</td>
<td>651.85</td>
<td>1377.5</td>
<td>18.2</td>
</tr>
<tr>
<td>1971</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAMPLED HOUSEHOLDS</td>
<td>50.37</td>
<td>41.69</td>
<td>96.71</td>
<td>371.78</td>
<td>10,319.54</td>
<td>693.10</td>
<td>1357.9</td>
<td>16.57</td>
</tr>
<tr>
<td>1973</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Analysis of Data from 1430 households in the 1971 and 1973 Consumer Price Index, Census and Statistics Department, Hong Kong.*
TABLE 5: NUTRIENT INTAKE IN THE MONTH IN WHICH CHINESE NEW YEAR FELL COMPARED WITH AVERAGE MONTHLY INTAKE, PER HOUSEHOLD

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>February 1971</td>
<td>2546</td>
<td>2904</td>
<td>5646</td>
<td>26257</td>
<td>695752</td>
<td>40874</td>
<td>82125</td>
<td>1048</td>
<td>107403</td>
<td>15022</td>
<td>36549</td>
</tr>
<tr>
<td>Mean monthly intake/ A.E.*</td>
<td>1684</td>
<td>1347</td>
<td>3152</td>
<td>12369</td>
<td>347381</td>
<td>20207</td>
<td>42701</td>
<td>564</td>
<td>54734</td>
<td>7291</td>
<td>19373</td>
</tr>
<tr>
<td>S.D.**</td>
<td>512</td>
<td>506</td>
<td>852</td>
<td>4490</td>
<td>11520</td>
<td>7345</td>
<td>13764</td>
<td>179</td>
<td>17726</td>
<td>2877</td>
<td>6060</td>
</tr>
<tr>
<td>January 1973</td>
<td>1639</td>
<td>1575</td>
<td>3507</td>
<td>13007</td>
<td>365075</td>
<td>25170</td>
<td>48262</td>
<td>596</td>
<td>64670</td>
<td>8717</td>
<td>21400</td>
</tr>
<tr>
<td>Mean monthly intake/ A.E.</td>
<td>1561</td>
<td>1292</td>
<td>2998</td>
<td>11525</td>
<td>319906</td>
<td>21486</td>
<td>42095</td>
<td>514</td>
<td>53821</td>
<td>7054</td>
<td>19487</td>
</tr>
<tr>
<td>S.D.</td>
<td>65</td>
<td>110</td>
<td>199</td>
<td>697</td>
<td>1998</td>
<td>1778</td>
<td>2445</td>
<td>38</td>
<td>4305</td>
<td>1073</td>
<td>1291</td>
</tr>
</tbody>
</table>


* Adult equivalent  
** Standard deviation
TABLE 6a: DISTRIBUTION OF ENERGY, CALCIUM AND ANIMAL PROTEIN INTAKE BY FAMILY EXPENDITURE PER CAPITA PER MONTH

<table>
<thead>
<tr>
<th>Family expenditure per capita</th>
<th>No.</th>
<th>%</th>
<th>Mean Energy KJ</th>
<th>Mean Calcium Mg.</th>
<th>Mean An. Protein g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.01-100.99*</td>
<td>82</td>
<td>11.48</td>
<td>4857</td>
<td>299</td>
<td>23</td>
</tr>
<tr>
<td>$101.00-150.99</td>
<td>175</td>
<td>24.51</td>
<td>7158</td>
<td>405</td>
<td>32</td>
</tr>
<tr>
<td>$151.00-200.99</td>
<td>144</td>
<td>20.17</td>
<td>8946</td>
<td>497</td>
<td>41</td>
</tr>
<tr>
<td>$201.00-250.99</td>
<td>98</td>
<td>13.73</td>
<td>9667</td>
<td>598</td>
<td>44</td>
</tr>
<tr>
<td>$251.00-300.99</td>
<td>91</td>
<td>12.75</td>
<td>12162</td>
<td>705</td>
<td>55</td>
</tr>
<tr>
<td>$301.00-350.99</td>
<td>37</td>
<td>5.18</td>
<td>1341</td>
<td>775</td>
<td>62</td>
</tr>
<tr>
<td>$351.00-400.99</td>
<td>23</td>
<td>3.22</td>
<td>15700</td>
<td>798</td>
<td>126</td>
</tr>
<tr>
<td>$401.00-550.99</td>
<td>34</td>
<td>4.76</td>
<td>16746</td>
<td>1081</td>
<td>125</td>
</tr>
<tr>
<td>$551.00+</td>
<td>30</td>
<td>4.20</td>
<td>20726</td>
<td>1291</td>
<td>103</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>714</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regression formula:

\[
E=5171.7+20.7F \quad C=255.7+1.4 \quad P=18.2+0.1F
\]

Ratio: 353.3 492.1 56.1

Significance P =

\[
P = 0.000 \quad P = 0.000 \quad P = 0.000
\]

\[
R = 0.58 \quad R = 0.64 \quad R = 0.27
\]

\[
R^2 = 0.33 \quad R^2 = 0.41 \quad R^2 = 0.07
\]

TABLE 6b: DISTRIBUTION OF ENERGY, CALCIUM AND ANIMAL PROTEIN INTAKE BY FAMILY EXPENDITURE PER CAPITA PER MONTH

<table>
<thead>
<tr>
<th>Family expenditure per capita</th>
<th>No.</th>
<th>%</th>
<th>Mean Energy KJ</th>
<th>Mean Calcium mg.</th>
<th>Mean An. Protein g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.01-100.99</td>
<td>15</td>
<td>2.09</td>
<td>4353</td>
<td>408</td>
<td>25</td>
</tr>
<tr>
<td>$101.00-150.99</td>
<td>72</td>
<td>10.06</td>
<td>6672</td>
<td>427</td>
<td>31</td>
</tr>
<tr>
<td>$151.00-200.99</td>
<td>114</td>
<td>15.92</td>
<td>8476</td>
<td>552</td>
<td>40</td>
</tr>
<tr>
<td>$201.00-250.99</td>
<td>133</td>
<td>18.58</td>
<td>9141</td>
<td>602</td>
<td>44</td>
</tr>
<tr>
<td>$251.00-$300.99</td>
<td>93</td>
<td>12.99</td>
<td>10035</td>
<td>681</td>
<td>49</td>
</tr>
<tr>
<td>$301.00-350.99</td>
<td>73</td>
<td>10.20</td>
<td>10482</td>
<td>678</td>
<td>51</td>
</tr>
<tr>
<td>$351.00-400.99</td>
<td>59</td>
<td>8.24</td>
<td>12311</td>
<td>831</td>
<td>59</td>
</tr>
<tr>
<td>$401.00-550.99</td>
<td>101</td>
<td>14.11</td>
<td>12925</td>
<td>902</td>
<td>67</td>
</tr>
<tr>
<td>$551.00+</td>
<td>56</td>
<td>7.82</td>
<td>16818</td>
<td>1137</td>
<td>81</td>
</tr>
<tr>
<td>TOTAL</td>
<td>716</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regression formula:
- E = 5858.8 + 14.4F
- C = 376.9 + 1.0F
- P = 27.6 + 0.07F

Ratio:
- 261.6
- 275.7
- 324.2

Significance P =
- P = 0.000
- P = 0.000
- P = 0.000
- R = 0.52
- R = 0.53
- R = 0.56
- R = 0.27
- R = 0.28
- R = 0.31
TABLE 7: THE DISTRIBUTION OF ENERGY, CALCIUM AND ANIMAL PROTEIN INTAKE BY FAMILY INCOME PER CAPITA PER MONTH

1973 (per adult equivalent per day)

<table>
<thead>
<tr>
<th>Family Income per capita</th>
<th>No.</th>
<th>%</th>
<th>Mean Energy KJ</th>
<th>Mean Calcium Mg.</th>
<th>Mean An. Protein g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.01-100.99</td>
<td>22</td>
<td>3.21</td>
<td>11710</td>
<td>727</td>
<td>56</td>
</tr>
<tr>
<td>$101.00-150.99</td>
<td>63</td>
<td>9.20</td>
<td>8230</td>
<td>559</td>
<td>40</td>
</tr>
<tr>
<td>$151.00-200.99</td>
<td>126</td>
<td>18.39</td>
<td>8884</td>
<td>602</td>
<td>43</td>
</tr>
<tr>
<td>$201.00-250.99</td>
<td>113</td>
<td>16.50</td>
<td>9267</td>
<td>624</td>
<td>45</td>
</tr>
<tr>
<td>$251.00-300.99</td>
<td>85</td>
<td>12.41</td>
<td>10025</td>
<td>676</td>
<td>47</td>
</tr>
<tr>
<td>$301.00-350.99</td>
<td>65</td>
<td>9.49</td>
<td>10192</td>
<td>675</td>
<td>49</td>
</tr>
<tr>
<td>$351.00-400.99</td>
<td>51</td>
<td>7.45</td>
<td>10934</td>
<td>731</td>
<td>54</td>
</tr>
<tr>
<td>$401.00-550.99</td>
<td>95</td>
<td>13.87</td>
<td>12478</td>
<td>841</td>
<td>63</td>
</tr>
<tr>
<td>$551.00 +</td>
<td>65</td>
<td>9.49</td>
<td>13599</td>
<td>924</td>
<td>70</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>685</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regression Formula: E=7982.8+7.4F C=522.9+0.5F P=36.0+0.05F

Ratio 70.0 77.1 124.9

Significance

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>P</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>R</td>
<td>0.30</td>
<td>0.31</td>
<td>0.39</td>
</tr>
<tr>
<td>R²</td>
<td>0.09</td>
<td>0.10</td>
<td>0.15</td>
</tr>
</tbody>
</table>

*31 cases with no reported income

** Despite the fact that the Consumer Price Index survey did not intend to sample very low income groups it is clear that very low income families are nevertheless included.
TABLE 8a: THE DISTRIBUTION OF ENERGY, CALCIUM AND ANIMAL PROTEIN INTAKE BY EFFECTIVE FLOOR AREA PER CAPITA

<table>
<thead>
<tr>
<th>Effective floor area per capita</th>
<th>No.</th>
<th>%</th>
<th>Mean Energy KJ</th>
<th>Mean Calcium Mg.</th>
<th>Mean An. Protein g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001-10.00</td>
<td>28</td>
<td>3.92</td>
<td>6109</td>
<td>333</td>
<td>26</td>
</tr>
<tr>
<td>10.001-20.00</td>
<td>177</td>
<td>24.79</td>
<td>8245</td>
<td>483</td>
<td>36</td>
</tr>
<tr>
<td>20.001-30.00</td>
<td>149</td>
<td>20.87</td>
<td>8480</td>
<td>504</td>
<td>40</td>
</tr>
<tr>
<td>30.001-40.00</td>
<td>76</td>
<td>10.64</td>
<td>10106</td>
<td>564</td>
<td>46</td>
</tr>
<tr>
<td>40.001-50.00</td>
<td>84</td>
<td>11.76</td>
<td>10212</td>
<td>644</td>
<td>62</td>
</tr>
<tr>
<td>50.001-60.00</td>
<td>47</td>
<td>6.58</td>
<td>10368</td>
<td>606</td>
<td>53</td>
</tr>
<tr>
<td>60.001-70.00</td>
<td>56</td>
<td>7.84</td>
<td>10251</td>
<td>586</td>
<td>49</td>
</tr>
<tr>
<td>70.001-80.00</td>
<td>10</td>
<td>1.40</td>
<td>13103</td>
<td>760</td>
<td>59</td>
</tr>
<tr>
<td>&gt;80.000</td>
<td>87</td>
<td>12.18</td>
<td>15278</td>
<td>377</td>
<td>87</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>714</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regression formula: \( E = 7463.1 + 54.8F \)
\( C = 406.4 + 3.9F \)
\( P = 18.2 + 0.1F \)

Ratio:
\( E = 113.2 \)
\( C = 9.0 \)
\( P = 56.1 \)

Significance \( P = \)
\( P = 0.000 \)
\( P = 0.000 \)
\( P = 0.000 \)
\( R = 0.37 \)
\( R = 0.43 \)
\( R = 0.27 \)
\( R^2 = 0.14 \)
\( R^2 = 0.18 \)
\( R^2 = 0.07 \)
TABLE 8b: THE DISTRIBUTION OF ENERGY, CALCIUM AND ANIMAL PROTEIN INTAKE BY EFFECTIVE FLOOR AREA PER CAPITA

<table>
<thead>
<tr>
<th>Effective floor area per capita (sq.ft)</th>
<th>No.</th>
<th>%</th>
<th>Mean Energy (KJ)</th>
<th>Mean Calcium (Mg.)</th>
<th>Mean An. Protein (g.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001-10.00</td>
<td>28</td>
<td>3.91</td>
<td>7788</td>
<td>598</td>
<td>40</td>
</tr>
<tr>
<td>10.001-20.00</td>
<td>172</td>
<td>24.02</td>
<td>8615</td>
<td>585</td>
<td>42</td>
</tr>
<tr>
<td>20.001-30.00</td>
<td>181</td>
<td>25.28</td>
<td>10073</td>
<td>664</td>
<td>49</td>
</tr>
<tr>
<td>30.001-40.00</td>
<td>113</td>
<td>15.78</td>
<td>10979</td>
<td>726</td>
<td>52</td>
</tr>
<tr>
<td>40.001-50.00</td>
<td>72</td>
<td>10.06</td>
<td>10598</td>
<td>499</td>
<td>52</td>
</tr>
<tr>
<td>50.001-60.00</td>
<td>47</td>
<td>6.56</td>
<td>11215</td>
<td>776</td>
<td>57</td>
</tr>
<tr>
<td>60.001-70.00</td>
<td>35</td>
<td>4.89</td>
<td>12627</td>
<td>791</td>
<td>57</td>
</tr>
<tr>
<td>70.001-80.00</td>
<td>14</td>
<td>1.96</td>
<td>11581</td>
<td>825</td>
<td>65</td>
</tr>
<tr>
<td>&gt;80.000</td>
<td>54</td>
<td>7.54</td>
<td>13739</td>
<td>943</td>
<td>70</td>
</tr>
<tr>
<td>TOTAL</td>
<td>716</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1973 (per adult equivalent per day)

**REGRESSION FORMULA:**
\[ E = 8571.4 + 46.8F \]
\[ C = 567.3 + 3.3F \]
\[ P = 40.2 + 0.3F \]

**RATIO:**
\[ \text{R} = 60.2 \]
\[ \text{P} = 64.3 \]
\[ \text{R} = 93.7 \]

**SIGNIFICANCE P =**
\[ P = 0.000 \]
\[ P = 0.000 \]
\[ P = 0.000 \]
\[ R = 0.28 \]
\[ R = 0.29 \]
\[ R = 0.34 \]
\[ R^2 = 0.08 \]
\[ R^2 = 0.08 \]
\[ R^2 = 0.12 \]
<table>
<thead>
<tr>
<th>Direct energy/ capita/day</th>
<th>1973</th>
<th>No.</th>
<th>Mean Energy KJ</th>
<th>Mean Calcium Mg.</th>
<th>Mean An. Protein g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000-5.000</td>
<td>88</td>
<td>12.29</td>
<td>9077</td>
<td>593</td>
<td>44</td>
</tr>
<tr>
<td>5.001-10.000</td>
<td>327</td>
<td>45.67</td>
<td>9067</td>
<td>739</td>
<td>53</td>
</tr>
<tr>
<td>10.001-15.000</td>
<td>191</td>
<td>26.88</td>
<td>11271</td>
<td>903</td>
<td>63</td>
</tr>
<tr>
<td>15.001-20.000</td>
<td>61</td>
<td>8.52</td>
<td>12986</td>
<td>1019</td>
<td>71</td>
</tr>
<tr>
<td>20.001-25.000</td>
<td>23</td>
<td>3.21</td>
<td>13416</td>
<td>970</td>
<td>67</td>
</tr>
<tr>
<td>25.001-30.000</td>
<td>13</td>
<td>1.82</td>
<td>13489</td>
<td>1241</td>
<td>96</td>
</tr>
<tr>
<td>30.001-35.000</td>
<td>8</td>
<td>1.12</td>
<td>18733</td>
<td>1120</td>
<td>87</td>
</tr>
<tr>
<td>35.001-40.000</td>
<td>2</td>
<td>0.28</td>
<td>9602</td>
<td>810</td>
<td>59</td>
</tr>
<tr>
<td>40.001-45.000</td>
<td>1</td>
<td>0.14</td>
<td>1223</td>
<td>1539</td>
<td>48</td>
</tr>
<tr>
<td>45.001-50.000</td>
<td>1</td>
<td>0.14</td>
<td>9987</td>
<td>963</td>
<td></td>
</tr>
<tr>
<td>50.001-55.000</td>
<td>1</td>
<td>0.14</td>
<td>1531</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55.001+</td>
<td>1</td>
<td>0.14</td>
<td>9987</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>716</td>
<td>100</td>
<td>E=7959.6+226.4</td>
<td>C=497.0+18.7</td>
<td>P=0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R²=0.13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Regression Formula:**

E = 2959.6 + 226.4

C = 497.0 + 18.7

P = 0.000

R² = 0.13

**P. Ratio:**

P = 0.000

R = 0.35

R² = 0.13
### TABLE 10: THE DISTRIBUTION OF ENERGY, CALCIUM AND ANIMAL PROTEIN BY INDIRECT ENERGY USE PER CAPITA PER DAY

(1973 per adult equivalent per day)

<table>
<thead>
<tr>
<th>Indirect energy/capita/day</th>
<th>No.</th>
<th>%</th>
<th>Mean Energy KJ</th>
<th>Mean Calcium Mg.</th>
<th>Mean An. Protein g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000-5.000</td>
<td>15</td>
<td>2.09</td>
<td>8827</td>
<td>626</td>
<td>46</td>
</tr>
<tr>
<td>5.001-10.000</td>
<td>62</td>
<td>8.66</td>
<td>7663</td>
<td>545</td>
<td>40</td>
</tr>
<tr>
<td>10.001-15.000</td>
<td>179</td>
<td>25.00</td>
<td>9254</td>
<td>595</td>
<td>43</td>
</tr>
<tr>
<td>15.001-20.000</td>
<td>176</td>
<td>24.58</td>
<td>9485</td>
<td>631</td>
<td>46</td>
</tr>
<tr>
<td>20.001-25.000</td>
<td>113</td>
<td>18.78</td>
<td>10602</td>
<td>684</td>
<td>50</td>
</tr>
<tr>
<td>25.001-30.000</td>
<td>64</td>
<td>8.94</td>
<td>12322</td>
<td>838</td>
<td>61</td>
</tr>
<tr>
<td>30.001-35.000</td>
<td>38</td>
<td>5.31</td>
<td>12164</td>
<td>807</td>
<td>62</td>
</tr>
<tr>
<td>35.001-40.000</td>
<td>19</td>
<td>2.65</td>
<td>15606</td>
<td>1053</td>
<td>77</td>
</tr>
<tr>
<td>40.001-45.000</td>
<td>17</td>
<td>2.37</td>
<td>13297</td>
<td>1007</td>
<td>65</td>
</tr>
<tr>
<td>45.001-50.000</td>
<td>8</td>
<td>1.12</td>
<td>13166</td>
<td>963</td>
<td>64</td>
</tr>
<tr>
<td>50.001-55.000</td>
<td>8</td>
<td>1.12</td>
<td>13601</td>
<td>1111</td>
<td>73</td>
</tr>
<tr>
<td>55.001+</td>
<td>17</td>
<td>2.37</td>
<td>16527</td>
<td>1198</td>
<td>88</td>
</tr>
<tr>
<td>TOTAL</td>
<td>716</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REGRESSION FORMULA:**

E = 7527.1 + 135.5

C = 470.2 + 10.8

P = 34.3 + 0.8

**F. RATIO:**

94.1

128.8

147.5

**F. SIGNIFICANCE P =**

\( P = 0.000 \)

\( P = 0.000 \)

\( P = 0.000 \)

\( R = 0.34 \)

\( R = 0.39 \)

\( R = 0.41 \)

\( R^2 = 0.12 \)

\( R^2 = 0.15 \)

\( R^2 = 0.17 \)
TABLE 11a: THE DISTRIBUTION OF ENERGY, CALCIUM AND ANIMAL PROTEIN INTAKE BY HOUSING TYPE

<table>
<thead>
<tr>
<th>Housing type</th>
<th>No.</th>
<th>%</th>
<th>Mean Energy KJ</th>
<th>Mean Calcium Mg.</th>
<th>Mean An. Protein g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment blocks</td>
<td>13</td>
<td>1.82</td>
<td>11957</td>
<td>680</td>
<td>63</td>
</tr>
<tr>
<td>Tenement blocks</td>
<td>468</td>
<td>65.55</td>
<td>10404</td>
<td>610</td>
<td>54</td>
</tr>
<tr>
<td>Resettlement estates</td>
<td>149</td>
<td>20.87</td>
<td>8421</td>
<td>498</td>
<td>39</td>
</tr>
<tr>
<td>H.K.H.A. Low cost housing</td>
<td>47</td>
<td>6.58</td>
<td>8351</td>
<td>495</td>
<td>38</td>
</tr>
<tr>
<td>Govt. housing scheme</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff quarters</td>
<td>8</td>
<td>1.12</td>
<td>7618</td>
<td>456</td>
<td>35</td>
</tr>
<tr>
<td>H.K.H.S. Estates</td>
<td>16</td>
<td>2.24</td>
<td>11134</td>
<td>655</td>
<td>44</td>
</tr>
<tr>
<td>Others</td>
<td>13</td>
<td>1.82</td>
<td>10036</td>
<td>474</td>
<td>40</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>714</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REGRESSION FORMULA:  
E = 10663.8 - 309.8  
C = 639.8 - 24.1  
P = 59.8 - 4.0  
F RATIO:  
2.8  
4.5  
2.4  
F SIGNIFICANCE P =  
P = 0.094  
P = 0.035  
P = 0.125  
R = -0.06  
R = -0.08  
R = -0.06  
R^2 = 0.004  
R^2 = 0.006  
R^2 = 0.003
TABLE 11b: THE DISTRIBUTION OF ENERGY, CALCIUM AND ANIMAL PROTEIN INTAKE BY HOUSING TYPE

1973
(per adult equivalent per day)

<table>
<thead>
<tr>
<th>Housing type</th>
<th>No.</th>
<th>%</th>
<th>Mean Energy</th>
<th>Mean Calcium</th>
<th>Mean An. Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>KJ</td>
<td>Mg</td>
<td>g</td>
</tr>
<tr>
<td>Apartment blocks</td>
<td>104</td>
<td>14.53</td>
<td>11676</td>
<td>810</td>
<td>57</td>
</tr>
<tr>
<td>Tenement blocks</td>
<td>297</td>
<td>41.48</td>
<td>11129</td>
<td>772</td>
<td>56</td>
</tr>
<tr>
<td>Resettlement estates</td>
<td>191</td>
<td>26.68</td>
<td>9337</td>
<td>687</td>
<td>43</td>
</tr>
<tr>
<td>H.K.H.A. Low cost housing</td>
<td>96</td>
<td>13.41</td>
<td>8739</td>
<td>536</td>
<td>40</td>
</tr>
<tr>
<td>Govt. housing scheme</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Staff quarters</td>
<td>4</td>
<td>0.56</td>
<td>11435</td>
<td>857</td>
<td>59</td>
</tr>
<tr>
<td>H.K.H.S. Estates</td>
<td>22</td>
<td>3.07</td>
<td>9048</td>
<td>678</td>
<td>48</td>
</tr>
<tr>
<td>Others</td>
<td>2</td>
<td>0.28</td>
<td>6414</td>
<td>543</td>
<td>35</td>
</tr>
<tr>
<td>Total</td>
<td>716</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REGRESSION FORMULA:
E = 12193.1 - 719.6
C = 839.7 - 56.6
P = 60.9 - 4.1

F RATIO:
E = 22.9
C = 29.7
P = 33.4

F SIGNIFICANCE P =
P = 0.000
R = -0.18
R2 = 0.03
**IMPORTS**

| Protein | Animal | 43.4 gm |
| Fat     | Animal | 72.2 gm |
| Fat     | Plant  | 610.3 gm |
| Energy  | Animal | 15293.5 KJ |
| Ca      | Plant  | 520.7 mg |
| P       | Plant  | 1380.1 mg |
| Thiamine| Plant  | 1.7 mg |
| Ascorbic Acid | Plant | 75.0 mg |

**RE-EXPORTS**

| Protein | Animal | 1.1 gm |
| Fat     | Animal | 4.9 gm |
| Fat     | Plant  | 63.4 gm |
| Energy  | Animal | 1275.7 KJ |
| Ca      | Plant  | 64.6 mg |
| P       | Plant  | 141.8 mg |
| Thiamine| Plant  | 0.08 mg |
| Ascorbic Acid | Plant | 12.9 mg |

**EXPORTS**

| Protein | Animal | 0.9 gm |
| Fat     | Animal | 0.8 gm |
| Fat     | Plant  | 9.9 gm |
| Energy  | Animal | 382.2 KJ |
| Ca      | Plant  | 87.1 mg |
| P       | Plant  | 63.6 mg |
| Thiamine| Plant  | 0.03 mg |
| Ascorbic Acid | Plant | 1.2 mg |

**KNOWN LOSSES**

| Protein | Animal | 4.9 gm |
| Fat     | Animal | 10.6 gm |
| Fat     | Plant  | 87.7 gm |
| Energy  | Animal | 2055.7 KJ |
| Ca      | Plant  | 103.4 mg |
| P       | Plant  | 246.6 mg |
| Thiamine| Plant  | 0.5 mg |
| Ascorbic Acid | Plant | 6.2 mg |

**TOTAL NUTRIENT OUTPUT**

| Protein | Animal | 6.9 gm |
| Fat     | Animal | 16.3 gm |
| Fat     | Plant  | 161.0 gm |
| Energy  | Animal | 3713.3 KJ |
| Ca      | Plant  | 255.1 mg |
| P       | Plant  | 452.0 mg |
| Thiamine| Plant  | 6.6 mg |
| Ascorbic Acid | Plant | 0.6 mg |

**TOTAL NUTRIENT INPUT**

| Protein | Animal | 73.3 gm |
| Fat     | Animal | 83.0 gm |
| Fat     | Plant  | 629.2 gm |
| Energy  | Animal | 16599.9 KJ |
| Ca      | Plant  | 799.0 mg |
| P       | Plant  | 1710.3 mg |
| Thiamine| Plant  | 1.9 mg |
| Ascorbic Acid | Plant | 161.8 mg |

**LOCAL PRODUCTION**

| Protein | Animal | 29.9 gm |
| Fat     | Animal | 10.8 gm |
| Fat     | Plant  | 18.9 gm |
| Energy  | Animal | 1306.4 KJ |
| Ca      | Plant  | 278.3 mg |
| P       | Plant  | 330.2 mg |
| Thiamine| Plant  | 0.2 mg |
| Ascorbic Acid | Plant | 86.8 mg |

**TOTAL NUTRIENT INPUT**

| Protein | Plant  | 58.5 gm |
| Fat     | Plant  | 72.2 gm |
| Fat     | Plant  | 610.3 gm |
| Energy  | Plant  | 15293.5 KJ |
| Ca      | Plant  | 278.3 mg |
| P       | Plant  | 330.2 mg |
| Thiamine| Plant  | 0.2 mg |
| Ascorbic Acid | Plant | 86.8 mg |

**TOTAL NUTRIENT INPUT**

| Protein | Animal | 66.4 gm |
| Fat     | Animal | 66.7 gm |
| Fat     | Plant  | 468.2 gm |
| Energy  | Animal | 12886.6 KJ |
| Ca      | Plant  | 543.9 mg |
| P       | Plant  | 1258.3 mg |
| Thiamine| Plant  | 1.3 mg |
| Ascorbic Acid | Plant | 58.1 mg |

Figure 1: Balance sheet of nutrients and somatic energy for Hong Kong, 1971 (per capita per day)
<table>
<thead>
<tr>
<th>NUTRIENT</th>
<th>RECOMMENDED DAILY ALLOWANCE</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROTEIN</td>
<td>30 gm</td>
<td>358%</td>
</tr>
<tr>
<td>ENERGY</td>
<td>10,100 KJ</td>
<td>128%</td>
</tr>
<tr>
<td>THIAMINE</td>
<td>0.96 mg</td>
<td>135%</td>
</tr>
<tr>
<td>ASCORBIC ACID</td>
<td>27.09 mg</td>
<td>314%</td>
</tr>
<tr>
<td>CALCIUM</td>
<td>450–550 mg</td>
<td>99–121%</td>
</tr>
<tr>
<td>IRON</td>
<td>8.22–16.11 mg</td>
<td>134–262%</td>
</tr>
</tbody>
</table>

Figure 2: Bar chart showing the dietary adequacy of the male adult equivalent daily intake of selected nutrients and somatic energy in Hong Kong, 1971. The male adult equivalent level of recommended intakes are calculated from Passmore et al (1974).
CHAPTER VIII

ENERGY USE AND HUMAN WELL-BEING IN CONTEMPORARY URBAN SETTLEMENTS: THE CASE OF HONG KONG
One of the most publicised problems of our times is the future of the world's energy supplies. Despite existing and previous energy crises the increase in consumption of extrasomatic energy remains at about twice that of population growth. A common justification for increasing energy use is that it is related to the standard of living and, by implication, health and well being in human populations. Certainly there is considerable evidence illustrating a relationship between GNP and energy consumption (Darmstadter, 1971), but the relationship is not a uniform one and there appear to be many exceptions (Sorenson, 1975). Examining a large range of social indicators, Mazur and Rosa (1974) found very few significant correlations between the level of any indicator and per capita energy consumption throughout the wide range of energy consumption in 29 countries with developed market economies. Amongst the consistent correlations were divorce and suicide rates, both increasing with higher energy use. That a positive relationship might exist between the level of energy consumption and health and well being in these countries seems equally unlikely, despite two to three-fold differences in their per capita energy consumption. Nevertheless, representatives of the developed world frequently emphasise that it is important to increase the 'standard of living' of developing countries and refer to rapidly growing energy consumption as an index of this stated desirable change.

Faced simultaneously with this universal demand for more energy and the certain exhaustion of oil-based fossil fuels, the response of scientific and political leadership in the developed world has been to initiate massive research and
development aimed at tapping alternative sources of energy to, in the words of a former US federal energy administrator "return to a doubling time of energy use of ten to twelve years" (Love, 1973).

Unfortunately, while relatively high energy consumption has enabled many beneficial developments in health and community services, it is abundantly clear that there are aspects of our present levels of energy consumption which significantly detract from the health and well being of individuals, particularly in the populations of the industrialised world. Therefore we consider it prudent to ask, and to examine whether further increases in energy use will generate further health problems, whether existing energy-related health problems are a feature only of the magnitude of energy in use or merely a feature of the way in which energy is used, and following these, whether our headlong rush to facilitate even greater energy use is justifiable in terms of the health and well-being of the human population.

To shed some light on these questions, we have formulated a number of crude working hypotheses in connection with the Hong Kong Human Ecology Programme.*

1. Technological advances and increases in energy and material budgets in human communities result in an increasing dependence of the population for survival and health, on these technological advances and increased energy and material budgets. A satisfactory

*This study is co-ordinated by the Urban Biology Group at the Australian National University and the field work is based in the Centre of Asian Studies, University of Hong Kong, and the Chinese University of Hong Kong, and has been assisted by the Hong Kong Government. It is also a UNEP/UNESCO programme, MAB Project 11. Details can be obtained from the Director, Dr. S.V. Boyden.
solution to the energy crisis will necessarily involve devising means of halting, and to some extent reversing, the progressive lengthening of these chains of dependency.

2. That there is a definable optimum level of energy use for any given human settlement, which, if exceeded, will tend to be detrimental to the health and well being of the people in that settlement.

3. That important relationships exist between patterns of energy use and materials flow in urban settlements and physiological and mental state of health, of the human occupants of the settlements.

A major concern of the Hong Kong programme is to examine the relationships between aspects of the urban environment and patterns of health and disease in the urban population. Energy flow is a fundamental feature of any human settlement and is seen by us as a key variable in the analysis of the environment-health interaction. It is appropriate in this context to outline an important principle behind the Hong Kong programme, that is, the principle of phylogenetic maladjustment. Stephen Boyden in particular has emphasised the importance of this principle in the study of health in contemporary human communities (Boyden, 1971, 1972). The principle is a corollary to Darwinian theory of evolution, according to which species become, through natural selection, increasingly well adapted in their genetically determined characteristics to the conditions of life in the environment in which they are
evolving. It follows from this fact that if the environmental conditions deviate significantly from those prevailing in the evolutionary environment, the likelihood is that individuals will be less well suited in their biological characteristics to the new conditions, and consequently some physiological or behavioural signs of maladjustment may be anticipated.

A reading of the history of energy use (see Cottrell 1955, White 1959) strongly suggests that man's step by step capture of increasing portions of the energy flow in the biosphere and his exploitation of static fossil fuel reserves has been the most important pre-requisite for the development of contemporary civilization. Clearly it is during the last 150 years that the most spectacular increase in energy use has occurred and in consequence, that innumerable changes of great magnitude in the human environment have been implemented. However, it also follows from evolutionary principles that these most recent changes in life conditions could not have been matched by complementary and adaptive changes in the genetic constitution of man. The environmental conditions to which man is most finely attuned are those which prevailed at least 10,000 years ago. In terms of the physical environment, this suggests only that which is already obvious; that such features as clean air and water and other aspects of the pristine environment are important for human health and well being. However, it is equally important to reflect on what Lesley White, an originator of the energy theory of cultural evolution, said in passing; that is, 'the type of social system developed during the human energy era was unquestionably

* i.e. with only the energy of his muscles or somatic energy at his disposal.
the most satisfying kind of social environment that man has ever lived in. By this we mean that the institutions of primitive society were most congenial to his nature and temperament". While provocative, this statement reminds us that the psycho-social prerequisites for human well being are also unlikely to have changed in response to recent changes in life conditions. In other words, we need be concerned not only with changes in the physico-chemical environment generated by high energy use, but also, and equally importantly, with the psycho-social environment generated in high-energy societies.

It is important to illustrate this concept with examples of both psycho-social and physico-chemical conditions which are likely to have prevailed in the evolutionary environment and which are frequently absent in high energy societies. Table 1 is a tentative and abbreviated list of desirable conditions of life for mankind, drawn up by the Human Ecology Group. The list is based largely on evolutionary considerations, although it is not suggested that all conditions are characteristics of all of the evolutionary environments of mankind.

It must be emphasised at this point that diseases which occur in high-energy societies and appear to be absent in low-energy societies, are often referred to as diseases of civilisation or of urbanisation (Waller 1970, Carlestam and Levi, 1971). They are not always directly related to higher energy use, although it is arguable that higher energy use has established the preconditions for the diseases to occur. The real question is, of course, how much of the maladjustment unique to high-energy communities can be removed while maintaining the same or an increased level of energy consumption.
Considerable evidence exists that many of the life conditions listed in Table 1 prevailed in the typical primeval environment (see Turnbull, 1961; Thomas, 1966; Lee and Devore, 1968; Lee, 1972 and Sahlins, 1972). Therefore, on the basis of the principle of phylogenetic maladjustment, any deviation from them might be suspected of giving rise to maladjustment. On this basis, it is fair to consider them as components of human 'need'. In fact, quite apart from the theoretical considerations, it is almost common-sense that such conditions should prevail to ensure human health and well-being.

Energy use is related to changes in these desirable life conditions and hence to changes in health and well-being in at least four ways. Through:

1. the particular form of energy in use
2. the particular technology applied to utilise the energy
3. the rate of change in energy use by type and magnitude of energy
4. the magnitude of energy use per se

Figure 1 illustrates the nature of this interaction between energy-use, life conditions and the biopsychic state of the human population, in broad terms.

Figures 2 to 5 illustrates specific examples of the environmental impact and consequent maladjustment occurring through each of the suggested means of interaction.

Each of these pathways are exemplified in more detail below:-

1. The particular form of energy used. (see Figs. 1 and 2)
   (a) Physio-chemical life condition.
- SO\textsubscript{n}, CO, toxic admixtures, PbOn
- smoke, particulate matter, visible or not readily detectable
- harmful levels of radiation, long and short term
- Potentially explosive or environmentally potent concentrations of fuel types, eg. town gas, crude oil spills etc.

(b) Psycho-social life condition.
- lack of identification with environment
- decrease in acceptable aesthetic environmental stimuli
- concern and frustration with undesirable environmental change.

(c) Confirmed or suspected maladjustment.
- complicated physical injury and social side effects from innumerable oil spills, explosions, coal mining disasters and so on.
- radiation induced genetic change and cancers (Selikoff, 1975, St.Clair Renard, 1974).
- diseases of stress (see 2(c)).

2. The particular technology applied to use energy. (see Figs.1 and 3a, b)

(a) Physico-chemical life condition generated.
- noise
- increased risk of severe physical injury.
- replacement of somatic energy consumption with extrasomatic energy through use of 'energy slaves'.
- increased positive ionization.

(b) Psycho-social condition generated.
- automation induced anonymity, decline in status
- redundance of learned manipulative skills
- increase in extrinsic over intrinsic control of daily activities, hence, decreased sense of involvement, achievement, and self respect.
increase in manipulative over convivial social environment. (Illich, 1974)

(c) Confirmed or suspected maladjustment.

- irritation, headache, partial or complete hearing loss (Denzel, 1964; Farr, 1967; Bryan, 1973; Moller, 1975).
- complicated physical injury, morbidity and mortality eg. motor car accidents. (Dubos, 1973).

3. The rate of change of energy use by type and magnitude. (see Figs. 1, 4)

(a) Psycho-social life condition generated
- rapid change in technology, hence rapid change in skill requirements, learned skills, often becoming redundant; constant retraining requirements leading to:
  - loss of security,
  - loss of status and self respect
  - inversion of skill base from old to young in family
  - decreased ability to cope with change among middle-aged and old.

(b) Confirmed or suspected maladjustment
- diseases of stress, see 2(c). (Dubos, 1961; Gelfand, 1971)

4. Magnitude of energy use per se (particularly energy per unit area). (see Figs. 1, 5)

(a) Physico-chemical life condition generated
- high energy use or heat release per unit area
- concentrated heat release in particular microclimate eg. industry.
- modification of micro- and macro-climate
- long term impact of macroclimate modification on food production
- thermal discomfort

(b) Psycho-social condition generated
- fatigue, irritation through prolonged thermal discomfort
- increased social friction, social upheaval.

(c) Confirmed or suspected maladjustment.
- heat stress, leading to heat mortality and morbidity generally, (Schuman, 1964; Kutschenreuter, 1967; Henschel, Clarke and Bach, 1971; Clarke, 1972) and in specific microclimates eg. industry (Astrand, 1975)
- indirect impact on human well-being via unpredictability of food production (Schneider and Dennett, 1975)
- diseases of stress, see 2(c).

The changes in the physico-chemical environment listed are familiar to most. Technological solutions to many of these energy related problems have been proposed. Whether they will be implemented ie. whether they will prove politically and economically acceptable is another matter. However, the impact of high energy use on the psycho-social environment, either directly or as is mostly the case, through the impact of high energy technology, is little appreciated. Any discussion on this problem that has taken place, again, mostly refers to problems of industrialisation and urbanisation (Carlestram and Levi, 1971). Inevitably industrialized and highly urbanised societies are high-energy societies when compared to their pre-industrial and rural predecessors. Higher energy use has been the enabling factor without which the technology making them possible could not have been operated, even if conceived. It follows, at least within broad categories of energy use, that a decrease in energy use must also mean a decrease in the number or magnitude of environmental conditions, or deviations from the evolutionary
environment which contribute to maladjustment in the human population. While this rule holds for large shifts in energy use it is, nevertheless, clear that significant reductions in energy flux can occur without in any way forcing a reduction change in the type of technology in use. Similarly it is or a possible to significantly reduce the impact of harmful forms of technology without in any way reducing the energy powering it.

Much is made here of the importance of maintaining for individuals a sense of purpose, a sense of involvement and achievement, opportunities to exercise learned manipulatory skills and so on. So far it has been observed that opportunities to achieve these desirable conditions have been eroded as energy use in societies increases, enabling rapid mechanisation and automation, for as Margaret Mead (1953) has described, 'mechanisation itself, whether in agriculture or in industry, separates man from the traditional processes and techniques of his social unit, from the skills which he learned as an aspect of his belongingness with the family, or of his identification with his father and his line of ancestors'

An insight into the potential impact of increased energy flow through mechanisation can be gained from the classical example of Brunner (1945) in reference to the installation of a water pump in a village community: 'You say that the pump will save our women effort and time. If that happens, what are they going to do with themselves all day long?'

The loss of skills, and with it the autonomy and creativity of the individual and the family unit is another important feature of high-energy society. The dilemma is again illustrated by Mead in discussing the traditional practice
of weaving by Greek women. She says 'Good mothers start weaving for their daughters almost at birth. Factory woven cloth is in use to some extent, but can all the home weaving disappear without impoverishing the life of the individual and the family?'

Having discussed concepts of the energy and health interaction, it is now appropriate to discuss it in the context of the urban setting of Hong Kong.
THE CASE OF HONG KONG

We have examined the interaction between energy use and human health and well-being in Hong Kong on two levels. Firstly, through the study of patterns of energy flow and end-use in the Hong Kong ecosystem, we have been able to document changes in the physico-chemical environment which may, in turn, be associated with changes in human health. Secondly, through a large 'Biosocial Survey' of a representative sample of the Hong Kong population we have gathered data allowing us to estimate both the levels of energy consumption and the physical and mental well-being of individuals and families. The procedures adopted in both kinds of examination were complex and warrant further explanation.

METHODOLOGY

The major source of data is the Biosocial Survey. This survey was conducted in order to improve our understanding of, amongst other things, the life conditions, patterns of mental and physical health, levels of physical activity, biological time budget, levels of energy and material consumption, and the response to high density living of the Hong Kong population.

The sample for the Biosocial Survey consisted of

*The Biosocial Survey was conducted by S. Millar of the Urban Biology Group, ANU, in collaboration with the staff of the Social Research Centre at the Chinese University of Hong Kong. Aspects of the survey dealing with energy were my responsibility.*
3,983 housing units from the main urban areas in Hong Kong. It is a random sample stratified spatially by Hong Kong census districts and by housing type. From each housing unit a single individual was selected for interview leading to a final sample of 3,983 adults aged between 20 and 59 years. Further details of sampling techniques and interview compilation and procedure are available from our research team (Millar, in preparation).

Per capita per day consumption of energy was obtained by asking respondents the cost of the various domestic and transport fuels purchased during the previous month. In Hong Kong, power authorities reckon accounts on a monthly basis, salaries are reckoned on a monthly basis and therefore most personal and household expenses are recalled most accurately for the period of a month. Respondents were also asked to estimate the time they spent travelling on the various modes of public or private transport they used. If they owned their own vehicle they were asked the cost of fuel used to power it during the previous month.

Prices of all fuels in use by respondents were gathered from the various utilities or fuel vendors for the particular months during which the survey was conducted (June to August, 1974). In order to convert the price paid for fuels into units of energy a MJ per (Hong Kong) dollar value was calculated for each fuel.
Using data gathered to describe patterns of energy consumption in transport in Hong Kong (Newcombe, 1975), a MJ per minute of travelling time for each mode of transport was calculated, and, together with the MJ per dollar conversion factors, a per capita per day energy expenditure was compiled for each respondent. Values were calculated for direct and indirect energy use. Direct energy use is defined as the energy used at the point of consumption by the individual or family, whereas indirect energy use also takes into account the energy which was expended to make energy available at the point of end-use. For example, for household electricity expenditure, direct energy use is given as the energy expended at the point of end-use whereas indirect energy use is a factor of 4.15 greater than this for it includes an estimate of the primary energy expended in mining, refining, transportation, conversion and distribution to make the energy available in the household. Similarly, with transport energy use, calculation of indirect energy use included an estimation of the energy used in production of the bus, train or other vehicle and the energy cost of maintaining it and providing it with its particular form of energy over its average lifetime. Invariably indirect energy is larger than direct energy use, but more particularly so if the direct energy includes the more sophisticated fuels such as electricity which have very energy-expensive production processes. We felt it important
to use indirect energy values as well as following the more conventional practice of using direct energy values because the former clearly emphasises the use of electrical appliances. The relationships which may exist between the use of electrical appliances, as 'energy slaves' in the household, and human well-being, are of considerable interest to us.

The levels of individual energy use (expressed in *per capita* per day terms) arrived at by this procedure, with the exception of transport other than private vehicles, are not an exact measure of the energy use by the respondent, but rather represents the mean of the household members' energy use. However, it is assumed that there is a reasonable level of sharing of energy-use in the household by household members, for example in lighting, water heating and so on. On the other hand most of the health and well-being indices relate only to the respondent. The exception here is the respondent's report of the respiratory health of the children in the household.

Several indices of health and well-being were included in the Biosocial Survey. Six of them are referred to in this paper. These include some psychometric scales which were developed in other studies, and some symptom scales which are unique to the Biosocial Survey.

Three scales developed by N.M. Bradburn (1969)
were included in the survey. These scales aim to measure well-being and its various components. The affect positive scale assesses recent pleasant experiences and the affect negative scale assesses recent unpleasant experiences. The third scale, the affect balance scale, scores the difference between the affect positive and affect negative scores and it has been found to correlate with the self-rating of happiness in life (Bradburn 1969). The scales, as used in our study, show adequate reliability, and they behave as we might expect them to according to Bradburn's interpretation of their use and function (Bradburn, 1969, Porrit in preparation).

Life enjoyment and satisfaction is our index compiled from two questions in the Biosocial Survey: whether the respondent was satisfied with his or her daily life and whether he or she found life enjoyable. This index is unique to the Biosocial Survey.

General physical health is measured by a composite index which is made up from a number of items: the number of recent bad pains, the interference by these pains with daily activity, the recent incidence of coughs, nausea and headaches, the recent experience of colds or flu and the self-report of recent personal health.
Respiratory infection is measured by two items, one which reported frequency of infections and the other the usual duration of infection. These items refer to the month prior to the interview and are available in respect of both the respondent and for the respondent's report of the children in the household.

The scores of the respondents for all of these measures were correlated with per capita per day direct and indirect energy use. Correlations significant at the 0.05 level or better are presented.

Because each additional number of a household above the first one or two members shares in the existing overheads of energy use, e.g. of lighting, cooling, cooking and so on, the effective increase in energy use is likely to be only a portion of the previous mean per capita energy use in the household. Therefore we have correlated the specified variables within households of the same size in order to increase the validity of the comparison.

As mentioned in the introduction to this section, research on the pattern of flow and end-use of energy in the Hong Kong ecosystem also provided data which could be examined in relation to health and well-being indices compiled from the Biosocial Survey. The spatial distribution of energy use in Hong Kong has been documented elsewhere (Newcombe, 1976) and in this study energy use per unit area, or more specifically, artificial heat generation per secondary
planning unit is correlated with the scores for each of the health and well-being indices averaged for the respondents residing in that area. The data on the spatial distribution of energy use, in addition to detailed information on the emission of SO\(_2\) from 1800 point sources in the urban area and upper atmospheric parameters has been fed into a computer model which estimates the dispersal and concentration of SO\(_2\) in the urban area of Hong Kong. (Kalma et al, 1976). From this data we have computed ambient ground level SO\(_2\) concentrations for each tertiary planning unit* (T.P.U.). These values, as well as estimating the ambient SO\(_2\) concentration, provide a reasonable index of general air pollution from the same sources (e.g. particulate matter). They are correlated with scores for all the above health and well-being indices averaged for each T.P.U.

In addition to relationships examined using data from the biosocial survey, a number of more general observations of energy-induced changes in the Hong Kong ecosystem are made, and the maladjustment which could result from these changes is discussed.

**INDIVIDUAL ENERGY USE AND WELL-BEING**

The strength of a correlation between two variables does not, of course, imply *per se* that one variable shares a causal

---

*T.P.U.: Tertiary Planning Unit, which is the smallest area utilised by the Hong Kong Government for data collection in relation to planning and monitoring processes. It is generally of the order of four to five street blocks, but the size varies from 0.12 sq. km. to 13.56 sq. km. in the urban area.
relationship with the other. However, a correlation between variables is consistent with the idea that there may be a relationship whereas if there is no correlation a causal relationship can be disproved or at least is less likely.

Correlations between the variables of individual energy-use and health and well-being are given in Tables 2(a) to 2(f). Table 2(a) contains the correlations of energy use with scores on Bradburn's affect negative scale. The data show, for two classes of household size, a significant negative correlation between direct and indirect energy use per capita and the number of recent unpleasant experiences measured by the affect negative scale. Table 2(b) shows that for three classes of household size, particularly for indirect energy use, there is a significant positive correlation of individual energy use with the number of recent pleasant experiences. The Bradburn affect balance, which essentially scores the difference between the scores obtained in Table 2(a) and 2(b), shows the most consistent correlations of scores on the three scales. The data in Table 2(c), in effect, shows that there is a positive correlation of individual energy use with individual happiness. The correlation is consistently stronger with indirect energy use than with direct energy use.
Table 2(d) shows correlations between a 'General Physical Health' index, and individual energy use. By this index the data show a significant negative correlation between ill-health and individual energy use. This correlation is stronger and more consistent with indirect energy use than with direct energy use.

In Table 2(e) the data on respiratory infection and energy use is presented. Here it was found that there was no correlation between respiratory infection in adults and their level of energy use; but there is, in two classes of household size, a significant positive correlation between the level of energy use (of the respondent) and respiratory infection amongst the children of the household. Again the correlation is stronger with indirect energy use than direct energy use.

Finally, in Table 2(f) the data on life enjoyment and energy use are presented. The correlations between these variables are the strongest and most consistent of all those obtained. In all classes of household size there is a positive correlation between the level of individual energy use and enjoyment of, and satisfaction with life.

As raised at the beginning of the methodology, a correlation between variables does not mean that a variation in one is a cause of variation in the other. In fact, a variation in two measures may be covered by variation in a third which is not being considered in the computation. In these analyses, the possibility exists that economic
status is a third variable with which both energy use and human well-being are related, and that the level of energy use and human well-being are not related directly to each other.

In order to examine this possibility the same correlations were performed after dividing each household class into low, medium and high economic status groups (economic status is determined by level of income and material standard of the household - the groups were roughly the same size). Here it was found that the same, or even stronger correlations existed within the high economic status groups, but not within the low and medium groups. Clearly the correlations exist despite economic status and not because of it. A plausible explanation of the lack of correlation within low and medium economic groups is that only the high economic group has a sufficient range of energy use (from almost zero to maximum per capita per day figures) to allow covariation with other variables to be measured. In fact, the variation of energy use within the low and medium was minimal compared with the high economic status economic group.

THE PROXIMATE ENVIRONMENT AND WELL-BEING

This section concerns correlations between ambient $SO_2$ concentrations, artificial heat generation and indices of health and well-being in a number of defined areas. In the case of $SO_2$, the values being correlated are for estimated ground level concentrations for stable climatic conditions computed for tertiary planning units in the urban area of Hong Kong.
There are a number of complicating factors which could affect the correlation process. Firstly, the SO$_2$ values are estimated by a computer model which is unable to take into account the highly complex effects of surface roughness in a densely structured urban environment with street corridors and so on. Secondly, the values obtained from the model are unable to be readily validated in the field, although existing evidence tends to support the distribution of SO$_2$ obtained from computation (see Kalma et al, 1976). Thirdly, the Hong Kong residential environment extends vertically for up to 20 storeys or more, with only a minute proportion of the population living at ground level. Therefore ground level concentrations of SO$_2$ only approximate, and mostly understate concentrations of SO$_2$ above ground. In fact, with some areas of high emission, ground level concentrations will be low because the point of emission will be located well above ground level, yet people will be living at the same, or at an even higher level than the point of emission.

It is clear from these considerations and from a close scrutiny of the data that a much more sophisticated treatment of the available data would be possible. Nevertheless, there are a number of interesting significant correlations of ambient SO$_2$ concentrations and health and well-being indices. Table 2(a) shows a positive correlation with the number of unpleasant
experiences and Table 2(b) shows significant negative correlations between $SO_2$ concentrations and the number of pleasant life experiences. Table 2(c) shows several significant negative correlations between $SO_2$ concentrations and, in effect, the happiness of the respondent.

The concentration of $SO_2$ in the atmosphere does not correlate with general physical health of the respondent although there is a positive correlation in one class of households with the incidence of respiratory infection in children. The respiratory infection index is composed in part of a report of colds and flue during the last month. In this section, which is not tabulated, $SO_2$ concentrations correlate positively with the incidence of cold and flu amongst children. ($R = 0.094$, $P < 0.05$, for 464 households with greater than 8 people.)

Artificial heat generation, apart from actually representing the level of heat from the use of extrasomatic energy released into the atmosphere at the point of end-use, is also a measure of the intensity of energy use per unit area. Therefore, it is a crude estimate of the impact of byproducts of energy-use (including $SO_2$), by all energy converting technologies, on life conditions. However, unlike $SO_2$ concentration, there is no attempt to locate the point of potential interaction between these products of energy-use and human health and well-being. For example, the pollutant byproducts of energy used in one place may have an impact on health in a quite distant place.
The level of artificial heat generation does not correlate in any consistent way with health and well-being indices.

Since in the case of air pollution, much of the impact of energy-use is distant from the point of end-use, the low or non-existent correlations with artificial heat generation do not negate the validity of correlations with \( \text{SO}_2 \) for which an attempt has been made to locate the point of potential interaction with human health.

**POTENTIAL IMPACT ON HEALTH OF GENERAL CHANGES IN LIFE CONDITIONS IN HONG KONG**

We are, of course, particularly concerned with changes in life conditions brought about by increases in the use of extrasomatic energy. From research in the Hong Kong Human Ecology Programme we are able to make at least two general observations about changes, or potential changes, in health and disease patterns related to changing levels of energy use.

In the first example we have related the overall growth in energy use in Hong Kong to changes in mortality patterns over the twenty year period 1951 to 1971 (see Colbourne, 1976). Of the major causes of death in Hong Kong, carcinoma of the lung is the only one to have increased, even on an age-specific basis, between 1951-1971. During the same period energy use in Hong Kong increased ten-fold.
The correlation between these two factors is 0.99 which is significant at the 0.01 level. Clearly factors associated with energy use are not the sole, or even perhaps the major cause of lung cancer in Hong Kong; but there is considerable subjective evidence which supports some kind of association between energy use and the incidence of lung cancer and, it may reasonably be anticipated, with other forms of respiratory maladjustment.

Firstly, the fossil fuels used in Hong Kong generate considerable pollutant byproducts close to densely populated urban areas. Secondly, the energy-use per unit area, particularly in highly populous parts of the urban area, with densities from 100,000 to 200,000 persons per sq. kilometer, is as high or higher than any so far recorded (Kalma and Newcombe, 1975). Thirdly, there are a number of epidemiological studies which have successfully related energy-use to lung cancer (Daly, 1959, Stock, 1967 and Buell and Dunn, 1967). Fourthly, preliminary analysis of the etiology of lung cancer in Hong Kong indicated that smoking was only closely related to the disease in men, leaving unexplained the high incidence of lung cancer in women (M.J. Colbourne, personal communication, 1975). A retrospective study on the etiology of lung cancer in Hong Kong is now underway in the Hong Kong programme.

The second observation arises out of research
by Kalma et al. (1976) which documents a considerable heat island effect of up to $2^\circ C$ averaged over all the Hong Kong urban area. In a climate which frequently provides the temperature and humidity admixture which commonly creates thermal discomfort, any additional heating of the urban microclimate is likely to create critical heat stress commonly leading to heat exhaustion and heat stroke (Henschel, 1967). In Figure 7, a graph which is adapted from Kutschenreuter (1969), we have plotted the days in Hong Kong in 1971 when the mean dry bulb temperature exceeded $29^\circ C$ and the mean dewpoint exceeded $23.5^\circ C$. It is clear that artificial heat generation, even if adding only 1 or $2^\circ C$ to these temperatures, will add significantly to heat stress in certain relatively common climatic conditions. We have already documented elsewhere (Kalma and Newcombe, 1975) that in some populous parts of the urban area, artificial heat generation greatly exceeds incoming solar radiation for extensive periods of each year.

**GENERAL DISCUSSION**

Before discussing the possible implications of the data presented, we must stress the fact that, while the correlations presented as part of the results are significant, they explain no more than a few percent of the variance between the variables in question. Therefore, they do not permit us to advance any more than tentative suggestions
as to the nature of the relationship between energy use and human well-being.

On the one hand the results of our study suggest that the more energy an individual uses the greater his happiness and his enjoyment and satisfaction with life. On the other hand, there is the consistent suggestion that high levels of energy use, or its byproducts, detract from individual well-being. It is particularly noteworthy that with all the happiness and life enjoyment measures the correlations are invariably stronger with indirect energy use than with direct energy use. It will be recalled that the reason for including indirect energy use in the analysis is that this measure of energy use emphasises the use of electricity, and also the use of energy expensive forms of transport such as private motor vehicles and taxis. The inference from the data is that the more energy slaves an individual can manipulate to his liking, the greater his happiness and life enjoyment. By energy slaves we mean all forms of electrical appliances such as T.V., radios, record players, tape recorders and various kitchen appliances. It is conceivable that such objects provide a measure of fulfilment for the individual and provide ready access to sources of stimulation in an otherwise monotonous environment.

However, it is equally clear that the relationship between high energy use and well-being is complex. In order to provide stimulation, to cater for
individual creativity and to modify the personal environment in ways found desirable to compensate for inadequacies in the life conditions of contemporary urban settlements, perhaps increasing amounts of energy are required. However, as suggested from the data on environmental modification by high levels of energy use, there is a feedback from change in the general environment to individual health and well-being. In the first instance, at least, it is likely that those able to deploy higher levels of energy use can insulate themselves from general environmental deterioration by utilising energy slaves to compensate for inadequacies in the general conditions of life. Ultimately, however, there must come a time when the amount of energy used to compensate for perceived inadequacies in life conditions irretrievably degrades the physical and social milieu.

This emerging pattern can be illustrated by two brief examples. Air conditioners are a form of energy slave which serve to cool the residential environment and to filter out the particulate matter and noise from the surrounding environment. However, air conditioners cannot do this without using large amounts of energy. This energy is converted ultimately to waste heat, which serves to increase the temperature of the surrounding environment and, particularly in densely populated areas like Hong Kong, must increase the demand for cooling devices. Our research on heat island effects in Hong Kong
shows that general temperature increases in the urban environment as a result of extrasomatic energy use are significant. It may be that the deleterious effects of using large numbers of energy slaves are not felt by those employing them but rather by those subjected to environmental deterioration caused by their use. However this need not always be the case. It may be coincidental that there is a positive correlation between, particularly indirect energy use and children's respiratory disease. It is well established that certain air conditioners cause ionisation of the atmosphere and that air ions are frequently deleterious to human health, particularly through respiratory ailments (Beckett, 1954, Kornbleuh, 1967). For those that can afford them air conditioners are an increasingly popular 'energy slave' in tropical Hong Kong. There was a tenfold increase in air conditioners installed in Hong Kong between 1964 and 1971. It is certainly possible that the positive correlation of energy use with childrens respiratory disease is related to an increase in the air-conditioned environment.

The second example of an energy slave with both good and bad effects on individual well-being is the motor car. There are unquestionably rewarding aspects of driving a motor vehicle, quite apart from the ease of access it provides for individuals in the urban environment to such essential resources as foodstuffs and recreational space. However, at the same
time this psychological well-being is won at a
cost to the health of the general environment and
in turn to the health of the people living in that
environment. In addition, the driver also increases
his chances of becoming a victim of his own energy
slave; debilitating car accidents are frequent;
people driving more than 19,000 kms in an urban area
per year more than double their chances of getting
lung cancer compared with those who drive less than
this distance (Mills, 1960), and the more individuals
rely on extrasomatic energy use for mobility the
less likely they are to remain physically fit (for
the relationship between physical fitness and heart
disease see Morris et al, 1973).

It is appropriate now to examine the results
of this study in regard to the hypotheses advanced
in the introductory section. In so far as it appears
that individual happiness and satisfaction with life
increases with increasing energy use, there is
nothing in our findings contradictory to the first
hypothesis. The second hypothesis suggests that
above a defineable optimum level of energy use in
any given human settlement, additional energy use
will be detrimental to individual health and well-
being. The data presented both supports and detracts
from the validity of this hypothesis. However, for
the hypothesis to be properly tested it will be necessary
to examine the relationship between individual
energy-use and well-being at much higher levels of per capita energy-use than those prevailing in Hong Kong. The per capita energy consumption in the U.S.A. was ten times, and in Australia 5 times greater than for Hong Kong in 1974. Clearly it is of the greatest importance to understand the point of balance between well-being from individual energy-use and maladjustment caused by changes in life conditions brought about by this energy use. Unless it can be shown that urban man can both employ large amounts of energy to do his work and entertaining, as well as avoid the side effects of his energy use, then the second hypothesis will be proven.

In regard to the third hypothesis we have demonstrated that varied and subtle relationships do exist between patterns of energy use and the physical and mental state of health of humankind in the settlement of Hong Kong.

In conclusion, it seems that a continued growth in energy consumption offers no panacea for the ills of high-energy society; that there are many problems which find their origin, rather than their solution in high energy consumption, and there appear to be serious inconsistencies in any theory which holds that additional energy use invariably leads to an increased standard of living if we count human health and well-being as an important component in any standard of living index.
This study adds support, then, to the notion that energy use can be both enabling and disabling. Increasingly we will be concerned with the disabling aspects if growth in energy use continues. A major task for the future is to unravel the intricate relationship between energy use and human health and well-being so as to ensure that the well-being provided by energy use in one context is not being counter-balanced by maladjustment caused by energy-use in another.
References


TABLE 1: SOME DESIRABLE BIOSOCIAL CONDITIONS OF LIFE FOR HOMO SAPIENS*

**Physico-chemical condition**
- Well-balanced nutrition in relation to phylogenetic requirements.
- Clean air for inhalation
- Low degree of exposure to noxious chemical compounds
- Low risk of severe physical injury with complications
- Noise levels at or around the primeval level
- Meaningful change in the visual environment
- Protection from levels of ionic radiation likely to be damaging to health
- Exposure to environmental temperatures in the range likely to have been experienced in the evolutionary environment
- Correct intake of calories in relation to requirements for basal and physical work performed

**Psycho-social condition**
- Balance between levels of sexual satisfaction and sexual stimulation
- Opportunities to sleep in response to the urge to do so by night or by day
- Opportunities and incentives for periods of vigorous physical activity at the primeval level
- Opportunities for spontaneous conversation with close companions on matters of mutual concern
- Opportunities for companionship with other members of the in-group
- Opportunities to move at will from one social phase to another (i.e. from one small group to another and to and from a state of solitude)
- Opportunities and incentives for creative activities (e.g. involving the exercise of learned manipulatory skills)
- High degree of emotional involvement (e.g. enjoyment, interest) in the activities of the day
- High degree of individual awareness of a role in the in-group or community (sense of responsibility)
- Good opportunities for self-expression and self-fulfillment

*Extracted from an unpublished checklist of desirable biosocial conditions of life by S.V. Boyden.*
TABLE 2(a): Product-moment correlation of household direct and indirect energy use, SO\textsubscript{2} concentration per TPU and artificial heat generation per SPU, with Bradburn's affect negative score for households of specified size*. Only correlations significant at the 0.05 level or better given.

<table>
<thead>
<tr>
<th>Variable</th>
<th>People per household:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One to three (725)**</td>
</tr>
<tr>
<td>Direct energy use per capita</td>
<td>-0.101</td>
</tr>
<tr>
<td>Indirect energy use per capita</td>
<td>-0.101</td>
</tr>
<tr>
<td>Artificial heat generation per SPU</td>
<td></td>
</tr>
<tr>
<td>SO\textsubscript{2} concentration per TPU</td>
<td>0.085</td>
</tr>
</tbody>
</table>

TABLE 2(b): Bradburn affect positive (as above)

| Direct energy use per capita             | 0.098  | 0.118 |
| Indirect energy use per capita           | 0.113  | 0.133 | 0.108 |
| Artificial heat generation per SPU       |       |       |
| SO\textsubscript{2} concentration per TPU | -0.101 | -0.133 |

TABLE 2(c): Bradburn affect balance (as above)

<p>| Direct energy use per capita             | 0.104  | 0.083 | 0.112 |
| Indirect energy use per capita           | 0.114  | 0.098 | 0.134 | 0.098 | 0.120 |
| Artificial heat generation per SPU       |       |       |
| SO\textsubscript{2} concentration per TPU | -0.106 | -0.107 | -0.076 |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>People per household:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One to three (725)**</td>
</tr>
<tr>
<td>Direct energy use per capita</td>
<td>-0.090</td>
</tr>
<tr>
<td>Indirect energy use per capita</td>
<td>-0.109</td>
</tr>
<tr>
<td>Artificial heat generation per SPU</td>
<td></td>
</tr>
<tr>
<td>SO$_2$ concentration per TPU</td>
<td></td>
</tr>
</tbody>
</table>

Table 2(d): General Physical health index

Table 2(e): Children's respiratory infection (as above)

<table>
<thead>
<tr>
<th>Variable</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct energy use per capita</td>
<td>0.087</td>
</tr>
<tr>
<td>Indirect energy use per capita</td>
<td>0.086</td>
</tr>
<tr>
<td>Artificial heat generation per SPU</td>
<td></td>
</tr>
<tr>
<td>SO$_2$ concentration per TPU</td>
<td>0.088</td>
</tr>
</tbody>
</table>

Table 2(f): Enjoy life/satisfaction index (as above)

<table>
<thead>
<tr>
<th>Variable</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct energy use per capita</td>
<td>0.093</td>
</tr>
<tr>
<td>Indirect energy use per capita</td>
<td>0.093</td>
</tr>
<tr>
<td>Artificial heat generation per SPU</td>
<td></td>
</tr>
<tr>
<td>SO$_2$ concentration per TPU</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1: Diagrammatic representation of the possible means by which energy use interacts with human health and well-being.
Figure 2: Diagrammatic representation of an example of the way in which a particular form of energy in use can interact with human health and well-being.

ENERGY

LIFE CONDITIONS

BIOPSYCHIC STATE

EMPHYSEMA, BRONCHITIS, ASTHMA, LUNG CANCER, CARDIOVASCULAR DISEASE

SULPHUR OXIDES AND TOXIC ADMIXTURES

FUEL OIL
Figure 3(a): Diagrammatic representation of an example of the way in which energy use, through the particular technology being used to convert it to work, can interact with human health and well-being.
Figure 3(b): Diagrammatic representation of an example of the way in which energy use, through the particular technology being used to convert it to work, can interact with human health and well-being.
Figure 4: Diagrammatic representation of an example of the way in which the rate of change in energy use can interact with human health and well-being.
Figure 5: Diagrammatic representation of an example of a way in which the magnitude of energy use _per se_ can interact with human health and well-being.
Figure 6: Graphical presentation of the relationship between temperature, humidity and heat stress (after Kutschenreuter, 1967).
CONCLUDING REMARKS
CONCLUDING REMARKS

In this concluding section, the findings of the work reported will be examined and discussed in relation to some fundamental concepts of ecology which are applicable to the urban environment. Consideration will be given to concepts of planning and management of the urban environment, and suggestions will be made relating specifically to the management of the Hong Kong ecosystem.

A major emphasis of the Hong Kong programme has been the integration of knowledge gathered through research in many different fields as it might contribute to our understanding of the functioning of urban ecosystems. An attempt has been made here to integrate knowledge gathered in some of the areas of research within the system ecology section of the Hong Kong Programme. For the Programme as a whole it was felt that there was great potential for the integration of knowledge arising from research in both the system and population ecology sections. Although broached in Chapter 8, this more comprehensive integration is outside of the scope of this thesis.

In the discussion which follows some comparisons are drawn between the properties of the Hong Kong ecosystem and those of natural ecosystem and the concepts which will be referred to are derived particularly from Odum (1969, 1971) and Margalef (1963). In addition, ecologic and economic modes of managing an urban system are discussed.
The city as an ecosystem

If we accept the original definition of an ecosystem as provided by Tansley (1935), according to which ecosystem is an open-ended, not necessarily self-sustaining portion of a larger system with which there is an exchange of materials, energy and information, then contemporary urban settlements, or cities, can be legitimately referred to as ecosystems.

There are, however, at least two important differences between the behaviour of a natural ecosystem* and that of an urban ecosystem. Firstly, from the principles of ecological succession which apply to natural plant and animal communities, there is a natural development towards a climax or mature stage of development characterised by certain distinct features. The urban ecosystem does not, of its own accord, develop towards a mature or homeostatic state for it is dominated by mankind and his culture, and it is man's management policies that largely determine a city's ecological behaviour.

Secondly, almost by definition, no urban ecosystem is ever likely to reach a self-sustaining, homeostatic state. Theoretically, however, it could develop a homeostatic relationship with its catchment or forage area, involving no net exchange of goods or materials crossing

* The term 'natural ecosystem' is used in this discussion to describe an ecosystem which is capable of becoming self-sustaining.
a hypothetical boundary dividing the city and its catchment area on the one hand from the wider environment on the other.

With regard to the consumption of energy and materials, there are several characteristic differences between mature and immature ecosystems. In an immature natural ecosystem both gross and net productivity are on the increase, resulting in rapid growth in the consumption of energy and materials. Most of the energy and materials are utilised in building structures which extend the control the various species exert over their environment (for example, insulating them from the environmental perturbations).

In the mature ecosystem, alternatively, gross productivity is steady, remaining at about the same, or below the level of earlier stages, while net productivity is zero because the processes of respiration are fully utilised. The environmental consequences of these differences between the two stages are several. Firstly, in immature ecosystems, there is considerable wastage of energy and materials because the emphasis on productivity decreases the emphasis on efficiency. In a mature ecosystem there is much recycling and conservation of materials, and waste organic matter is an important source of energy which is used efficiently. It is worthwhile noting, in the context of this discussion, a law of biological systems described some time ago by Lotka (1922): 'where the supply of available energy is limited, the advantage will
go to that organism which is most efficient, most economical, in applying to preservative uses such energy as it captures. Where the energy supply is capable of expansion, efficiency or economy, though still an advantage, is only one way of meeting the situation, and so long as there remains an unutilised margin of available energy, sooner or later the battle, presumably, will be between two groups or species equally efficient, equally economical, but the one more apt than the other in tapping previously unutilised sources of available energy.

We have shown that the Hong Kong ecosystem is similar to an immature ecosystem in that 40% of the extrasomatic energy imported to the ecosystem is lost even before it reaches the technology which will convert it to work at the point of end-use. Moreover the rate of growth of energy consumption is high, with energy use doubling every 7 to 8 years (see Chapter 2). Similarly, energy conservation is virtually non-existent, even though during a period of energy shortage in Hong Kong, worthwhile conservation was possible without much effort or hardship. Similarly we have shown that up to 20% of the nutrients entering the Hong Kong ecosystem as human food are ultimately unavailable for human consumption, and that in the case of the important mineral phosphorous, 60% of the total input to the Hong Kong food system is irrevocably lost (see Chapter 6). While attempts to recycle nutrients are being made, the nutrients that will be recycled if present plans are implemented will still represent only a miniscule proportion of the quantity dispersed in the Hong Kong ecosystem as wastes.
In addition, from a detailed study of energy use in the Hong Kong food system (chapter 5) we demonstrated the 'law of diminishing returns' which applies to attempts to increase productivity by decreasing species diversity and holding the ecosystem at an immature stage. We have shown that in order to double or triple productivity, the extrasomatic energy inputs per unit of somatic energy in food has increased from 10 to 250 times (see Chapter 5)

There are also important differences with respect to the relationship which an animal community or a city ecosystem has with its wider catchment or forage area which are of significance to future urban planning.

Mature ecosystems exert great control over the supply of critical materials, and organic sources of energy, ensuring the supply of these resources, almost entirely from within the ecosystem. System stability is high as a result of this capacity to regulate resource availability to avoid shortages, and frequently stability comes through the development of diversity in the sources of supply of materials, so that if any one source suffers through temporary shifts in environmental conditions, others are available to replace its contribution. In that sense, mature ecosystems heighten their capacity to regulate biotic functions by insulating themselves from the more unpredictable aspects of the wider environment, such as climate. Conversely, immature ecosystems rely entirely on external sources of supply for energy and key materials over which they exert little control,
and the systems are unstable since there is little diversity in key resource supply and little insulation from environmental perturbations.

Like a natural ecosystem, Hong Kong receives all its energy either directly or indirectly from one source. However, in a natural ecosystem, the energy source is recurrent solar irradiation and not declining stocks of fossil fuels as is the case of Hong Kong which derives all its energy from the Middle East. Although an attempt is being made to diversify the sources of supply from without by negotiating for fuel from China, little effort is being made to utilise energy from renewable resources of organic refuse, sewage and solar radiation available within the ecosystem (see chapter 2). Present trends in food production in Hong Kong will have the effect of increasing vulnerability rather than stability. Information, technology and key materials are assembled through networks of supply stretching around the globe, whereas the former, albeit marginally less productive, food system relied on only local and regional inputs, and thereby offered far greater stability (see chapter 5). On the other hand, the average Hong Kong diet, though far richer than the traditional Chinese diet, is provided through the utilisation of fewer land-based resources than is the case with contemporary Western diets. However, having developed a greater reliance on the sea for nutrients, the Hong Kong ecosystem has become more susceptible to the impact of pollution of the more sensitive and less productive environment of the ocean (see chapter 6).
Referring again to climate as an example of an unpredictable aspect of the wider environment, the Hong Kong ecosystem exerts no control over climatic perturbations which might disrupt its food supply, although its sources of food nutrients are, it seems, sufficiently diverse to buffer the effects of crop failure in any one area of supply. Yet internally, the stability of the Hong Kong ecosystem is being eroded because the trends in energy use are such as to give rise to, rather than protect the community from climatic perturbation (see Chapter 3). Again the policy considerations arising from these discussions are dealt with in detail in the respective sections of the thesis, but suffice it to say here that it is of critical importance that Hong Kong begins to exploit the sources of energy and nutrients continually available from within its own ecosystem. Furthermore, because the renewable sources of energy in the Hong Kong ecosystem can never make up its total requirements, it is important to diversify the sources of the energy it must import from the wider environment. In this manner it will more successfully buffer the effects of impending shortages in energy and key materials.

Although the kinds of policy directions suggested here might be arrived at without referring to concepts of ecology, they stand out clearly as logical alternatives if an ecosystem model of urban planning is adopted. Current practices in the management of the Hong Kong ecosystem are based mostly on market pressures, in other words on economic rather than ecological models.
Economic and ecologic approaches to ecosystem management

Economic models of ecosystem management are markedly deficient in their treatment of renewable resources, and in terms of catering for important biological 'externalities' of resource management. These weaknesses can be illustrated by using information gathered in the course of research in the Hong Kong Programme.

For all intents and purposes, the element phosphorus can be regarded as a non-renewable resource. Phosphorus is momentarily concentrated in the human food system at the loci of urban settlements and thereafter dispersed, particularly into oceanic systems. Phosphorus dispersed in the ocean only finds its way again into human food chains by gradually moving through the various trophic levels, from detritus decomposers to primary and secondary producers, and thus into food chains from which fish for human and animal food is harvested, or from which guano for fertiliser is produced. However, the total amount of phosphorus recycled in this manner is negligible compared with the amount of phosphorus lost. For example, of the 3,500 million tons of phosphorus carried to the sea each year, only about 3% is returned as guano (Cole, 1958). In Hong Kong, 3,600 tons of phosphorus are lost from the food system each year, four times the amount applied in Hong Kong in phosphatic fertilisers, and eight times the phosphate content of imported fertilisers (see chapter 6). However, market forces operate to make it more profitable to import
phosphatic fertilisers than to recycle phosphorous from organic wastes. In fact, phosphatic fertilisers are transported 24,000 kms. to Hong Kong at an energy cost which greatly exceeds the investment of energy required to recycle phosphate from local waste. An ecologic approach to ecosystem management would lead to an appreciation of the importance of the irrevocable loss of phosphorous and would use economic mechanisms to ensure that phosphorous was extracted from the organic wastes which represent a fortuitous concentration point of this element prior to its dispersal.

The waste disposal problem in Hong Kong also illustrates a second major deficiency in the economic approach to ecosystem management. The trend away from the use of organic fertilisers in Hong Kong agriculture (see chapter 5) and towards the use of synthetic chemical fertilisers has been promoted because economic calculations, which only consider the short-term increase in productivity, make the use of chemical fertilisers appear financially sound.

However, these economic calculations do not take into account the ecosystem disruption caused by the disposal of organic wastes into land, freshwater and marine ecosystems. In effect, they do not take into account the cost of rebuilding the soil when its organic structure is depleted, of paying to have pollutants removed, of losses in marine productivity through eutrophication, and of particular importance, they do not account for the costs of the biopsychic maladjustment in the human population caused by
widespread environmental degradation. These factors can be regarded as externalities which an ecological concept of ecosystem management would take into consideration.

The human component

The impact of urban planning on human health and well-being is frequently ignored, yet unquestionably the most important components of a man-made ecosystem are people. Indeed, there seems little point in developing urban planning concepts and strategies for managing the urban environment if the well-being of people is not the prime consideration. Throughout the Hong Kong programme we have stressed the importance of the Hippocratic postulate that human health is ultimately a function of the quality of the environment. In Chapter 8 we have attempted to view the changes in life conditions brought about by high intensities of energy use, and in regard to the principle of phylogenetic maladjustment, we have examined the deviations these conditions represent from those prevailing in the evolutionary environment. We have demonstrated that the kinds of life conditions generated by the 1971 levels of energy consumption in Hong Kong appear to be associated with both well-being and maladjustment in the Hong Kong population.

In another section (see chapter 4), an index of environmental impact has been formulated (the energy exposure index) and is used to show that in the more industrial parts of Hong Kong the impact of energy use on human well-being is likely to be higher than in many major urban areas
of the western world where per capita energy consumption is considerably higher than in Hong Kong. Similarly, we have demonstrated that pollutant densities and climate perturbation resulting from 1971 levels of energy use were considerable (Kalma et al., 1976).

Despite the existing disadvantages of the present high level of energy consumption, a recent paper presented to the engineering society in Hong Kong, stressed the technological feasibility, and economic desirability of increasing energy consumption in Hong Kong fivefold by the year 2000 (Allingham, 1975). The author does not consider the impact of the proposed level of energy use, either on the physico-chemical composition of the Hong Kong environment or on the well-being of the Hong Kong population.

Because it is difficult to objectify changes in the quality of human life brought about by economic growth, assumptions are frequently made that (for example) economic growth, measured by GNP or by energy consumption expressed in joules per capita, are reliable indexes of human well-being. These assumptions are clearly questionable, but to date they have not been systematically challenged. In parts of this study we have attempted to analyse the impact of the changed life conditions in high-energy societies on human well-being and to direct attention towards the establishment of planning and policy making processes that cater more effectively for the well-being of the individual. We have stressed
the value of an ecologic approach to urban ecosystem management because any measures to conserve energy, to recycle materials, to increase ecosystem stability and to diversify and integrate functions of the biotic system generally, are likely in the long run to enhance the quality of life of individuals. Accordingly, a comprehensive inventory of the flow of energy and key materials in the urban environment, made with a view to increasing the "maturity" of the urban ecosystem is, of itself, likely to be beneficial. Nevertheless, it is possible to improve the technical efficiency of the ecosystem without enhancing the quality of life. For example, an adjustment to a particular machine may improve the efficiency with which it uses energy, but retain unchanged its deleterious effect on individual well-being. So the ecosystem approach to increasing human well-being in urban settlements is not an alternative, but a complementary approach to the evolutionary perspective of the conceptual framework applied in the Hong Kong Human Ecology Programme. We are in the very early stages of a movement towards alternative, people-orientated, ecosystem management. Hopefully the future will see not only a refinement of theory, but also opportunities to implement changes in the management of contemporary urban ecosystems.
REFERENCES


ENERGY USE IN TWO LARGE CITIES: A COMPARISON OF HONG KONG AND SYDNEY, AUSTRALIA

J. D. KALMA

Division of Land Use Research, CSIRO, Canberra City, A.C.T. (Australia.)

and

K. J. NEWCOMBE

Urban Biology Group, Australian National University, Canberra City, A.C.T. (Australia.)

(Received April 5, 1975)

INTRODUCTION

Recent United Nations predictions indicate that by 2000 AD 85 percent of the population of developed countries will live in metropolitan areas. This continuing accumulation of people in urban areas has led to a growing awareness of the need for comprehensive multi-disciplinary studies of how cities function. Many studies are now made of the interplay between the natural environment and the cultural and behavioural environment in human communities. Although the majority of important factors and processes cannot readily be described in quantitative terms, certain components of the urban system such as energy flow do lend themselves to quantitative analysis.

Energy use has become an all-embracing factor in modern societies and the accelerating rates of power consumption in most developed countries are well known. International energy crises and environmental conflicts associated with energy use, have drawn attention to the general lack of understanding of the role of energy in increasingly urban societies.

Odum and several authors have discussed the concentrated flow of energy into industrial cities. They point out however that few comparative studies have been carried out on the energetics of urban communities, although much work has been done on energy budgets of countries or natural and agricultural ecosystems. Most published studies are of a broad input–end-use type at a national level. Rappaport and Kemp have studies the energetics of small isolated communities.

Proper management of energy, from its source to ultimate sink is the predominant energy problem and it requires, as Hafele has pointed out, "a thorough investigation of energy in all its complex interrelations with the biosphere." Only in that way can progress be made towards conservation of energy and minimization of abuse of the environment from energy use.

A key factor in energy conservation is improvement in the efficiency of fuel use. In order to determine efficiency and the impact of its improvement on reducing demands, one must know the actual processes of fuel use, their efficiency and the quantities of fuel involved. This is a particularly demanding task in the urban environment.

Domestic and commercial buildings and transportation are major users of energy especially in cities. Here exist, therefore, through building design, town planning and selection of urban transportation systems, potentially important areas for energy conservation and for reducing the environmental problems resulting from energy use.

In this paper we report on energy use in the metropolitan areas of Hong Kong and Sydney.
Australia. Although some data are available on energy use in several major cities in Europe and North America, information on how such data have been obtained is rarely provided. A major objective of the present inventory-type study is therefore to arrive at and discuss methods and assumptions which may be used elsewhere. This study also discusses for the first time the spatial distribution of energy use in major cities and its seasonal and diurnal variation. With methods and techniques common to both study areas, inter-city differences in patterns of energy use are highlighted, thus stressing the need for similar studies for specific cities elsewhere.

This report is based on detailed studies by Kalma et al.8 in the Sydney Statistical Division and by Newcombe in the Crown-Colony of Hong Kong. Although these studies have much in common, they are part of two different programs. The general aim of the Hong Kong Urban Ecology Program is to describe the system and population ecology of man in the urban environment of Hong Kong. The Sydney study is part of an urban climatology program on the inadvertent modification of the urban atmospheric environment, a study which resulted in a recent paper by Kalma in which the possible contribution of waste heat disposal to Sydney's urban heat island is studied with numerical simulation techniques.

In a subsequent paper we shall report on a study of some of the more important interactions between energy use and the urban atmospheric environment in Hong Kong, in particular sulphur dioxide pollution from the use of industrial fuel oil, carbon monoxide pollution from road transport and the impact of waste heat disposal on urban climate.†

Work is currently also in progress by one of us (K.J.N.) on the interrelations between energy use and the bio-social environment of Hong Kong.

BACKGROUND INFORMATION ON STUDY AREAS

a. Sydney

Sydney (lat. 34°S) is Australia's largest city and capital of the State of New South Wales. Situated on Australia's east coast, the Sydney Statistical Division (SSD) had in mid-1971 a total population of 2.9 million people, which is 22.5 percent of the Australian population and 59.5 percent of that of New South Wales. The land area of the SSD is 4072 km², 35 percent of which is urban. Less than 10 percent of the total population live outside the urban area. The SSD comprises 42 Local Government Areas (LGA) ranging from 6 to 513 km² in area and from 50 to 7200 persons/km² in population density. Sydney is moderately industrialized and the SSD is a discrete demographic entity.

b. Hong Kong

Hong Kong (lat. 22°N) is located on the south coast of China, extending into the South China Sea. Its population in March 1971 was 3.9 million people of whom about 80,000 were living on boats. Hong Kong's land area including the New Territories is 1046 km². There are 253 islands, the largest ones being Hong Kong Island, Lamma Island, and Lamma Island. Urban areas with more than 88 percent of the Hong Kong population comprise 146 km² or 14 percent of the total land area of the Colony. In the present study Secondary Planning Units (SPU) ranging from about 1 to 38 km² and from 637 to 141,000 persons/km² in population density served as subdivisions of the urban areas of Kowloon and Hong Kong Island. In the New Territories and other rural areas combinations of secondary and tertiary planning units have been used, ranging from 1 to 221 km² and from 100 to 19,000 persons/km² in population density.

The selection of Hong Kong for the present study followed the recognition of several factors. Firstly, the Colony is a discrete geographical, political, economic and demographic entity. Secondly, excellent statistical records have been kept for long periods by most government departments in Hong Kong. Thirdly, the Colony offers an extreme range of population densities. Lastly, Hong Kong's experience in recent years is relevant to many rapidly urbanizing and industrializing countries in Asia.

TOTAL ENERGY USE IN SYDNEY AND HONG KONG

All Australian data given in this paper refer to the period 1/7/70-30/6/71 (i.e. the Australian financial year). The Hong Kong data are based on the calendar year 1971. Units of energy used are megajoules (MJ). Local Australian and Hong
Kong gross calorific values have been used for each fuel. It should be noted that hydro-electricity has been expressed as the inherent heat value of the generated electricity.†

Australia used $19,640 \times 10^6$ MJ in primary energy in 1970/71 with black and brown coal (44 percent) and crude oil (49 percent) as the major sources of energy. Thus per capita energy use in 1970/71 was about $165 \times 10^3$ MJ/ha/yr. The State of New South Wales in 1970/71 consumed $8030 \times 10^6$ MJ or $170 \times 10^3$ MJ/ha/yr. Coal provided 58 percent of its energy and petroleum products 40 percent.10,11

Total imports of energy into the Sydney Statistical Division excluding bunker (in 1970 were $2712 \times 10^6$ MJ, with crude oil accounting for 74 percent, coal and coke for 14 percent and thermal electricity for 10 percent. However, $238 \times 10^3$ MJ were re-exported as refined petroleum products from its three refineries. Thus net use was $2474 \times 10^6$ MJ or $88 \times 10^3$ MJ/ha/yr. Conversion losses and usage at power stations and transmission losses were $72 \times 10^6$ MJ and conversion losses and in-plant usage of town gas were $51 \times 10^6$ MJ. Finally, losses at the three oil refineries were $312 \times 10^6$ MJ. Thus $2039 \times 10^6$ MJ was available for use in industry, commerce, transport and the domestic sector.6

Net imports of energy into Hong Kong (excluding bunker) in 1971 were $1247 \times 10^6$ MJ or about $32 \times 10^3$ MJ/ha/yr. Refined petroleum products dominate energy imports (98 percent). Conversion losses and usage at power stations and electricity transmission losses amounted to $481 \times 10^6$ MJ. Similarly, conversion losses and usage at gasworks and reticulation losses were about $9 \times 10^6$ MJ. Thus $757 \times 10^6$ MJ was available for distribution to industry, transport, commerce and the domestic sector.

When comparing these two cities it should be noted that Sydney is dependent on thermal electricity generated outside the Sydney Statistical Division. In fact 84 percent of all SSD electricity is generated elsewhere in thermal power stations and 12.5 percent is imported hydro-electricity. Thus losses incurred elsewhere in converting coal and fuel oil into thermal electricity for SSD use have not been considered above. They amount to $680 \times 10^6$ MJ. In a closed system this would have increased per capita energy consumption from 68 to about $120 \times 10^6$ MJ/ha/yr. Hong Kong on the other hand generates all its own electricity but has no refineries. Energy losses incurred elsewhere in refining petroleum products used in Hong Kong are about $225 \times 10^6$ MJ. If Hong Kong had been self-sufficient in refining capacity, per capita energy use would have increased from 32 to around $40 \times 10^3$ MJ/ha/yr.

United Nations data12,13, indicate that per capita energy use in Australia is about half the North American figure and similar to the figures for U.K. and the Netherlands. Within the Asian region, Hong Kong has the third highest per capita energy consumption behind Japan and Brunei, surpassing Singapore ($26 \times 10^3$ MJ/ha) and South Korea ($24 \times 10^3$ MJ/ha by same margins. Hong Kong is experiencing a rapid growth in energy use. Its annual growth rate over 1964-71 was 8.9 percent, compared with 2.3 percent in Australia over the same period.10 Per capita figures for Australia ($165 \times 10^3$ MJ/ha) and the State of New South Wales ($170 \times 10^3$ MJ/ha) are very similar. However, they are twice as high as the figure for the Sydney Statistical Division. This is due to the fact that Sydney imports virtually all its electricity, whilst most of the New South Wales heavy industry is located outside the SSD.

A detailed breakdown of total end-use of individual fuels and total use by each consumption sector for the SSD and Hong Kong is given in Tables 1a and 1b respectively. Although most heavy, energy-intensive industries in New South Wales are located outside the SSD, industry's share of total energy use in the SSD is considerably greater than in Hong Kong. Hong Kong is a centre of light industry, dominated by the textile industry. The distribution between industry and commerce is not always clear and it is interesting to note that the combined share of industry and commerce in both areas is similar at just over 50 percent. Another feature apparent from Table I is the greater use of coal, coke and town gas in the SSD.

Energy use in the SSD and Hong Kong is compared in Table II with data for a number of other urban and industrial areas and with representative national figures. However, little is known about the methods used in arriving at figures for most of these cities and regions, except for Hong Kong, the SSD and, to a certain degree, Sheffield and Cincinnati. The four national figures, taken from recent U.N. statistics, are undoubtedly accurate.

† For converting from one energy unit to another the following factors are used: 1 MJ = 10^6 J = 947.82 Btu = 238.85 kcal = 0.2778 kWh.
J. D. KALMA AND K. J. NEWCOMBE

### TABLE I

**Effective end-use of energy by fuel and by consumption sector in the Sydney Statistical Division (A) and Hong Kong (B) (× 10^8 MJ)**

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Industry</th>
<th>Commerce</th>
<th>Transport</th>
<th>Domestic</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal, coke</td>
<td>222.6</td>
<td>29.5</td>
<td>4.2</td>
<td>6.3</td>
<td>262.6</td>
<td>12.9</td>
</tr>
<tr>
<td>Town gas</td>
<td>36.9</td>
<td>20.0</td>
<td>—</td>
<td>47.5</td>
<td>104.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Electricity</td>
<td>119.2</td>
<td>50.6</td>
<td>—</td>
<td>135.0</td>
<td>304.8</td>
<td>14.9</td>
</tr>
<tr>
<td>Petroleum products</td>
<td>507.5</td>
<td>119.2</td>
<td>718.5</td>
<td>20.0</td>
<td>1385.2</td>
<td>67.0</td>
</tr>
<tr>
<td>Wood</td>
<td>1.1</td>
<td>—</td>
<td>—</td>
<td>1.1</td>
<td>2.2</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>All fuels</strong></td>
<td>887.3</td>
<td>219.3</td>
<td>722.7</td>
<td>209.9</td>
<td>2099.2</td>
<td>100</td>
</tr>
<tr>
<td>%</td>
<td>43.5</td>
<td>10.8</td>
<td>35.4</td>
<td>10.3</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

**B. Hong Kong (1971)**

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Industry</th>
<th>Commerce</th>
<th>Transport</th>
<th>Domestic</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal</td>
<td>0.79</td>
<td>3.13</td>
<td>—</td>
<td>3.91</td>
<td>7.83</td>
<td>1.0</td>
</tr>
<tr>
<td>Coal, coke</td>
<td>10.15</td>
<td>4.77</td>
<td>—</td>
<td>11.92</td>
<td>11.92</td>
<td>1.6</td>
</tr>
<tr>
<td>Town gas</td>
<td>0.9</td>
<td>3.85</td>
<td>—</td>
<td>5.41</td>
<td>10.19</td>
<td>1.3</td>
</tr>
<tr>
<td>Electricity</td>
<td>72.79</td>
<td>63.99</td>
<td>0.56</td>
<td>42.78</td>
<td>130.12</td>
<td>22.8</td>
</tr>
<tr>
<td>Petroleum products</td>
<td>147.88</td>
<td>97.16</td>
<td>216.11</td>
<td>81.34</td>
<td>547.49</td>
<td>71.7</td>
</tr>
<tr>
<td>Wood</td>
<td>—</td>
<td>—</td>
<td>4.49</td>
<td>4.49</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td><strong>All fuels</strong></td>
<td>232.54</td>
<td>169.90</td>
<td>216.67</td>
<td>137.93</td>
<td>757.04</td>
<td>100</td>
</tr>
<tr>
<td>%</td>
<td>30.7</td>
<td>22.4</td>
<td>28.6</td>
<td>18.2</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Energy use figures in Table II have been given on a per capita basis and on a unit area basis. The table has been arranged according to decreasing population density. Several significant points emerge from inspection of the table. Firstly, although intensity of energy use generally decreases with decreasing population density, differences between countries confound this general pattern. Thus it is not surprising that, despite their lower population densities, New York City exceeds Sheffield and Cincinnati exceeds Hong Kong in energy use per unit area. Secondly, important

### TABLE II

**Energy use in selected countries, regions and cities**

<table>
<thead>
<tr>
<th>Country, region or city</th>
<th>Reference</th>
<th>Year</th>
<th>Population density (persons/km²)</th>
<th>Energy use $10^4$ MJ/10^6 TMY $10^8$ MJ/km² TMY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheffield</td>
<td>14</td>
<td>1952</td>
<td>10417</td>
<td>58</td>
</tr>
<tr>
<td>New York City</td>
<td>15</td>
<td>1965</td>
<td>9693</td>
<td>150</td>
</tr>
<tr>
<td>West Berlin (urban)</td>
<td>16</td>
<td>1967</td>
<td>9829</td>
<td>68</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>this study</td>
<td>1971</td>
<td>3272</td>
<td>52</td>
</tr>
<tr>
<td>Cincinnati (urban)</td>
<td>17, 18</td>
<td>1963</td>
<td>2513</td>
<td>338</td>
</tr>
<tr>
<td>Hamburg (urban)</td>
<td>19</td>
<td>1965-70</td>
<td>2410</td>
<td>165</td>
</tr>
<tr>
<td>Los Angeles (urban)</td>
<td>19</td>
<td>1965-70</td>
<td>2000</td>
<td>331</td>
</tr>
<tr>
<td>Ruhrgebiet</td>
<td>16</td>
<td>1965-70</td>
<td>1932</td>
<td>277</td>
</tr>
<tr>
<td>Outer New York</td>
<td>15</td>
<td>1965</td>
<td>1057</td>
<td>145</td>
</tr>
<tr>
<td>New Jersey</td>
<td>15</td>
<td>1965</td>
<td>835</td>
<td>256</td>
</tr>
<tr>
<td>Sydney (Stat. Div.)</td>
<td>8</td>
<td>1970-71</td>
<td>688</td>
<td>88</td>
</tr>
<tr>
<td>Fairbanks (urban)</td>
<td>19</td>
<td>1965-70</td>
<td>508</td>
<td>733</td>
</tr>
<tr>
<td>Nordrhein-Westfalen</td>
<td>16</td>
<td>1965-70</td>
<td>499</td>
<td>264</td>
</tr>
<tr>
<td>West Germany</td>
<td>12, 13</td>
<td>1972</td>
<td>238</td>
<td>167</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>12, 13</td>
<td>1972</td>
<td>222</td>
<td>159</td>
</tr>
<tr>
<td>United States</td>
<td>12, 13</td>
<td>1972</td>
<td>22</td>
<td>244</td>
</tr>
<tr>
<td>Australia</td>
<td>12, 13</td>
<td>1972</td>
<td>2</td>
<td>172</td>
</tr>
</tbody>
</table>
differences exist between cities and regions in the same country, both per capita and per unit area. For example in West Germany per capita use in the industrial province of Nordrhein-Westfalen is about four times and energy use per unit area one-fifth of that in residential West Berlin. Similarly, in the USA per capita energy use in New York City is less than half and energy use per unit area more than twice that in Los Angeles. Thirdly, per capita figures for the four countries given in Table II all exceed per capita use in individual cities, with the exception of Fairbanks and possibly Hamburg. The reason for this is that heavy energy-intensive industries such as iron and steel works, chemical factories and major power stations are almost all located outside urban areas, as is of course the energy-intensive mining industry. This fact is borne out by comparing energy use per capita in the industrial regions of Ruhrgebiet and Nordrhein-Westfalen with the West German national figure. Finally, the particular position of the SSD and Hong Kong in this international comparison should be noted. Per unit area use in these urban areas is exceeded by all other cities. The same is true on a per capita basis, except for the low figure for Sheffield in 1952.

Spatial differences in energy use within cities are considerable and they hinder objective intercity comparisons, because of the often arbitrary decisions in defining urban areas. In the following section the spatial distribution of energy use in Sydney and Hong Kong is discussed in detail and some of the above-mentioned problems are illustrated.

SPATIAL DISTRIBUTION OF URBAN ENERGY USE

a. Sydney Statistical Division

In the SSD total energy use may be distributed over individual LGAs (shires or municipalities) by averaging population, industrial, commercial and transport activities over each individual LGA. This spatial allocation to individual LGAs of their share in the total SSD energy budget is done by consumption sectors (see Table Ia).

Total domestic energy use was 269.9 × 10^8 MJ. This has been allocated to individual LGAs according to population. Commercial work force data have been used to distribute total commercial energy use (219.3 × 10^8 MJ) to individual LGAs according to the size of the commercial work force in each area. The monetary value of power, fuel, light, oils and water used by industry in each area was available and, considered as proportional to total industrial energy use in these areas, was then used to distribute 387.3 × 10^8 MJ. This distribution was later found to be in good agreement with recently released data on total industrial energy use in each LGA during 1971/72. 96 percent of all transport energy was used in road transport. Total transport energy was therefore assumed to be proportional to road traffic volume in individual LGAs. Because no adequate spatial data were available on traffic volume, three years of traffic accident statistics were used for individual LGA's to allocate total energy use in transport of 722.7 × 10^8 MJ. Point losses of energy in conversion and through usage at power stations, gasworks and refineries have been allocated to the appropriate LGA's (399.8 × 10^8 MJ). Total transmission and reticulation losses (34.8 × 10^8 MJ) were included in the final spatial distribution and allocated on a total area basis.

The average intensity of energy use in the SSD in 1970 was 0.61 × 10^9 MJ/km^2/yr. Calculations for individual LGA's show that it ranges from 0.02

FIGURE 1 Spatial distribution of artificial heat generation in the Sydney Statistical Division in 1970. (1: City of Sydney 2: Leichhardt; 3: Camdem)
in rural Camden to $15.58 \times 10^8$ MJ/km²/yr in the City of Sydney. The complete spatial distribution of 1970 artificial heat generation in the SSD is shown in Figure 1. An important shortcoming of this very simple allocation technique is that many LGA's cannot be regarded as areas with even distribution of population or commercial and industrial activities. Furthermore, no independent checks on this estimation method are available.

b. Hong Kong

In Hong Kong 75 percent of all electricity used for domestic purposes could be allocated to individual areas on the basis of actual consumption data. The remaining 25 percent was allocated on the basis of population density. The resulting total distribution of domestic electricity was subsequently applied to town gas and those other fuels used for domestic purposes where the actual distribution was not known. All electricity used for non-domestic purposes was distributed on the basis of information on electricity use by area and consumer category, and detailed land use maps. This distribution of electricity use for non-domestic purposes (expressed as percentage of sector-total for each area) was subsequently used for allocating the use of several other non-domestic fuels. Information on spatial distribution of town gas use was available from the supplier. The Colony's Air Pollution Control Unit provided information on the location of and use by industrial consumers of fuel oil, which accounted for 61 percent of total fuel oil use. The balance was allocated as per commercial (4 percent) and industrial (35 percent) electricity use. The total domestic, commercial and industrial use of kerosene, LPG, coal, coke and charcoal is known. The spatial distribution of domestic use of all these fuels is assumed to follow population density. Their commercial and industrial use follows that of electricity use. Gas oils, diesel fuels and distillates not used in transportation were allocated according to known individual consumers and the balance according to the spatial distribution of commercial and industrial electricity use. Energy use in road transport was allocated according to traffic volume data for 270 check points from the Colony's Traffic Survey Division. Marine use was allocated to Victoria and Aberdeen Harbours on the basis of data on marine activity and fuel-supply. Energy use in rail transport use followed traffic density along fixed routes. Energy use in aviation both on the ground and in Hong Kong air-space was distributed on the basis of flight information and statistics on aircraft movements.

The average intensity of energy use in Hong Kong in 1971 was $1247 \times 10^8$ MJ or $1.19 \times 10^8$ MJ/km²/yr. This is nearly double the SSD value although energy use per capita in Hong Kong is only $32 \times 10^3$ MJ/hd/yr compared with a SSD value of $88 \times 10^6$ MJ/hd/yr. The spatial distribution of artificial heat generation in the Colony of Hong Kong is shown in Figure 2. Outside urban Hong Kong and Kowloon, values of $0.4 \times 10^8$ MJ/km²/yr are exceeded only in more densely populated areas such as Yuen Long and Tai Po. In the urban area of Hong Kong Island artificial heat generation reaches values of about $22 \times 10^8$ MJ/km²/yr in the Central, Wan Chai and North Point/Quarry Bay areas. The high value for Tsing Yi Island is due to the big power station on that island. A maximum value of nearly $110 \times 10^6$ MJ/km²/yr is obtained in the Hung Hom/Tok Kwa Wan area, where population density is close to 100,000/km², and where a major power station and gasworks are located.
c. Comparison with New York/New Jersey

Unfortunately studies on the spatial distribution of energy use in other cities have rarely been reported in the literature and relevant information which could have been used for comparative purposes is therefore virtually not available, with one recent exception. In Table II reference was made to a report by the U.S. Department of Health, Education and Welfare\(^5\) on air pollution abatement activities in the New York/New Jersey area. The report contains data on the use of the seven major fuels for 1965 in nine counties in New Jersey, five counties in New York City and three counties in New York State. Appropriate U.S. caloric values of bituminous coal, anthracite, fuel oil distillate, residual fuel oil, natural gas, gasoline and diesel distillate were used to arrive at total energy use in $10^8$ MJ/yr for each of the 17 counties. These values were converted into intensity of energy use in $10^8$ MJ/km²/yr. Figure 3 shows the 1965 spatial distribution of artificial heat generation in units of $10^8$ MJ/km²/yr in the New York/New Jersey region based on these data.

Values in New Jersey range from 0.5 in rural Somerset to 46 in urban Hudson. In New York City values are shown to range from three on Staten Island to 50 in Manhattan, whereas in outer New York values range from 0.7 to $2.6 \times 10^{10}$ MJ/km²/yr.

A comparison of the intensity of energy use in the SSD, Hong Kong and the New York/New Jersey region shows a similarity in the range of values between the SSD and New Jersey and between Hong Kong and New York. The maximum value of annual energy use/km² in Kowloon however exceeds that of Manhattan by a factor of two.

As shown in Table II the energy use per capita in New Jersey, New York City and outer New York is 256, 150 and $145 \times 10^8$ MJ/hd/yr respectively, which is considerably less than the U.S. national average of $344 \times 10^8$ MJ/hd/yr. The general implications of this difference between urban and national per capita use have been discussed above. Here it suffices to state that the spatial variation in unit area energy is greatest in Hong Kong and smallest in New York/New Jersey. Such variation is of course closely linked with the distribution of major point-uses. It also reflects variation in economic and industrial activity, transport and personal affluence.

TEMPORAL DISTRIBUTION OF ENERGY USE

2. Seasonal

In places with distinct seasons and significant annual temperature variation, it is obviously important to assess the seasonal variation in energy use. Its magnitude in relation to that of the driving force of the natural energy balance at the earth’s surface, the incoming solar radiation, is important in that it gives a first order impression of the impact of waste heat disposal on urban climate. The information on seasonal variation in artificial heat generation is not readily available and several broad assumptions have had to be made in both study areas.

Data on traffic volume and electricity sales to industry for the SSD support the assumption that no seasonal variation exists in energy use in transport and industry. It has also been assumed for Sydney that domestic use of coal, heating oil, kerosene and firewood and commercial use of heating oil, town gas and coal are restricted to the three winter months only and that average daily

FIGURE 3 Spatial distribution of artificial heat generation in 17 counties in the New York/New Jersey metropolitan area based on 1965 data published by U.S. Dept. of Health, Education and Welfare.\(^5\)
(1: Manhattan; 2: Staten Island; 3: Hudson; 4: Somerset.)
use of these fuels throughout winter is constant. The seasonal distribution in domestic and commercial use of electricity is estimated from records of electricity sales. Domestic use of gas and commercial use of fuel oil and diesel fuel over the year is estimated according to the seasonal variation in electricity use by those sectors.

On the basis of the above assumptions total energy use in the Sydney Statistical Division has been estimated for an “average” day in July (mid-winter) and in January (mid-summer). Estimates have also been made for one average and two extreme LGAs: Camden (rural), Leichhardt (industrial) and the City (Central Business District). Table III shows these estimates. It also shows energy use expressed as a percentage of average incoming solar radiation. This percentage ranges from 0.02 percent in January for Camden to 49.1 percent in July for the City of Sydney. With only 20 percent of total energy use in the SSD in the domestic and commercial sector and with the increasing importance of air-conditioning in summer, it is surprising to note from Table III that the differences between summer and winter are considerable, especially when compared with solar radiation. Energy use differences are largest in residential Camden, intermediate in the city with its limited industry and rapidly increasing air-conditioning in summer and smallest in industrial Leichhardt. The B/A differences are of course much greater because of the opposite fluctuations in solar radiation. It should be added that variation between days of the week has not been considered.

In Hong Kong seasonal load curves were available for both electricity and town gas for all individual consumption sectors. Seasonal variation was assumed to be non-existent in commercial use of gas oils, diesel fuels and distillates as well as in energy use by rail transport and aviation. Monthly releases from bond were used to estimate seasonal variation in the use of motor spirit in road transport and of industrial gas oils in marine transport. For all other fuels appropriate load curves of electricity and gas were used individually or in combination, to distribute seasonally use by individual consumption sectors. Table IV gives total energy use for average days in the coldest month February and in mid-summer (July) in the whole of the Colony and in four Secondary Planning Units.

<table>
<thead>
<tr>
<th>Region</th>
<th>Surface area (km²)</th>
<th>Winter Energy use (B)</th>
<th>B/A</th>
<th>Summer Energy use (B)</th>
<th>B/A</th>
<th>Year Energy use (B)</th>
<th>B/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney Statistical Division</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camden</td>
<td>205.95</td>
<td>8</td>
<td>0.0008</td>
<td>4</td>
<td>0.0002</td>
<td>6</td>
<td>0.0004</td>
</tr>
<tr>
<td>Leichhardt</td>
<td>12.25</td>
<td>1699</td>
<td>0.173</td>
<td>1430</td>
<td>0.063</td>
<td>1523</td>
<td>0.091</td>
</tr>
<tr>
<td>City of Sydney</td>
<td>23.93</td>
<td>4827</td>
<td>0.491</td>
<td>3992</td>
<td>0.175</td>
<td>4269</td>
<td>0.254</td>
</tr>
</tbody>
</table>

* Long-term averages of mean daily incoming solar radiation for July, January and the year are 9,839, 22,820 and 16,793 × 10^3 MJ/km²/day respectively.

---

**J. D. KALMA AND K. J. NEWCOMBE**

**TABLE III**
The intensity of daily energy use (B) for July, January and the year (in 10^3 MJ/km²/day) compared with total incoming solar radiation (A) in the SSD and three representative local government areas.

<table>
<thead>
<tr>
<th>Region</th>
<th>Surface area (km²)</th>
<th>Winter (July)</th>
<th>B/A</th>
<th>Summer (January)</th>
<th>B/A</th>
<th>Year</th>
<th>B/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney Statistical Division</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camden</td>
<td>205.95</td>
<td>8</td>
<td>0.0008</td>
<td>4</td>
<td>0.0002</td>
<td>6</td>
<td>0.0004</td>
</tr>
<tr>
<td>Leichhardt</td>
<td>12.25</td>
<td>1699</td>
<td>0.173</td>
<td>1430</td>
<td>0.063</td>
<td>1523</td>
<td>0.091</td>
</tr>
<tr>
<td>City of Sydney</td>
<td>23.93</td>
<td>4827</td>
<td>0.491</td>
<td>3992</td>
<td>0.175</td>
<td>4269</td>
<td>0.254</td>
</tr>
</tbody>
</table>

**TABLE IV**
The intensity of daily energy use (B) for February, July and the year in the Colony of Hong Kong and four representative sub-areas (in 10^3 MJ/km²/day), compared with total incoming solar radiation (A).

<table>
<thead>
<tr>
<th>Region</th>
<th>Surface area (km²)</th>
<th>Winter (February)</th>
<th>B/A</th>
<th>Summer (July)</th>
<th>B/A</th>
<th>Year</th>
<th>B/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong</td>
<td>1046</td>
<td>278</td>
<td>0.021</td>
<td>352</td>
<td>0.017</td>
<td>314</td>
<td>0.019</td>
</tr>
<tr>
<td>Hung Hom</td>
<td>2.0</td>
<td>25278</td>
<td>1.877</td>
<td>35657</td>
<td>1.701</td>
<td>29996</td>
<td>1.809</td>
</tr>
<tr>
<td>North Point</td>
<td>4.02</td>
<td>4787</td>
<td>0.355</td>
<td>6427</td>
<td>0.307</td>
<td>5556</td>
<td>0.336</td>
</tr>
<tr>
<td>Kwan Tong</td>
<td>12.95</td>
<td>1573</td>
<td>0.117</td>
<td>1969</td>
<td>0.094</td>
<td>1823</td>
<td>0.110</td>
</tr>
<tr>
<td>South East</td>
<td>38.12</td>
<td>37</td>
<td>0.003</td>
<td>40</td>
<td>0.002</td>
<td>39</td>
<td>0.002</td>
</tr>
</tbody>
</table>

* Long-term averages of mean daily incoming solar radiation for February, July and the year are 13,470, 20,900 and 16,580 × 10^3 MJ/km²/day respectively.
Of the four SPU's given in Table IV Hung Hom is extreme in its population density of about 95,000/km$^2$ and has both a major power station and gasworks. North Point's population density is also very high (about 45,000/km$^2$) but its power station is less important. Kwan Tong is a centre of light industry and has a population density of 35,000/km$^2$. Finally South East, on Hong Kong Island, is rural and residential with a population density of about 500/km$^2$.

Contrary to the SSD, energy use in Hong Kong is greatest in summer, probably as a result of massive use of air-conditioning.

Expressed as a percentage of incoming solar radiation, artificial heat generation on an area basis in the Colony of Hong Kong is larger than that in the SSD, especially in winter. Spatial differences in Hong Kong are less than in the SSD, apart from the one very high value in the Hung Hom area shown in Figure 2.

b. Diurnal

System load curves are available for mid-summer and mid-winter showing the diurnal trend in electricity use by individual consumption sectors in the SSD. These load curves are considered to be indicative of total energy use throughout the day in the industrial, commercial and domestic sectors. The diurnal distribution of energy use in transport was estimated from average two-monthly traffic volume data for a number of representative traffic counting stations in the Sydney area. Total daily counts between stations varied widely but the diurnal distribution of traffic at these stations was remarkably similar. These assumptions enable total energy use by all individual sectors to be distributed for average days in January and July over twelve two-hour periods as shown in Figure 4 for the whole SSD and the same three LGA's as given in Table III. It can be seen that minimum energy use occurs between 1 and 3 a.m., and maximum energy use between 7 and 9 a.m. and between 3 and 5 p.m. A secondary minimum occurs around noon.

For Hong Kong diurnal load curves are available for the electricity supply system in mid-summer and mid-winter without differentiation between individual consumption sectors. Similarly an average diurnal load curve for the whole year is available for town gas. These three curves have firstly been used for total electricity and total gas use. It is assumed that the diurnal distribution in industrial energy use follows closely the electricity load curve for mid-winter, which is free of the additional load from air-conditioning in the domestic and commercial sectors, apparent in the mid-summer curve. Total use of kerosene, LPG and firewood and the domestic use of charcoal is assumed to follow the load curve for gas. Use of fuel oil, coke, coal and the balance of charcoal is all predominantly industrial and is assumed to be similar in its diurnal distribution to the electricity load curve for mid-winter. The non-transport component of medium-weight fuel oils such as gas oils, diesel fuels and distillate, is used in the commercial and industrial sector. The major part of its commercial use is in hotels and restaurants and its diurnal distribution follows known patronization patterns. The balance is distributed evenly over the 7 a.m.–7 p.m. period. The diurnal distribution of energy use in road transport is based on a similar assumption as that made for Sydney, namely that the diurnal distribution in traffic volume for a number of representative counting stations is adequate. Marine transport was assumed to follow a similar pattern. Rail transport and aviation are assumed to use energy throughout average summer and winter days as indicated by their scheduled services.

The mid-summer (July) and mid-winter (February) diurnal distribution of energy use is shown in Figure 5 for the Colony of Hong Kong and three of the four sub-areas referred to in Table IV. The main differences between Hong
CONCLUDING REMARKS

The international comparison of Table II makes it clear that national per capita energy use figures are not directly applicable to individual cities (or regions). It also shows that figures on the intensity of energy use obtained for one city cannot be applied to another city in the same country. The large differences indicate that the geographical location and physical layout of cities, the nature of the activities of their population and the dependence of each urban system on exosomatic energy are often sufficiently different to warrant detailed studies of energy use in specific cities. Such studies have important implications for the supply, distribution and conservation of energy, for environmental control and urban planning and for a better understanding of how cities function.

There is a general lack of comparative data on urban energy use and more significantly, of acceptable and well-defined methods for energy use inventories. This has led to the present comparative study in which the same methods have been used to study energy use, its spatial distribution and its variation in time, in two cities as different as high-density Hong Kong and dispersed Sydney.

Although per capita energy use in the Colony of Hong Kong is just over one-third of that in the Sydney Statistical Division, the mean level of energy use intensity in Hong Kong is nearly twice that in the SSD. Population densities in both areas cover a wide range. This fact, together with the difficulty in properly defining urban areas, provides the rationale for a detailed study of the spatial distribution of energy use per unit area. The results of such analyses appear to be of considerable interest to several disciplines. The socio-economic aspects of energy use in Hong Kong for example are now being studied in the context of recently completed bio-social surveys and one of the main inputs in that study is the spatial distribution of energy use, described in this paper. A study is also in progress of the impact of energy use on the atmospheric environment in Hong Kong, considering air pollution and the disposal of waste heat to the atmosphere.

From an environmental point of view it is obviously important to consider the use and ultimate disposal of energy in the context of the natural energy balance at the urban surface. It is for that reason that the seasonal and diurnal distribution of energy use have been studied in detail in this paper and comparisons have been made with incoming solar radiation, as the driving force of the natural energy balance.

Ratios of energy use to incoming solar radiation for both areas taken in their entirety are shown to be low (1–2 percent), because vast areas of non-urban land are included in the study area. Spatial and temporal differences in both cities, however, are considerable. Mid-Winter daily energy use in the Central Business District of Sydney reaches 49 percent of incoming solar radiation (Table III). Similarly mid-winter daily energy use in Hong Kong's Hung Hom area is nearly twice the daily total of incoming solar radiation (Table IV).

It is obvious that heat rejection of such a magnitude must have a significant impact on regional urban climate. However, not all waste heat is rejected as sensible heat direct to the atmosphere. For example in conventional steam-electric power stations about 85 percent of the waste heat goes out in the cooling water with 15 percent going up the stack as hot flue gas. Many such plants use the once-through water cooling system. Alternatively, waste heat can be transferred to the
air through cooling towers. In the evaporative type cooling tower heat is transferred as latent heat to the atmosphere. In the dry type sensible heat is dissipated by air convection. Similar problems occur in many industrial processes. Thus careful analysis is required of methods of heat rejection before the environmental impact of waste heat can be assessed. Another problem in this context, which deserves more attention, is the delay between use of energy and its ultimate disposal to the atmosphere, for example in space-heating.

So far, this paper has dealt with the use of extra-somatic energy in cities. It is of interest to briefly consider the magnitude of somatic energy, i.e., metabolic heat from humans in both cities. An average person's metabolic energy use in Sydney is about 13.4 MJ/day. About 75 percent of this heat is dissipated by conduction, convection and radiation. With 2.8 million people in the SSD, about $102.5 \times 10^8$ MJ/yr of metabolic heat is therefore dissipated which is almost equal to the total amount of town gas used in the SSD. For humans in Hong Kong an average daily metabolic heat of 11.7 MJ/day has been assumed, allowing for the lower body weight of its Chinese population. Again about 75 percent of this is dissipated in the atmosphere as sensible heat and by radiation. Hong Kong's 3.9 million people thus dissipate $124.9 \times 10^8$ MJ/yr of metabolic heat to the atmosphere, which is comparable with the total use of extra-somatic energy in the domestic sector.

It is interesting to estimate the relative magnitude of metabolic heat dissipation in some of the highly populated Secondary Planning Units, given in Table IV. In North Point 176,500 people live on 4.02 km². They therefore dissipate $385 \times 10^8$ MJ/km²/day or 7 percent of the intensity of all extraneous energy use in that area. A figure of $302 \times 10^8$ MJ/km²/day may be calculated for Kwun Tong, or 17 percent, for an area of 12.95 km² with 446,700 people.

Finally, we wish to draw attention to problems of growth. Per capita energy use in most countries continues to increase and urbanization persists. Jaske²² stated that the environmental side effects of energy use should be considered as a potential limit to metropolitan development. He predicted that in 2000 AD daily energy use in the entire Boston-Washington area will be about 50 percent of incoming solar radiation in winter and 15 percent in summer. It should be noted that Landsberg²³ estimated for North American cities a current annual value of 15 percent and that East²⁴ reported for 1967-68 for Montreal an annual value of 24 percent. As pointed out before, Hong Kong is experiencing rapid growth in energy use with a mean annual increase of about 9 percent reported over 1964-71. Jaskes's suggestion²² that metropolitan dispersal of energy use, people and industrial activity should be considered as part of a solution for the environmental problems caused by the ever-increasing intensity of urban energy use, must thus not be taken lightly, especially if no significant improvements in the efficiency of energy use come about. One should recognize however that in many cases metropolitan de-concentration or dispersal may be constrained by factors such as the general physiography of the region as is the case in Hong Kong, or by high national population densities (the Netherlands). It is also realized that urban dispersal, as in the Sydney Statistical Division, causes urban sprawl with many serious problems such as excessive energy use in transport and communications and in the provision of goods and services.

In conclusion it is therefore important to note that one cannot propose changes without adequate knowledge of the role of one of the key factors in modern urban societies, that is the dependence on and use of energy.

REFERENCES

THE RATIONALE FOR A LOW ENERGY ALTERNATIVE

Ken Newcombe

One of the great drives which led people to participate in the Aquarius Festival at Nimbin, which subsequently added some sizeable communes to those already in the area, was expressed as the need to escape from the bondage of the city. It was not only the pervasive environmental degradation in the cities, but the powerlessness to effect the changes which seemed so essential in one's own life, and absolutely, obviously imperative amongst the cities' dispossessed minorities. To participate in contemporary city life one has inevitably to become a consumer, to be subservient to its materialism, and to simultaneously jettison personal principles of conservation and equity in order to survive.

Unknowingly, in most cases, the search for an alternative was a search for a low energy society, a mode of existence where the impact of the energy controlled by anonymous institutions and individuals was not of such magnitude that it could severely restrict the options of mobility, recreation and creative work available to each person in his everyday life.

*All’s address is Alternative Living Foundation, C. Students’ Representative Council, University of New England, Armidale, 2351.
ENERGY AND HUMAN SOCIETY

One underlying and fundamental variable in contemporary human society is the flow and end use of somatic and extrasomatic energy*. Man, by virtue of being part of the earth’s ecosystem, is as reliant as are all living things on solar energy as the fire of life. Initially man’s mechanical muscle power of up to one horsepower per day was the measure of his impact on his environment, and his ability to do work. This energy, as now, was derived from the metabolic conversion of plant and animal converters at about twenty per cent efficiency. Plants are the prime converters of solar energy and the rate at which they converted energy ultimately determined the carrying capacity for the human species. Solar radiation represents an energy source far, far higher than the demands of industrial man, but his ability to harness its energy has been minimal to date. Total solar radiation entering the earth’s atmosphere is about 1000Q per year and man’s entire demands are currently about 225mQ.†

During the nineteenth and twentieth century man has built himself an immensely complex industrial society by exploiting solar energy stored as fossil fuels over geological time. Now the power that can be wielded by one man over his fellows and his environment is no longer measurable by his muscular strength and that of his subordinates, but by the sophistication of the technology he possesses to convert this stored solar energy into work at a given place and in time. Given the hierarchical nature of industrial and post-industrial institutions, fewer and fewer people control greater and greater amounts of energy. The ultimate example of this is the capacity of the American president to bomb a nation state, Cambodia, for more than eight months before either the American people or their representatives knew about it.

The search for a radically different life style should be made quite consciously in terms of a low energy alternative for at least three reasons, given here in order of increasing importance.

First, the store of convenient oil-based fuels which now make up sixty-one per cent of the world’s total consumption are limited to perhaps thirty years at current and anticipated consumption levels.‡ In that time shortages will probably result from imbalances in production and demand created by international politics and in tapping the known reserves and making them uniformly available in relation to global demand. The technology to use direct solar energy is not well developed. The inevitable establishment of nuclear generators is proceeding slowly because of fears of their long term environmental impact. There is a marked imbalance in the distribution of abundant coal reserves and so too the technology to convert them into liquid and gaseous fuels. Given these situations, the energy crisis we have already experienced may be a common feature of the future.

A dependency on a high energy life style is unwise in such circumstances, but even aspirants to a low energy life style are to some extent caught in the network of dependency on centralised energy systems and are therefore equally affected by the brown-outs caused by the demands of those who have chosen to consume regardless of the resource situation.

Secondly, the use of energy in particular forms and in particular ways has a proven biological impact on the human species. The combustion of coal, fuel oils and middle weight oils releases sulphur oxides which act as irritants for sensitive membranes in the eyes, throat and lungs often causing severe respiratory problems. The combustion of motor transport fuels gives rise to carbon monoxide, lead oxides and various unburnt hydrocarbons and particulate matter. Dangerous emissions of these by-products of energy use can come especially from major points of high emission such as power stations, public incineration plants and so on. Combined with emissions from motor transport, they give rise to the familiar photochemical inversions in Australian cities and the admixture of gases which can form dangerous levels of ozone and complex carcinogens. The urban climate is significantly modified by the generation of artificial heat from human activities.§

In Sydney on a mid-winter’s day the heat generated by human activities is often more than half the total incoming solar radiation.¶ A full review of the studies relating air pollution to health problems in the United States concluded that twenty to fifty per cent of morbidity and mortality from bronchitis,

---

* Somatic energy: 'That energy which is utilised, through the metabolic processes, within a living organism.'
** Extrasomatic energy: 'That energy which flows through or is utilised by a human community and which is not utilised through metabolic processes within a living organism.'
§ H. H. Lansberg, in the study of climatic changes in the new Washington suburb of Columbia, as cited in Mordy, WA; 1972.
¶ 'Energy and the Biosphere' presented to 'Energy, Man and Environment' seminar, February 3rd–5th, 1972, Gottlieb Duttweiler Institute for Economic and Social Studies, Zurich, Switzerland.
twenty-five per cent from lung cancer, twenty per cent from all other respiratory diseases and twenty per cent from cardiovascular disease could be alleviated by a fifty per cent reduction of air pollution at a public health expenditure saving in 1971 of a minimum of $U.S.2,080,000,000*.

A useful guide to the environmental degradation of an area is the intensity of energy use per unit area. Certainly the more energy used per unit area, the higher the rate of change in the environment is likely to be. I propose a further index which is perhaps of greater significance to the biology of man and that is the ratio of population density to energy use per unit area. In Hong Kong over an urban area of roughly the same energy intensity as the peak intensity found in Sydney, the ratio of population density to intensity of energy use is over five times higher†.

Thirdly, the social impact of energy use is little understood, and may have the most serious long-term effects. Contemporary industrial societies have developed institutions which have a stifling momentum, are resistant to change from within and are of such great proportions that change from without requires considerable concerted, selfless, effort which makes the task an improbable one to achieve. They have created a social environment which Emery calls the ‘turbulent environment’‡. He describes them as environments ‘that are likely to follow their own lines of action regardless of the size or shape or direction of the input of the individual organisation’. In regard to the bureaucratic exploitation of inanimate (extrasmotic) energy Emery states ‘it has sapped and undermined our ability to resolve the business, to map and determine our own futures’§. Emery’s thesis is supported by Illich who says that ‘high quanta of energy degrade social relations just as inevitably as they destroy physical milieu’.||

High energy societies deny equitable participation and deprive the energy-less members of the population the right to effect changes meaningful in terms of their own life styles. It elevates the traditional edict of consumerism, viz. ‘a second car and a colour television will enhance my personal well being’, one order of magnitude higher or ‘what fuels the production and drives the mechanical genius of the products I believe I

---

† As yet unpublished research by K. Newcombe on the spatial distribution of artificial heat generation in Hong Kong as part of the Hong Kong Human Ecology Programme of the Urban Biology Group, Australian National University.
need, it is necessary to have now, and to proliferate in perpetuity'. Unthinkingly they are justifying the politicians' quest for more energy despite its unproved worth and disproportionate social costs.

The acquisition of one more appliance is the acquisition of one more 'energy slave' to do work which most people can already competently handle. The purchase of the energy slave implies a commitment to purchase its energy requirements, which means a vested interest in the continued supply of that energy and an implied dependence for well-being on the continued exploitation of energy resources. As each family gains possession of another energy slave, not only do they become more reliant on its energy requirements, they become potentially subservient to the services it provides. For the danger exists that they will lose the tools and information to undertake the task it performs when it is unable to be employed.

It is in this manner that the so-called energy crisis creates the illusion of a real energy crisis and there seems to be only one option—to find more energy.

The biological significance of the individual use of energy slaves is either unknown or poorly understood. It may be that in the greatly changed environment of some urban areas the use of particular energy slaves may be adaptive for the individual. In Hong Kong a television and a phone facility may maintain the otherwise disrupted family communication and serve to psychologically expand the otherwise extreme physical densities. At the same time the use of a combustion engine for transportation which releases toxic emissions in a densely populated area, creates additional noise, and competes for space with the human beings, may be maladaptive.

Even though the impact on the individual of various patterns of energy use is not well known, the historical trends show an ever increasing per capita consumption of energy. Paleolithic man, some 500,000 years ago, repeatedly lost and found and finally secured, the ability to make fire, which raised the per capita energy consumption from no more than 2500 Kcal per day from food energy to 4500 Kcal per day with the combustion of firewood*. The neolithic revolution of 6,000 to 8,000 years ago brought about the domestication of plant and animal converters of energy and probably raised the level of per capita consumption to 12,000 or 15,000 Kcal per day. It is suggested that at the height of the low technology industrial era around 1850, the daily per capita consumption was 70,000 Kcal in England, Germany and the United States. Now the United States consumption of fossil fuels is 224,000 Kcal per capita per day and Australia's is 109,000 Kcal per capita per day compared with that of the non-industrial states of Burma and Nepal with only 1,300 Kcal per capita per day and 196 Kcal per capita per day respectively. The growth rate in energy consumption in Australia is currently greater than two and a half per cent per annum.

The efficiency of food production follows the same sort of trends. Hunter-gatherers and early Neolithic peoples obtained a return of up to twenty units for each unit of energy invested in food gathering or swiddenist agriculture. Contemporary Western agriculture requires an investment of four to five units of energy to provide one unit of energy available for consumption at the consumer's table. It is obvious that an exponential growth in energy consumption is not sustainable in the long term. Nevertheless, the proponents of increased energy consumption consider that the temporary energy crisis we have suffered was simply a delay in fulfilling the ultimate goal of a doubling time in energy consumption of ten to twelve years. The long term impact of such exponential growth begins to look foreboding when estimates are made about the amount of energy consumed in proportion to the total flow of energy in the biosphere. If one only considers the current growth rates of United States electricity consumption, assuming that the heat it generates upon utilisation is distributed evenly over the U.S., then in one hundred years the rate of heat release per annum from this source alone will be equal to the incoming solar radiation from the sun in the same period. With the dramatic changes in urban climate from artificial heat sources already documented, the release of heat of this magnitude could have far-reaching effects on the global climate.

---

¶ Richard Love, with reference to his statement on 'the return to a 10-12 year doubling time', N.Y.T.S. in South China Morning Post, 12th November, 1973. He was then Chief Adviser on energy matters to President Nixon.
After documenting potential sources of energy and providing an optimistic picture of future energy availability, Hubbart concludes that an exponential growth is impossible, if only because of the limiting factor of places to locate power plants.  

So at best the quest for more energy from all the potential alternative sources is filled with hazards and contradictions. We must ask, as does Luten, 'Is the correlation between increasing energy use and human welfare good enough and is the hypothesis that more energy means a better life plausible enough to warrant any hopeful extrapolation?'

In the Hong Kong Human Ecology Programme we developed an hypothesis early in 1973 which reads 'that above a certain level of per capita energy consumption for a given environment, any additional amount of energy consumed will not be of additional benefit in terms of the health and well being of the individual concerned' or alternatively 'that the additional amount of energy consumed will be of positive disadvantage to the individual and his society'. More recently Lllich came to a remarkably similar conclusion when he says 'that beyond a certain median per capita energy level, the political system and cultural context of any society must decay. Once the critical quantum of per capita energy is surpassed, education for the abstract grasping of a bureaucracy must supplant the legal guarantees of personal and concrete initiative. This quantum is the limit of social order.'

It is abundantly clear that at some time in the future the per capita consumption of energy must fall or obtain a constant sustainable level in line with the environmental parameters that will restrict a further growth in its consumption. It would seem absurd to blunder on into the middle distance in the hope that we will arrive at such a level by trial and error, for the cost of a higher energy society in physical and social terms is already demonstrably high. What must be done is to assess the real and illusory seeds of an energy subsidy to muscle power in each of the changed environments which man has built and from which he cannot easily retreat, and to base the criterion of energy use around the goal of equity in a genuinely participatory democratic society. The determination of a desirable level of per capita energy consumption for each human environment will not only be difficult to obtain but difficult to implement. This is particularly so given the compulsive urge of the Western populace to follow the seductive wooing of the industrial complex and participate in overt materialism that is neither conservative of matter nor energy. However daunting the task may be, it is necessary to make a start.

ENERGY IN RURAL COMMUNES

In Australia, many rural communal life styles resulted from a feeling that a shift to the land was essential in order to develop an alternative in an unharrassed, less intense environment. Although I participated in the Nimbin experience and have visited small communes in the Mullumbimby area, I have not been able to follow up the post-Nimbin festival developments and therefore am unable to discuss actual commune practices. Nevertheless, a general approach to low energy alternatives should still be applicable and viewing the specific example of alternative food production in energy terms may be instructive.

The Table is a comparison of intensively-farmed crops using high energy subsidy western agricultural techniques. Data from the production of potatoes in the United Kingdom is presented along with data for corn production in the United States. The energy subsidies applicable to Australian agriculture are available from quite detailed research but are applicable to the entire agricultural production rather than solely intensive farming methods, hence the U.K. and U.S. data are of more use for this exercise. In both cases the inputs for transportation from the farm gate to the consumer's table have been deleted from the comparison. The examples are compared with the energy subsidies required from a commune farming an acre of ground sown with mixed vegetable crops. The season is taken to be four months and the inputs and yields are considered for that period. Footnotes explain the entries in the alternative farming column and explain the potential saving for each item of inputs.

It can be seen that a considerably higher labour input is allocated for the alternative form than for the others. This is based on the assumption that a communal farm will engage most members of the

---

THE RATIONALE FOR A LOW ENERGY ALTERNATIVE

<table>
<thead>
<tr>
<th>Energy units in 1,000 Kcals per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Labour</td>
</tr>
<tr>
<td>Machinery</td>
</tr>
<tr>
<td>Gasoline</td>
</tr>
<tr>
<td>Electricity</td>
</tr>
<tr>
<td>Nitrogen</td>
</tr>
<tr>
<td>Phosphorous</td>
</tr>
<tr>
<td>Potassium</td>
</tr>
<tr>
<td>Seeds</td>
</tr>
<tr>
<td>Irrigation</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
<tr>
<td>Yield</td>
</tr>
<tr>
<td>Kcal return/Kcal input</td>
</tr>
</tbody>
</table>

1.1 Taken as labourers needing 21,770 Kcals per week and working for forty hours. At that rate one hour of work requires a somatic energy input of 544.25 Kcals. Assuming that 120 hours of manual work are required for manual preparation of one acre of ground and three hours daily for 120 days to irrigate, weed, protect and otherwise maintain and finally harvest the crop, then 489 hours × 544.25 Kcals = 261,240 Kcals.

1.2 Assuming that 120 lbs of metal implements are required to work one acre of land: that they have a life of use or loss of ten years; that they require 9,400 Kcals per pound to manufacture based on (†) and that maintenance is part of the labour costs, then one crop of four months requires one third of the energy network inputs, or 9,400 × 120/30 = 37,000 Kcals.

1.3 Assuming no mechanisation involving motor driven equipment no gasoline will be utilised in the agricultural production.

1.4 Assuming that no electricity will be used in agricultural production other than minimal domestic requirements.

1.5 Assuming that composting of organic wastes from the household with added leaf mulch and so on is used to add humus to the soil. Assuming that wherever possible poultry, pig, cow and other animal manure is used as fertilizer and that sensible rotational practices are applied so that nitrogenous legumes are grown at least one crop per year. Also assuming that sewage sludge and compost from Swedish 'Clivus' systems and the like are utilised where possible (†).

1.6 The figure given for corn seed was applied roughly to the seed input to a densely cropped acre of vegetables of mixed variety, from leafy greens to roots and tubers.

1.7 Assumes that in an alternative system water catchment is carefully worked out through damming using keyline systems (‡) or that wells, streams and recycled waste water from domestic recycling plans are used for surface and sub-surface irrigation. Also that where trickle irrigation, or the like, is not able to be practised, water is carried manually as in Asian small plot systems.

1.8 There are various methods to be exploited to try and keep pests down without pesticides, e.g. growing plants in particular combinations (†), using non-persistent home-made sprays, such as boiled decoction or cigarette butts for nicotine, and so on. Incidentally, however, insects will take about seven to ten per cent of the crop in accordance with the usual take in a stable /ecosystem and with domesticated plants are bound to take more if they are abundant. The maintenance of a monoculture is always at additional energy costs, either in direct food loss or in insecticide production to save the food that would be lost. See the discussion in the text restricted use of pesticides. Herbicides can be replaced by continual weeding and present less of a problem in a highly labour intensive situation for intensive farming. The swiddenists' approach to non-food plants in the crop area is to let those grow which will ultimately provide part of the regenerating forest. They do not usually sow plants of a particular kind together, rather, distributing them randomly about the plot creating a mixture. This technique could also be practiced as an alternative to endless weeding, but yields will probably be lower.

1.9 If drying of foods is required, it is assumed that solar energy is used and not artificially heated rooms or kilns.

1.10 Assuming that a mixed vegetable crop in one acre of land over a four-month period can raise about 7,085 Kgrams of vegetables, taking average data from Chinese vegetable gardening in Hong Kong, and that twenty per cent of this will be lost to insects or reduced yield because of weed competition. Assuming that mixed vegetables will have an average value of sixty five Kcals per one hundred grams portion (‡) and that this gives a total of 3,684,200 Kcals.

commune in agricultural production, making for a labour-, rather than machine-, intensive system. The alternative communal farming has been projected as a 'purist' model in that no artificial chemicals are added as fertilizer, herbicide or pesticide. In this case the assumption has been made that yield will be reduced by about twenty per cent because of the natural toll on plant matter by insects and possibly a reduced growth rate as a result of their onslaughts, even though it is assumed that the crop will be closely tended. If one did not want to follow a totally 'purist' approach to farming, then considerable savings in insecticide treatment have been found by only treating the ravaged areas, and giving significant reduction in energy subsidy*. Portable equipment has also developed which can give highly selective spot treatment†. If one adopted these methods, the yield should be the same as for high energy subsidy agriculture and the ratio of input to return in energy terms still about the same.

The Table shows that by this necessarily crude comparison the energy input to energy return is at least five times as high as that obtained by current agricultural techniques. In general the principle applies that such labour intensive agriculture will not generate the surpluses of food which go to support the materialism of the urbanised populations, but does support the highest population on the land itself. Probably small amounts of food will be surplus after communal consumption and by bartering or by utilising the food cooperative system, trade-offs for other essentials can be made. In that sense the alternative form of production is in tune with the philosophy espoused by the 'alternatives' movement.

A commune can make a number of decisions about its modus operandi which will considerably reduce its energy consumption and add to its autonomy. The many architectural innovations which populated the Nimbin fields in May 1973 exemplified the creative potential of the counter culture. Combined with an understanding of self sufficient energy systems, structures which combine a minimum of materials, simplicity of construction and a high standard of convenience and sanitation can evolve.

Solar collectors and windmills for power generation have been a special feature of Australian research and related research is now booming in the U.S. and Europe‡. Direct solar energy can provide the reduced requirements of a communal situation with water heating, space heating and even air conditioning. The range of alternatives and examination of their potential is now commonplace.§

Solar energy can assist the operation of water recycling units, utilising algae tanks and digestors for effluent, which in many cases are commercially available and are ideal for the pooled skills of the commune to put into operation. At the same time operative systems have been developed which revive the ancient Chinese practice of using organic wastes from household and sewage to generate methane for cooking.¶

Apart from the initial capital cost which varies in proportion to the amount of technical skill available for construction and installation, most autonomous housing plans have minimal recurrent costs. Outside of the use of innovative technology to recycle, conserve and collect useful energy and materials, a personal commitment to consume less energy-expensive transport is a major component of a low energy life style.

The private car is the most energy expensive and socially destructive energy slave yet manufactured. In this respect a disappointing aspect of the Nimbin Festival was the reluctance of people to abandon their motorised transport even during the festival itself.

The spread of urbanisation, the isolated one-storey structure on a 1000 square metre lot and the vast reticulation of roadways has not only been constructed with the use of a motor car in mind but it makes the motor car virtually the only acceptable form of transport to get-to and from place of employment or leisure activity. The more private transport there is, the less efficient public transport becomes, almost to the point of its extinction as a viable alternative. A person who chooses not to own a car is condemned to relative immobility in a society where private cars dominate the roads and the transport system. Equity of energy use with particular reference to transport systems is dealt with lucidly by Illich*. 

---

† Personal communication with R. Coffey, Electrical Engineering Department, University of Hong Kong, regarding his development of hand held electrostatic sprays which give highly localised spot treatment saving probably more than fifty percent of energy inputs in this category.
‡ Australian company is Beasley Solarpac for solar water heaters. See also Annual Reports of Commonwealth Scientific and Industrial Research Organisation, Mechanical Engineering Division, Highett, Victoria, regarding development of solar energy technology (1970–73).
¶ See note B p. 229.
THE RATIONALE FOR A LOW ENERGY ALTERNATIVE

It has been estimated that the family car in the United States demands 278 million Kcals per year in direct cost. In Australia I calculate that the direct costs would be 445 million Kcals; including the capital costs and maintenance of the vehicle about 450 million Kcals per year. This gives a per capita cost of about 112 million Kcals per year for a four member family, not including the cost to society of maintaining the network of road systems, engineering projects to facilitate traffic flow, the space allocated to garages and sales departments, production plants and public and private car parks, to mention just a few of the obvious overheads. 1

The alternative for a commune is either to go without motorised transport or to obtain a heavy duty utilitarian vehicle which is used for the business of the commune, rather than for pleasure jaunts, and to provide backup transport for individuals with pushbikes and a lot of walking and hitchhiking. Preferably the commune members should be able to maintain the vehicle themselves. In this manner, by making certain assumptions about its use, the per capita energy costs should be reduced to about 3 million Kcals per year. 2 The transport options of pushbikes or very low powered motorised vehicles and much walking are worthy changes to implement in the city environment as well.

ENERGY AND THE CITY ENVIRONMENT

Finally we must face the stark reality that the real thrust for alternative low energy life styles must come in the city environment. As much as it may seem desirable to come back to 'our roots' and till the land, this can never be more than a fading vision for the majority of people in a heavily urbanised post-industrial age with the prospect of population growth well into the twenty-first century. It is easy to be convinced that the only alternative is the rural commune based largely on human energy, and to agree with White who says 'the type of social system developed during the human energy era was unquestionably the most satisfying kind of social environment that man has ever lived in... that the institutions of primitive society were the most congenial to his return and temperament'. But there can be no universal return to the human energy era and though the rural commune movement can be a rewarding experience for increasing numbers of people, it would be dangerous to offer the illusion that this was 'where it could be' for everyone. Rather, the rural commune can be a vital testing ground for alternatives that must find root in the city environment. They must recognise this obligation and not become distant outposts for down-trodden escape artists.

The contemporary city environment is dominated by high energy coercive institutions making universally enforceable decisions which have far-reaching behaviour modifying effects, e.g. housing authorities, transport authorities and state planning authorities. The tendency is to limit the spectrum of alternatives largely by cutting out the low-energy options and instilling confidence in hierarchies of power, where unaccountable high energy employment is a matter of status rather than blatant manipulation, e.g. schools, training colleges and corrective institutions.

It is generally recognised that a degree of social re-organisation will be necessary to cope with the multi-dimensional impacts of energy use. This re-organisation must be extended to cope with the social impact of energy use and to contain it within a framework of participatory democracy. Already the individual's power to effect change is pitifully small in comparison to those high in a political or industrial hierarchy, whose power is being enhanced and exaggerated out of all proportion to accepted public confidence and accountability by the long-lasting impact of the energy use they have at their disposal.

Since energy is fundamental to the operation of all living systems, and since man has comparatively recently learnt to harness large energy subsidies to do his work, the relationships between energy use and contemporary institutions have come under close scrutiny. Energy use therefore presents a valuable entry point to an examination of the contemporary social structure and to the ongoing search for alternatives.

---


2. Assumes 15,000 miles per year, a vehicle life of ten years, fuel consumption of 20 mpg. Consumption of 750 gallons/year at 7.5 lbs. per gallon and 81,349 Kcals/gal = 445 x 106 Kcals. Capital costs calculated from Stephen R. Berry and Margaret F. Fels, The Energy Cost of Automobiles, Science and Public Affairs, December 1973, pp. 11-118; 58-60. Gives 31,968,000 Kcals for construction of automobile of 3,400 lbs. Take ten per cent additional energy for maintenance and divide by ten for life of vehicle in years. The estimate of 3 million Kcals was made assuming a mileage of 7,000 per year in a heavy duty vehicle of fifteen years life for a twenty member commune. Other assumptions remaining the same.

3. See note 1 above.

5. H. T. Odum, Environment, Power and Society (New York, 1971), discusses such aspects as power and politics of religion apart from basic ecology of energy. An excellent introduction to the study of energy and institutions.