Greenhouse — and smart buildings

By the end of today, millions of Australians will have driven to work alone, taken a lift to a work-place inside an air-conditioned multi-storey building, driven to various business appointments, perhaps taken a detour on the way home to pick up the kids from school, and sat down in the privacy of a home that may be 30 or 40 km away from the office.

The point about all of this is that, in an age when scientists have warned the world of accelerated global warming as a result of increased emissions of 'greenhouse gases' such as carbon dioxide, Australians are daily contributing to the problem by merely living a conventional urban life-style.

Not that we have much choice in the matter — our life-style is largely dictated by a built environment that we have inherited from an earlier age, when energy was meant to be consumed and rarely conserved.

Over the last 30 years, energy use in multi-storey city buildings — and consequent greenhouse gas emissions — has increased by a factor of up to 30 per occupant. This is due to such things as the rising ratio of available office space to occupants, the increased use of air-conditioning and office machines, a growing number of lifts and escalators, and greater use of glass facades.

Responding appropriately to the threat of the greenhouse effect is a major challenge facing planners as we prepare for our entrance into the twenty-first century. Their responses will fall into one or more of three categories: 'do nothing' or 'wait and see'; develop strategies to cope with the predicted effects of global warming; or, more assertively, put constraints on our current patterns of energy usage to limit future emissions.

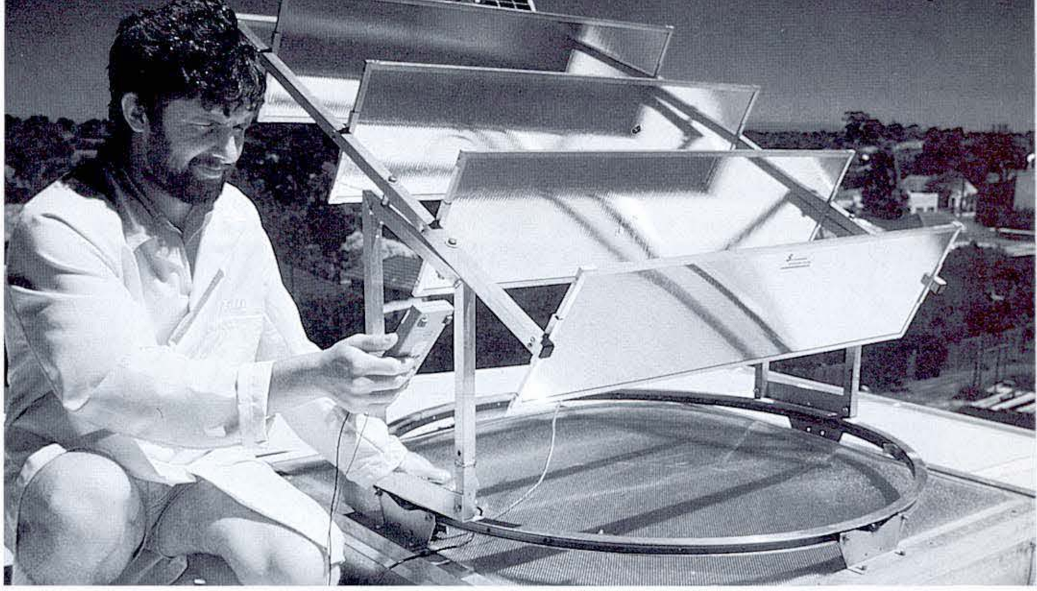
Buildings as systems

Rational planning of energy-efficient urban systems (see the box) is one of the keys to atmospheric health, since much of the carbon dioxide that contributes to global warming derives from the burning of gas, oil, and coal to generate the electricity consumed in cities and to power cars and other vehicles. For the past two decades, the process of optimising urban systems has interested Dr John Brotchie, who heads the Planning and Management Systems group at the CSIRO Division of Building, Construction and Engineering in Melbourne.

In the early 1970s, together with colleague Dr Ron Sharpe, he developed a mathematical model, TOPAZ, that arranges components of cities — including transport systems — or of individual buildings to achieve a desired goal, such as minimising energy use (see *Ecos* 1).

Part of the group's latest work has focused on buildings — in particular, the question of how new technologies can be

Building and, eventually, demolition need to be considered along with operation and maintenance when assessing energy and greenhouse effects.



Solar energy can play an important role in reducing fuel use and CO_2 emissions. Here a sun-tracking skylight is undergoing tests.

integrated into them to reduce energy use and greenhouse gas emissions. The 'intelligent building' is not a new concept, but what the CSIRO group has done is introduce systems techniques such as optimisation to improve communication and energy efficiencies. Dr Brotchie's team is partly funded by a grant from the Building Research and Development Advisory Council.

The approach he favours involves treating the whole building and the activities it houses as an integral system. The first component of the system consists of the building's uses — such as commercial services, car-parking, plant operation, and public access. The second comprises the interactions between these activities — principally the movements of people, information, and conditioned air.

The third component, the spaces designed to accommodate these interactions, is closely linked to the fourth, the networks that 'carry' them. The latter include: the building's structural framework; the lifts, escalators, corridors, and stairs; the ducts that carry heated or cooled air; and, of course, the communications networks that handle information flows. The energy systems can be further subdivided into energy storage, energy transfer, energy conversion, and energy conservation.

Means of achieving desired economic or energy goals encompass, in broad terms, improving the design of components, substituting one component for another, and rearranging components. When the desired goal has been defined — for example, maximum cost-effectiveness or minimum total energy use — the process can be referred to a computer.

The CSIRO team have developed the TOPMET system, a PC-based variant of TOPAZ, to balance competing factors in achieving an optimal result. According to Dr Brotchie, reductions in energy costs of 10 to 30% are possible through such optimisation.

Technologies and materials

Researchers at the Division of Building, Construction and Engineering had earlier helped develop criteria for the design of low-energy domestic housing (see *Ecos* 36). The CSIRO built a demonstration house that featured extensive wall and ceiling insulation, an aspect that allowed 'passive' use of solar energy, together with 'active' solar heating for water and internal spaces. The average heating bill for the house proved to be about one-quarter the average cost of heating a house in Melbourne.

Dr Brotchie's group has since identified promising energy-saving measures and technologies for larger buildings. These include: ice-storage systems for air-conditioning (see *Ecos* 61); heat pumps; co-generation; insulation and double-glazing; low-energy lighting; and solar energy.

Co-generation involves the use of natural gas to produce heat and power. Its attraction is its relative efficiency. Power stations convert about 30–40% of their heat input into electricity. Co-generation plants, on the other hand, have efficiencies of 80% or more — 30% as electricity and 50% or more as heat. This heat can be transformed into cool air via heat pumps. They use it to evaporate a refrigerant; the cooling energy is produced when the refrigerant condenses.

The large areas of glass decorating the outsides of modern buildings may look good, but they trap too much heat in summer. Protective glazing can reduce penetration by between 20 and 80%, but Dr Brotchie believes that an even better solution is to combine it with external shading, which reduces the level of penetration by an additional 30%.

The greatest energy savings occur when technologies such as these are combined, and that's where another design tool from CSIRO, BUNYIP — BUilding eNergY Investigations Package — comes in. The program was developed by Mr Mike Wooldridge. BUNYIP, which can run on a microcomputer or mainframe, can be used to assess the energy efficiency of the design components of new or retrofitted buildings, giving users the chance to evaluate design ideas and forecast costs.

In Dr Brotchie's view, integration of the design and management of a building offers the best strategy for minimising its contributions to greenhouse emissions. Greenhouse emissions begin with the 'harvesting' of raw materials for the building, the transport of these materials, their manufacture into components, and then actual assembly of the building. Then come use of the building, retrofitting, maintenance, demolition, recycling of materials, and disposal of final products; the emissions associated with each stage must be considered.

For example, one of the most common materials used in buildings — Portland cement — contributes about 2·5% to global CO_2 emissions through energy used up in its production and through the chemical process of removal of CO_2 from calcium carbonate. Dr Brotchie suggests that new cements — such as one developed by researchers at the Division, which uses waste material and low-energy processing — could reduce these emissions by up to 80%. The product is currently being assessed by cement manufacturers in Italy, India, and Australia.

Artificial intelligence

Dr Brotchie's research has led him to the conclusion that computers and telecommunications will be central features of an energy-efficient future. An obvious benefit of these technologies is that they reduce the need for people to travel inside and between buildings — lifts and cars can give way to bundles of cables and radio waves.

But the most important application of information technology in a greenhouse-oriented future is probably in 'smart' environment-control systems for buildings. Artificial intelligence — 'expert systems', 'neural networks', and the learning capability of computer-based systems — can be used to optimise both the design and operation of buildings, keeping track of changes in user demands or in the environment and initiating appropriate responses.

Artificial intelligence systems could, for example, continually fine-tune the operation of air-conditioning equipment to best meet user needs — responding to day-to-day and seasonal changes in the outside environment and to changes in user activity. From user adjustments to air-conditioning controls, such systems could gauge user preferences and their variations over time. Through learning and anticipating user needs, they could 'instruct' the building's components to meet those needs with minimum energy and emission costs.

Dr Brotchie's team is developing techniques to build such responsive systems. They are focusing on 'fuzzy logic' techniques that acquire information on user preferences by monitoring day-to-day behaviour or user responses to alternative propositions.

Dr Brotchie believes that neural networks — circuits that roughly simulate the interactions of the brain's neurons — may form an important component of the smart building of the future. Neural networks are currently being developed for pattern recognition and optimisation, and both of these areas are relevant to the design and management processes proposed by the CSIRO group.

As for expert systems used in building design, Dr Sharpe's team has already developed WINDLOADER, a system for wind engineering design based on the Australian Wind Loading Code. WINDLOADER is available commercially and has been proposed as a model for computerisation of European wind codes.

Together with the Australian Uniform Building Regulations Co-Ordination Council, A.V. Jennings, and Butterworths, the team is also developing an expert-system version of the Australian building code, BCAIDER, that will allow architects and engineers to design buildings using the latest information on safety and environmental requirements and enable faster processing of building applications.

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More about the topic

Intelligent systems for tall buildings. J.F. Brotchie, J. Ehmke, and R. Sharpe. *Proceedings, Fourth World Congress on Tall Buildings — '2000 and Beyond', Hong Kong, November 1990.*

Greenhouse implications for building. J.F. Brotchie, J. Ehmke, A. Rodger, R. Sharpe, and S. Tucker. *Proceedings, CSIRO National Conference on Greenhouse and Energy, Sydney, December 1989.*

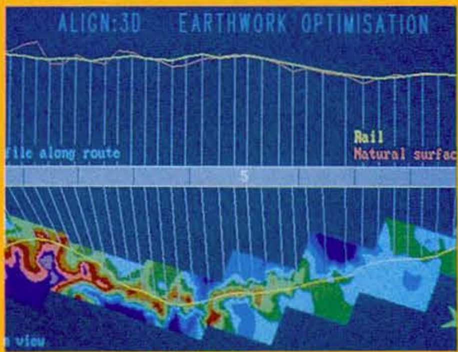
The legacy of the metropolis

Although the urban landscapes of the late twentieth century are not model low-energy systems, we're stuck with them. Those heat-leaking buildings surrounding us represent the accumulated capital wealth of many generations of Australian endeavour. We simply can't afford to raze them and begin again.

Planners do occasionally have the luxury of building new energy-efficient towns or cities, but for most of us most of the time, home, work, and play involve making the best of the buildings, roads, city centres, and drainage systems that comprise what has been affectionately dubbed our 'crumbling infrastructure'.

Dr Brotchie's proposals for the development of cities that emit reduced levels of greenhouse gases are based on the idea of the 'multi-centred' system, where work, shopping and recreational facilities, and home are located within the same area, reducing the need for extensive daily commuting. His analysis of North American and Australian cities in new urban areas and redeveloped 'multi-centred' cities shows that potential savings on travel costs and consequent greenhouse emissions can be 50% or more.

Features of 'greenhouse-friendly' urban systems will include: energy-efficient transport, both within and between cities; reduced trip length and commuting distance through 'multi-centred' urban planning; low-density population to assist local self-sufficiency (the mass movement of food and garbage consumes large quantities of energy); high population densities in situations where economies of scale are achievable; appropriate energy-pricing policies; increasing use of telecommunications as a substitute for travel; and conversion to low-energy technologies.



Output from ALIGN–3D — a computer package to aid the design of inter-city rail and road routes.

As with buildings, optimisation with the help of a computer can be used to plan cost-effective arrangements of land, transport, and communication networks and to evaluate pricing and other policies aimed at minimising emissions or achieving reduction targets.

Apart from the packages mentioned in the main article, the CSIRO team has developed a new technique — ALIGN–3D — for the optimal design of inter-city rail and road routes. ALIGN–3D has been shown to produce cost savings in earthworks of up to 30% over conventional methods, with savings also in emissions from inter-city travel.

Together with Professor Allan Rodger of the Department of Architecture and Building at the University of Melbourne and Mr John Devenish of the Victorian Ministry of Housing and Construction, Dr Brotchie last year prepared a submission to the Victorian Minister for Planning and Environment in response to a draft strategy on 'greenhouse' that had been released by the State government.

In the submission, the three authors pointed out the important role of information and telecommunications technologies in the energy-conscious future. Because about 40% of the Australian workforce is employed solely to perform information-related activities, the possibility exists of more people 'telecommuting' by computer every day, rather than wrestling with peak hour traffic.

Further, developments in telecommunications — fast-packet switching systems, local and wide-area networks, fibre-optics, and wide-band communications — mean that services such as electronic mail, teleconferencing, and video-conferencing will become more accessible. Indeed, Dr Brotchie's group is working with Telecom on planning the infrastructure requirements of new fast-packet switching and wide-band communications networks.

According to Professor Rodger, planners will have to start thinking in terms of local communities and myriad small changes to the present building stock, rather than what he terms the 'king hits' of conventional development. In fact, he believes that they will have to begin thinking in terms of urban 'units' of between 20 and 50 houses, which would be more responsive to change than today's large, single-centred systems.

Greenhouse implications for urban systems. J.F. Brotchie, R. Sharpe, and A. Rodger. *Proceedings, CSIRO National Conference on Greenhouse and Energy, Sydney, December 1989.*