An urban heat island

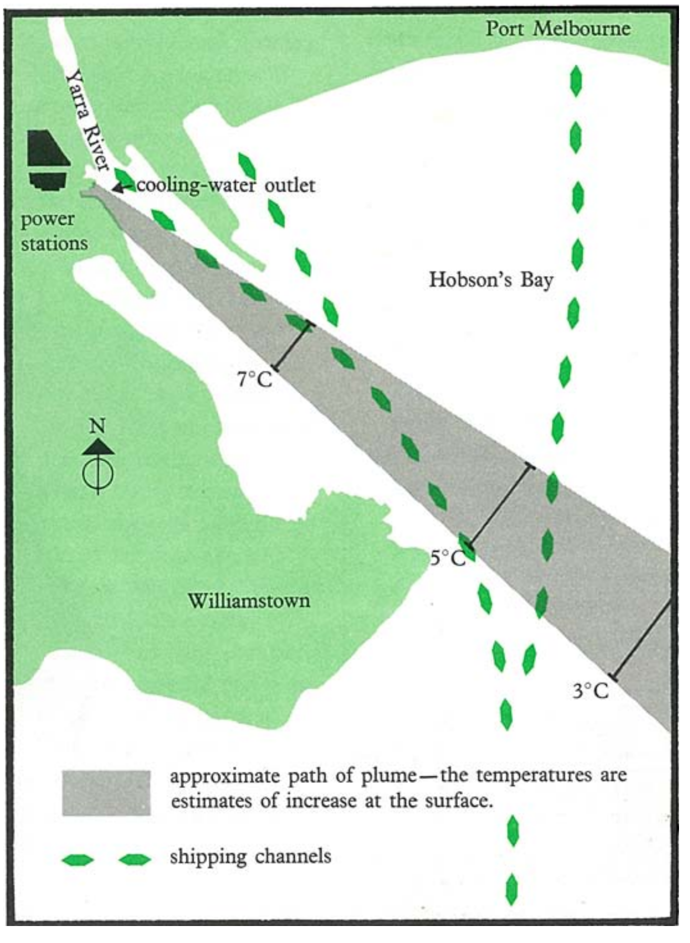
When you build a city you change the local climate. Concrete, asphalt, and stone absorb and store heat more efficiently than vegetation and loose soil; buildings and other structures affect wind speeds and atmospheric mixing; and factories, cars, and many other things eject vast amounts of heat.

The result is what meteorologists call an urban heat island. On a mid-winter's morning the temperature in the centre of Sydney is likely to be 3–4°C above that on the outskirts; this temperature difference is characteristic of big cities world-wide.

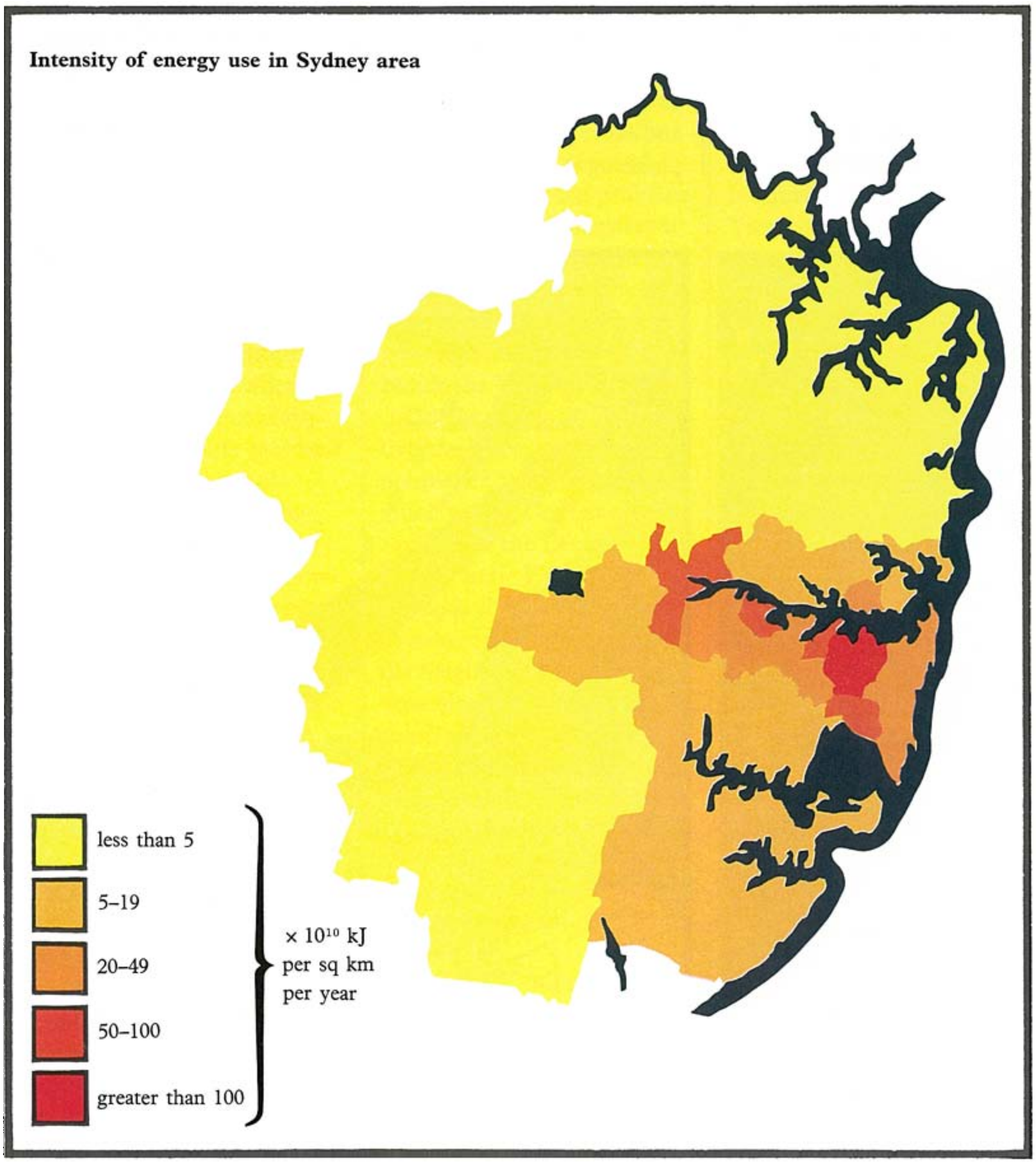
Much needs to be learnt about the causes and effects of local climatic changes in and around cities; their relevance to the siting of industrial and residential areas, air pollution minimization, and other aspects of urban planning is obvious.

Energy use and the associated heat generation are important elements of the climatic picture in a city, and they have been studied in Sydney by Dr Jetse Kalma and Dr Richard Millington, of the CSIRO Division of Land Use Research, and Dr Alan Aston of the Division of Plant Industry. One interesting finding is that the heat produced in the Sydney and South Sydney Council areas in a year equals about 25% of the amount coming in as solar radiation. The percentage falls rapidly as one moves out from the city centre: in the Leichhardt municipality, an inner industrial area, it is about 9% and at Camden, on the urban fringe, about 0·1%.

In winter the percentages are higher than in summer, mainly because the sun shines less brightly. In the inner city in July, average



Sydney.



heat production equals about about 49% of the sun's contribution, and on 3 days in the month this figure is likely to rise to more than 76%. Artificial heat generation in proportion to incoming solar radiation is at a maximum in early mornings and late afternoons and at a minimum in the middle of the day.

Using computer simulation models developed by Canadian scientists, Dr Kalma has estimated increases in temperature likely to be produced by the heat generated in different parts of the Sydney area on July mornings between 7 a.m. and 9 a.m., periods when the effect should be at its maximum.

Moving downwind, from the western fringe into the city centre, these expected increases vary from 0·2°C to about 3°C. Average temperature records for July show a similar pattern between 7 a.m. and 9 a.m. Dr Kalma concludes that, for the time interval considered, artificial heat generated within the city boundaries appears to cause most of the temperature increase downwind over the city.

As the area for their study of energy use and heat generation, Dr Kalma, Dr Aston, and Dr Millington chose the Sydney Statistical Division (S.S.D.), which covers about 4075 sq km and includes rural areas such as Camden as well as the city and suburbs. They worked from statistics for 1970.

Using data from the energy suppliers, they calculated the total input of primary energy (the energy potential of fuels —not electricity, for example, which is a secondary product of these fuels) for the year. This amounted to 339×10^{12} kilojoules (kJ). About one-third of this was lost in generating and transmitting electricity, manufacturing and reticulating gas, and refining crude oil, and some of the primary energy brought into

the area (24×10^{12} kJ) was used outside it as aeroplane and railway fuel.

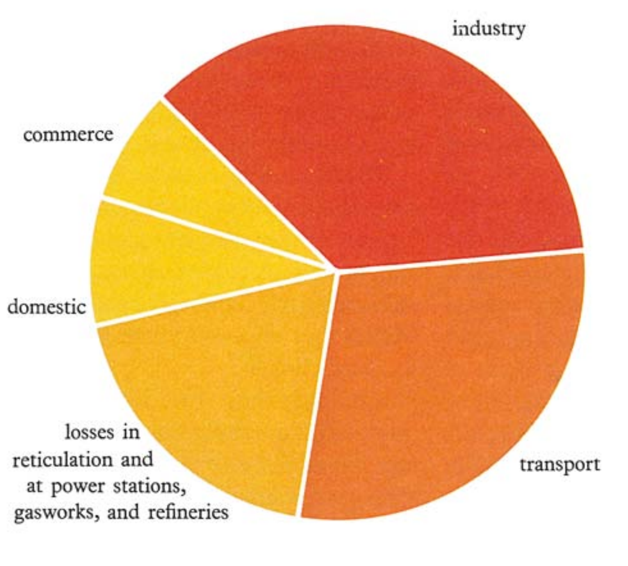
Energy lost in the conversion of primary to secondary sources as well as energy put to work finishes up as waste heat, but some of the loss occurs outside the S.S.D. The scientists calculated the total artificial heat generated in the S.S.D. in 1970 as 247×10^{12} kJ, with industry and transport making much greater contributions than commerce and domestic energy use (see the graph).

To measure variation in energy consumption and heat production within the S.S.D., they looked at statistics relating separately to each of the region's local government areas.

They assumed that domestic energy use in an area was proportional to population, and commercial energy use to the work-force of commercial establishments. Local industrial energy use was calculated from statistics obtained from the 1967–68 census of the manufacturing industry, which contains detailed information for each local government area.

Data on artificial heat generation by motor vehicles were difficult to obtain, mainly because figures on traffic volume on an area basis are very rare. Dr Kalma and his colleagues based their calculations on the assumption that traffic volume in an area, and hence energy consumption for transport, is proportional to the number of traffic accidents in the area. They used accident totals for the 3-year period 1969–71.

Sydney's 1970 energy consumption break-up



They assumed that reticulation losses for electricity were proportional to area. Local losses in water supply, gasworks, refineries, and power stations were calculated individually.

Energy use for the year was found to vary from about $0 \cdot 4 \times 10^{10}$ kJ per sq km in outer areas to about 156×10^{10} in the inner city. The average for the study area was about 6.1×10^{10}kJ per sq km (see the map).

When estimating seasonal variation in energy use, they made the assumption, supported by data on traffic volume and electricity sales, that energy use in transport and industry does not vary significantly during the year. They assumed also that domestic use of coal, heating oil, lighting kerosene, and firewood and commercial use of heating oil, reticulated gas, and coal are restricted to the three winter months. Seasonal variation in domestic and commercial energy use was estimated from figures showing the consumption of these fuels and monthly electricity sales.

On the basis of these data and assumptions, which the scientists stress are approximations, they calculated that average energy use in the study area was $62 \cdot 4 \times 10^{10}$ kJ per day in January and $75 \cdot 0 \times 10^{10}$ in July, compared with an average for the year of $67 \cdot 8 \times 10^{10}$ kJ per day.

Variations in commercial, industrial, and domestic energy use during the day and night were estimated from electricity supply load curves broken up into 2-hour sections. A similar break-up of transport energy use was derived from traffic volume data. The figures show that commercial energy use was at its greatest between 9 a.m. and 1 p.m., industrial between 11 a.m. and 1 p.m., domestic between 7 p.m. and 9 p.m., and transport between 7 a.m. and 9 a.m.

It is not only the things people burn for their various purposes that alter the natural heat situation in cities, it is also the people themselves and animals. An average person's metabolic energy use is about 13 400 kJ per day, and about 75% of this heat is believed to be dissipated by conduction, convection, and radiation. The S.S.D. contains about 2·8 million people, generating about $10 \cdot 25 \times 10^{12}$ kJ per year.

If estimates that there is one animal for every 10 people and that their metabolism averages 3350 kJ per day are right, animals in the study area generate $0 \cdot 25 \times 10^{12}$ kJ per year.

Total metabolic heat generation therefore amounts to about $10 \cdot 5 \times 10^{12}$ kJ per year, which is about the same as the energy value of all the reticulated gas sold in the region.

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