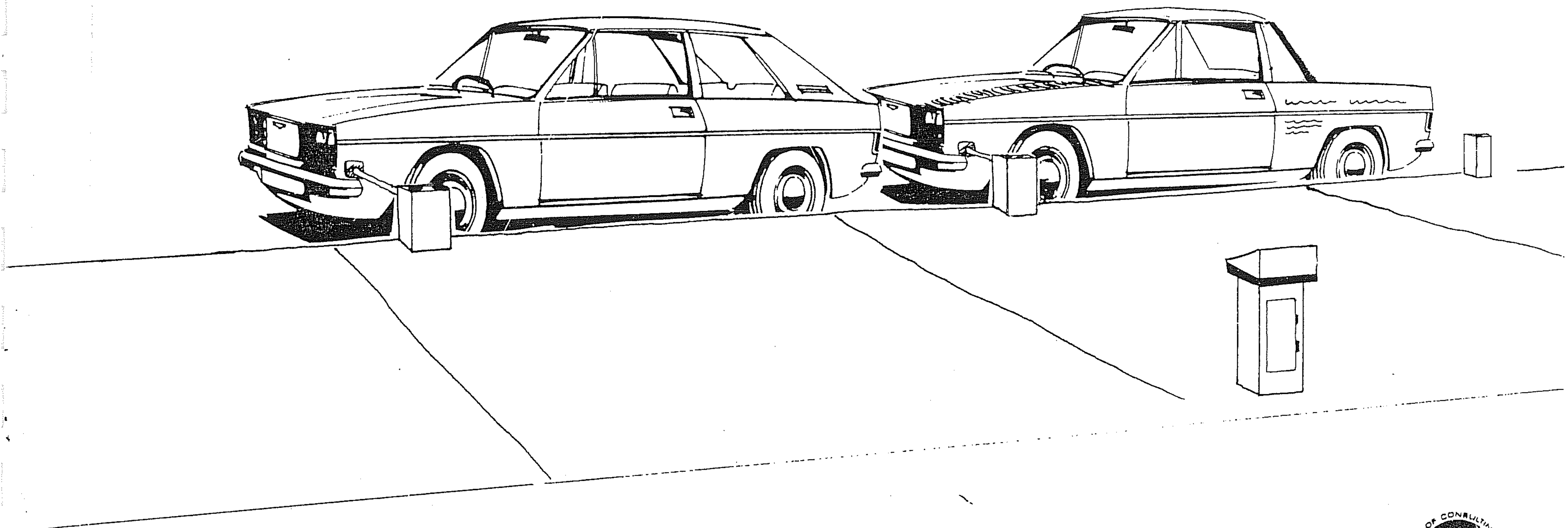
ASSOCIATION OF CONSULTING ENGINEERS AUSTRALIA

25TH ANNIVERSARY NATIONAL PROJECT

THE INTRA-CITY USE OF ELECTRIC CARS



THE ASSOCIATION OF CONSULTING ENGINEERS, AUSTRALIA

NATIONAL PROJECT

THE INTRA-CITY USE OF ELECTRIC CARS

PROJECT DIRECTOR

F.J. BROOKMAN, B.E.(Hons.), M.I.E. Aust.

PROJECT TEAM

W.E. BASSETT AND PARTNERS PTY. LTD.
F.J. BROOKMAN AND ASSOCIATES
DAMES AND MOORE
MERZ AND McLELLAN AND PARTNERS
EUGENE SMITH AND HONE PTY. LTD.
H.G. WALTER AND PARTNERS PTY. LTD.

FOREWORD

In promoting its 25th Anniversary quest for an engineering project of national significance, the Association of Consulting Engineers Australia was seeking a project concept which would contribute to the nation's development and be of benefit to the community.

This we believe we have achieved with John Brookman's scheme for encouraging the intra-city use of Electric Cars by establishing a network of power-linked parking meters to extend the range of these vehicles.

The Association of Consulting Engineers Australia, being the professional body to which the great majority of Australian consulting engineers belong, was founded in 1952 by a small group of independent consulting engineers practising in Australia and this year, with 660 members, celebrates its Silver Jubilee.

To commemorate this occasion the ACEA decided to sponsor a National Project and sought among its members for projects providing engineering solutions for some of the problems confronting the nation today. From an impressive array of entries, all of them imaginative, based on sound engineering principles and of importance to Australia's development, an independent panel of eminent judges selected John Brookman's project as the best and the ACEA subsequently commissioned him to direct a multi-discipline team of ACEA members to produce this report.

The ACEA will distribute this document widely: to the Commonwealth and State Governments, electricity generating and distributing authorities, motorists' organisations, industry and commerce. The National Project is, we believe, an important contribution to Australia at a time of increasing national awareness of the need for energy conservation in view of the reducing reserves of petroleum and consequent higher fuel prices.

By encouraging the introduction of Electric Cars which would draw on power generated from our vast coal resources, we would be able to reduce air and noise pollution in our cities.

HAROLD C. RICHARDS,
President.

CONTENTS:

Page No.

Page No.

TABLES:

FIGURES: Page No.

THE ASSOCIATION OF CONSULTING ENGINEERS, AUSTRALIA

25TH ANNIVERSARY: NATIONAL PROJECT

"THE INTRA-CITY USE OF ELECTRIC CARS"

THE IMPACT ON THE NATION

JUNE 1978

FEDERAL OFFICE,
75 MILLER STREET,
NORTH SYDNEY, N.S.W. 2060
TELEPHONE: 922-4711

PREFACE

In examining "The Intra-city Use of Electric Cars", the infrastructure and effects on power generation and distribution, alternative energy resources and the environment are briefly reviewed.

This report shows that with or without emission controls on the exhausts of internal combustion engined cars, and providing that there is no dramatic change in car performance or technology, the demand for motor spirit and crude oil supplies in Australia will be difficult to satisfy during the period 1985 to 2000. The costs associated with these demands will be massive, and the dependence on sources that may become politically unreliable could place an onerous burden on the nation.

The introduction of Electric Cars on a "free market" basis will inevitably be slow initially, even on the high assessment of penetration assumed in this report. It is evident that compression of the time scale and a forced initial development of the market are essential to avoid problems with oil supplies and balance of payments.

It is this challenge, to grapple with and answer the problems of the not-too-distant future, that must be brought before the community.

The Commonwealth and State Governments will need to display realism, courage and leadership to make political decisions now that will lay sound foundations for a concerted effort by industry and the community at large to project Australia into the next century without a massive burden of debt and as a free independent nation.

To achieve substantial initial penetration of the market, the Government should take into account the energy and environmental benefits that will be derived and assess the cost savings that potential owners will contribute to the nation's welfare. These savings, reflected in tax credits, would compensate the owners for the additional vehicle and battery purchase price that will undoubtedly apply because of the initially small production.

This study investigates the available market by population and traffic projections for principal metropolitan areas in each State, and assesses the parking/charging, power distribution and generation, and energy resource demands for the Nation. Environmental impacts and the saving of oil fuel are included.

The projections of traffic demand have been based largely on the data obtained for the Modified Sydney Region and have been extrapolated, using population projections for the States and principal cities and Australia wide data on vehicular registrations to enable an assessment of market penetration, and consequent power and energy resource demands across the nation. Extrapolating these demands to other areas in Australia will undoubtedly lead to some imprecision; however, noting that most other major cities have a greater density of vehicle registrations than exists in Sydney, we believe that the report is of value in indicating the probable trends and the consequent implications.

The report underlines the need for urgent action in developing the Electric Car and establishing it as a major item for commuter transportation. Further topics for investigation by governments and industry are suggested and early work in these areas is of importance.

RECOMMENDATIONS

1. In view of the long lead times required for investigation, design, development and manufacture of Electric Cars and the supporting facilities, and also the urgent need to minimise the effect of the impending energy crisis in Australia and across the world, it is essential that planning be initiated without delay. Although the power generation bodies are State bodies, the problem is national and the Federal Government should set up appropriate committees immediately to report within one year in great detail on:

   - policy requirements for establishing the Electric Car market, with realistic targets for market penetration,

   - establishment of co-operation between all levels of government, and industry for the manufacture, operation and maintenance of vehicles and support facilities,

   - the development of standards for vehicles and support facilities,

   - the marketing requirements, taking into account the need to persuade people to adjust their transportation habits and demands.

2. There should be an urgent review of Australia's energy and material resources with particular refererence to the requirements of transportation. This task should be undertaken by the Federal Government liaising with industry to obtain an assessment of the availability of these resources for commercial exploitation, having due regard for the ease of development and the funding necessary.

3. Because of the significant increase in total fuel consumption resulting from the use of emission control devices on car exhausts across the nation, when only the environments of the larger cities are those which need to be protected, further studies on the application of pollution controls on vehicles and their effects resulting from extended use would be appropriate. Car manufacturers should be encouraged to develop engines with emissions low in pollutants, by the introduction of policies combining incentives for achievement and penalties for non- compliance.

4. The Federal and State Governments should review the sales tax and licensing structures for vehicles in relation to the fuel consumption and pollution effects, with due regard for the location and intended use of the vehicles, and should encourage the sales and use of Electric Cars with tax credits and preferential licensing fees.

5. There should be further studies on the effects of introducing Electric Cars into the Australian market, and these would include:

- the changes necessary in the manufacturing processes, with regard to investment, plant, and workforce skills,
- the retraining and/or re-deployment of labour to ensure the minimum disruption,
- the effects on the servicing industries, with possible changes in local facilities,
- the disposal of battery wastes and the polluting effects on the environment, with particular reference to lead and electrolyte.

SUMMARY

The profligate consumption of petroleum products for transportation which is anticipated to more than double the nation's demands by the year 2000, and the rapid depletion of Australia's known oil reserves will create immense problems with the nation's external balance of payments during the period 1985 to 2000 and beyond. Without extensive new oil fields being rapidly brought into production, the cost of petroleum imports will quadruple to about $4,900 million per annum by 1985 and rise to about $6,660 million per annum in the year 2000, expressed in 1977 currency. Refer Table 1.1.

Without any significant oil reserves as a buffer, the nation will be dependant on the policies of the oil exporting countries and the competition with other thirsty countries for the restricted world supplies may escalate the selling price to the extent that we must contemplate degradation of the nation's standard of living unless we act now on plans for definite alternatives in the transportation demands for liquid fuel supplies.

To avoid such costly imports, Australia must become self reliant for energy supplies, at least for transportation, and the introduction of Electric Cars for city use will offer a solution to part of this vast problem.

At present, Australia has approximately 85 times as much energy available in the ground from coal as from oil. Electric Cars deriving energy from coal-fired power stations will consume less energy than conventional cars, and represent a more efficient use of resources and money.

The motor car represents approximately 77% of all road vehicles across the nation, and accounts for approximately 55% of all energy consumed in personal or goods movement; including transport by commercial vehicles, public transport, trains, aircraft, and shipping. Some 70% of this amount is consumed by cars for personal transport in urban areas, divided equally between commuter and city business trips as one group and all other trips, including shopping, social and recreational and personal business trips. Thus, at present, commuter and city business trips in cars consume approximately 20% of all fuel used for all transportation purposes throughout Australia.

Whereas the Electric Car at the present state of development has sufficient range to cater for 90% of all urban journeys, allowing for return, there is insufficient reserve to allow additional journeys in any one day and to ensure confidence in the ability to complete a given journey satisfactorily without incurring the extensive delays associated with recharging depleted batteries. The provision of "Park and Charge" facilities, at kerb-side, in parking areas, stations and garages distributed widely in the central business districts, commercial and industrial areas, will allow batteries to be recharged during the many idle hours of the day, thereby greatly enhancing the range and performance of existing Electric Cars. This improvement in range and performance in city driving conditions should meet the requirements of the majority of city car users, and should tend to overcome the "Electric as a second car" syndrome which, because of the high cost of a new car, has inhibited introduction and the generation of pressure for development of this type of vehicle.

The introduction of the Electric Car as a commuter vehicle will require the provision of the appropriate "Park and Charge" facilities at convenient locations and in sufficient numbers throughout the cities at an early date, as a stage by stage process; this will tend to stimulate the use of Electric Cars as extra vehicles within households as time goes by. With increasing cost, energy and environmental restraints it is considered that the conventional internal combustion engined vehicle may be a station waggon type vehicle used only for long trips or for leisure purposes, and that by the year 2000 the Electric Car will have penetrated the available urban market significantly, within a probable range between 24% and 54%.

"Park and Charge" meter facilities are envisaged as being of the coin operated type initially and will be established at kerb-side, parking areas, shopping centres, parking stations and garages to provide supplementary charging facilities to commuter traffic to ensure adequate range for most city transportation requirements. It is expected that as the numbers of Electric Cars increase and the network of charging facilities becomes larger, the magnetic card operated meters with central console connected to computer control will be installed. This type of meter will enable economies of operation and allow the power authorities to adjust metering conditions to suit the operation of the whole power supply system.

Assuming that approximately 70% of Electric Cars use these facilities consistently, the anticipated total installation costs to the year 2000 would be around $300 million at 54% penetration of the market.

Generally the load imposed on the electricity distribution systems of most cities would not be of major significance and would be beneficial in most cases in levelling the peak loads currently being experienced. It is probable that some upgrading of residential distribution systems would be required to cater for the domestic peaks in the evening and the requirement for charging cars when returned to residential garages. This situation may require special methods of controlling the charging of cars during the domestic peak period.

CONCLUSIONS

The introduction of Electric Cars throughout Australia will be gradual during the period 1980 - 2000, unless major external pressures are applied to the free market; either from the economy responding to the world energy crisis or by government persuasion.

Investigation of low and high market penetration reveals that the Electric Car will not otherwise have a significant impact on the nation until about 1993. By that time the number of conventional cars will have increased substantially, and will only tend to reduce to the present number after the turn of the century.

Assuming that all conventional cars will be fitted with emission control devices of the existing type, motor spirit consumption will double by the end of the century; however, if Electric Cars penetrate the market at the high estimate level, motor spirit consumption will peak at 160 % of the present demand during 1993 and reduce to approximately 145 % by the year 2000. Further reduction in total fuel consumption will require:

- greater penetration of Electric Cars, probably encouraged,
- a major improvement in car technology, and/or
- a drastic reduction in car size and use.

Removal of the present emission control devices would reduce the latter figure to about 125 % of present demand.

The money saved by the introduction of Electric Cars in reducing the bill for imported fuel will be far greater than the cost of alternative power, fuel and distribution installations associated with "Park and Charge" meters; and the benefits are:

- the expenditure on the above items will be within Australia to a large extent,
- the nation will be less dependant on external sources of fuel, and
- there will be a significant improvement in the environment, with pollutants being emitted under controlled circumstances at specific locations.

With recharging facilities such as "Park and Charge" meters, distributed widely throughout city areas to enable frequent topping up of battery charges, the Electric Car will have more than sufficient range for the requirements of the great majority of urban motorists for commuter, business and personal trips. The cars are likely to use lead-acid batteries for power storage up to the turn of the century, and will be of small to medium size by today's standards with accomodation for 4 - 5 persons. Acceleration will be modest but adequate compared to present small cars. It is probable, however, that some re-organisation of traffic may be necessary to accomodate the generally lower standard of performance compared to the conventional car at present, although as Electric Cars obtain substantial penetration of the market the tendency for traffic conflicts between cars of unequal performance will reduce.

The vast quantities of coal available in Australia will ensure a plentiful supply of energy for the foreseable future, and the additional power required by Electric Cars will not cause any large demands on existing or planned generating capacity. At the high level of market penetration at the turn of the century, the additional power requirement will only be some 7 % of other power generation requirements and can be accomodated easily between the years 1990 - 2000 by advancing the normal planning by some 12 - 18 months.

The introduction of Electric Cars to the market will be sufficiently gradual to avoid severe dislocation of the industries supporting the manufacture of the conventional car. The demand for conventional cars is expected to increase at a gradually reducing rate until the year 2000 and this will give ample time for industry to adjust to new technology and skills associated with Electric Cars.

The large scale introduction of Electric Cars as commuter transportation will require the establishment of infrastructure of varying magnitude:

- to serve the manufacture, operation and maintenance of vehicles,
- to provide support facilities in the form of "Park and Charge" meters and appropriate up-grading of power reticulation in C.B.D., commercial, industrial and residential areas,

- to provide additional power generation and energy resource capacity in the years approaching 1995 - 2000,
- to ensure adequate continuity of mineral resource development,
- to cater for the concentrated disposal of wastes such as power station effluents, and battery lead, electrolyte and cases.

1. THE FUEL CRISIS AND BALANCE OF PAYMENTS

1.1 INTRODUCTION

In an energy-starved world, oil supplies will become scarce and very expensive by the year 1985, and Australia's known oil supplies will be depleted. Unless extensive new oil fields are discovered and brought into production at an early date the cost of crude oil imports will rise from about $4,904 million p.a. in 1985 to about $6,665 million p.a. in the year 2000, at present currency values and world prices of crude oil. If the rate of currency inflation averages only 8% p.a., these values will increase to approximately $9,076 million and $39,142 million p.a. respectively.

To avoid such costly imports, and possible stagnation of the economy, Australia must become self reliant for energy supplies at least for transportation, and the introduction of Electric Cars for city use will offer a solution to part of this vast problem.

The Electric Car will derive its energy from power stations which in the main use coal as fuel, whereas the internal combustion engined vehicle uses oil which is a limited resource. In Australia there is 85 times as much coal energy available as there is oil energy and the Electric Car requires 18% less fuel energy than a petrol vehicle to travel the same distance, considering total energy from the ground source to road wheels.

The motor car represents approximately 77% of all road vehicles across the nation, and accounts for approximately 55% of all energy consumed in personal or goods movement; including transport by commercial vehicles, public transport, trains, aircraft and shipping. Some 70% of this amount is consumed by cars for personal transport in urban areas, divided equally between commuter and city business trips as one group and all other trips, including shopping, social and recreational and personal business trips. Thus, at present, commuter and city business trips in cars consumes approximately 20% of all fuel used for all transport purposes throughout Australia.

Whereas the Electric Car at the present state of development has sufficient range to cater for 90% of all urban journeys, allowing for return, there is insufficient reserve to allow additional journeys in any one day and to ensure confidence in the ability to complete a given journey satisfactorily without incurring the extensive delays associated with

TABLE 1.1: PETROLEUM IMPORTS - Based on existing trends and technology.

	1975	1980	1985	1990	1995	2000
Australian population: persons-million	13.4	14.24	15.06	15.89	16.69	17.46
Cars and station waggons No. -million	4.74	5.84	6.76	7.63	8.38	8.90
Motor spirit consumed kilolitres -million						
a) off-road engines	3.25	4.35	5.17	5.91	6.38	6.73
b.1) cars and waggons	8.29	11.70	14.70	17.82	19.23	20.28
b.2) other vehicles	1.46	2.07	2.60	3.15	3.39	3.58
Total	13.00	18.12	22.47	26.88	29.00	30.59
Petroleum consumed kilolitres -million	35.54	48.72	59.93	71.68	77.34	81.58
Petroleum imports kilolitres - million	13.34*	17.63*	59.93+	71.68+	77.34+	81.58+
Value of petroleum imports at $13.00 per barrel; 1977 currency. $ million p.a.	1093	1442	4904	5862	6323	6665
Value of petroleum imports with inflation at 8% p.a. $ million p.a.	934	1820	9076	15943	25267	39142

* Petroleum mix: Imports 37.5%, Australian 62.5%.
\+ Petroleum imports: 100% of Australian demand.

A kilolitre is approximately 220 imperial gallons.

recharging depleted batteries. The provision of "Park and Charge" facilities, at kerbside, in parking areas, stations and garages distributed widely in the central business districts, commercial and industrial areas, will allow batteries to be recharged during the many idle hours during the day, thereby greatly enhancing the range and performance of existing Electric Cars. This improvement in range and performance in city driving conditions should meet the requirements of the majority of city car users, and should tend to overcome the "Electric as a second car" syndrome which, because of the high cost of a new car, has inhibited introduction and the generation of pressure for development of this type of vehicle.

The introduction of the Electric Car as a commuter vehicle will require the provision of the appropriate "Park and Charge" facilities at convenient locations and in sufficient numbers throughout the city at an early date, as a stage by stage process; this will tend to stimulate the use of Electric Cars as the main car for everyday use as time goes by. With increasing cost, energy and environmental restraints it is considered that the internal combustion engined vehicle may be a station waggon type vehicle used only for long trips or for leisure purposes, and that by the year 2000 the Electric Car will have penetrated the available urban market significantly, within a probable range between 24% and 54%.

1.2 ENERGY CONSUMPTION

1.2.1 THE CONVENTIONAL (INTERNAL COMBUSTION ENGINED) CAR

The motor spirit component of all petroleum products consumed by the Australian market has averaged approximately 36% over the last 10 years, and is projected to rise to an average of 38% over the next 10 years (Ref.: Oil and Australia - 1976; Australian Petroleum Institute Ltd.). This quantity is allocated for the period to 1975 as follows:

a) 25% to all off-road petrol engines, i.e. boats; and fixed and mobile plant (including industrial, agricultural and domestic).

b) 75% to all petrol-engined road vehicles; of which some 85% are cars and station waggons.

For the period between 1975 and 2000, when emission control devices are installed on all new vehicles, and allowing for the consequent increase in fuel consumption, the allocation is adjusted to:

a) 22%.

b) 78%.

The allocation of the motor spirit, and the quantities of crude oil required are projected from 1975 to 2000, taking into account the saturation of the car market (ownership ratios ranging from 0.306 to 0.510 cars per person), and the progressive introduction of emission control devices on all new cars. From the data derived from limited comparative road testing of popular vehicles, the average increase in fuel consumption was 23%. However, it is considered that whilst high figures are evident at present it is possible that technology will improve and, accordingly, the rate of increase in fuel consumption has been adopted as 18%. It should be noted that more stringent emission controls were originally proposed to be implemented progressively from 1980 onwards, but it is understood that these requirements are under review.

The rate of introduction of cars with these devices as a proportion of the total car market is a function of the average life of a car, and this has been assessed in relation to new car registrations and wastage rates as being approximately 14 years. In Los Angeles, where there is extensive documentation on car survival rates, it should be noted that the average life of a car is 10 years.

Assuming that the technology of conventional cars remains constant and that inflation occurs at an average rate of 8% per annum, Table 1.2 indicates the relative total costs of motor spirit to the motoring public, with and without the emission control devices. This relativity has taken account of the trend to the use of smaller cars, but may change as a result of variation in emission control application. The fuel cost in 1975 at the pump was assessed at an average of $0.16 per litre, across the country, ignoring the effects of discounting that occurs in some city areas.

TABLE 1.2: TOTAL COST OF MOTOR SPIRIT AT THE PUMP.

Total Australian consumption for cars and waggons (Inflation 8 % p.a.)

	1975	1980	1985	1990	1995	2000
Fuel price at pump $/litre	0.160	0.235	0.345	0.508	0.746	1.096
Consumption without emission controls million kilolitres.	8.29	10.98	13.28	15.17	16.34	17.16
Fuel cost at pump $million p.a.	1,326	2,581	4,587	7,699	12,186	18,803
Consumption with emission controls million kilolitres.	8.29	11.70	14.70	17.82	19.23	20.28
Fuel cost at pump $million p.a.	1,326	2,751	5,072	9,053	14,346	22,227
Cumulative cost from 1975 of 18% fuel losses due to emission controls $million	0	456	2,657	8,617	20,160	38,339

1.2.2 THE ELECTRIC CAR

The Electric Car envisaged for the Australian market is in the small to medium range, seating four to five persons, length 4.1 metres and weighing 1,300 kg. The car would be powered by a 20 kw. motor drawing current from lead-acid batteries and would have maximum speed of approximately 90 kmph and a minimum range under urban conditions of 70 km.

Demands on power stations to supply electrical energy to satisfy all the "free" market" Electric Car loads will range from less than 1½% to 7% of all other electricity generated, assuming that the above car will consume power from the meter at the rate of 0.55 kwh/km. These demands can easily be accommodated and will only mean that towards the end of the century commissioning of power stations need only be advanced by 12 to 18 months.

Total investment required for the high estimate of market penetration of the Electric Car by the year 2000, at present values is:

	$ million
• magnetic card meters, 70% of total parking demand	266.4
• coal mining	343.0
• power stations	1,002.0
	1,611.4 *

* Assuming inflation at 8% p.a., this amount will be equivalent to $9,640 in the year 2000. At the projected rates of Electric Car penetration of the market, this capital expenditure would be more than offset by the saving in the reduced cost of fuel imports during the period to the year 2000.

TABLE 1.3: COST OF ELECTRICITY AT THE METER. Total for all Australian cars. High market penetration: Inflation at 8% p.a.

	1980	1985	1990	1995	2000
Electricity price at meter $/kwh.	0.045	0.067	0.098	0.144	0.211
Total power cost to motorists $ million p.a.	12.4	89.7	286.7	899.0	2798.7

1.3 BALANCE OF PAYMENTS

By consuming electrical energy derived from the vast coal resources within the nation, the Electric Car will enable a significant reduction in the consumption of motor spirit to be achieved. During the period 1985 - 2000, when Australia's known reserves of petroleum will be depleted, the consequent saving in fuel imports will be substantial. Table 1.4 provides details of the relative annual values of coal consumed and petroleum saved when considering conventional cars with and without emission controls.

At the high level of market penetration by Electric Cars, the cumulative saving in import expenditure to the year 2000 will exceed $2,000 million in 1977 currency at present prices for petroleum crude. The cumulative cost of coal consumed in this period would be approximately $245 million. This expenditure would not affect the nation's external balance of payments.

The balance of payments could be improved substantially by the complete repeal of legislation for the control of exhaust emissions from conventional cars, however this would be at the expense of much worse pollution in the larger cities unless Electric Cars gained a very high degree of market penetration.

TABLE 1.4: FUEL BALANCE SHEET FOR AUSTRALIA. 1977 Currency.

Reduction in quantity of and expenditure on petroleum for motor spirit due to introduction of Electric Cars compared to conventional cars with and without emission controls.

		1980	1985	1990	1995	2000
Value of coal consumed by Electric Cars. $ million p.a.	H	1.6	6.0	10.6	17.5	28.6
	L	1.0	3.2	5.7	9.4	15.4
Petroleum saved by ECars C cars with emission control kilolitres - thousand p.a.	H	67	359	856	1927	3869
	L	40	158	378	851	1711
Value $ million p.a.	H	5.5	29.4	70.0	157.7	316.5
	L	3.3	12.9	30.9	69.6	140.0
Petroleum saved by ECars C cars without emission control kilolitres - thousand p.a.	H	64	322	726	1633	3279
	L	38	142	321	721	1450
Value $ million p.a.	H	5.2	26.3	59.4	133.6	268.3
	L	3.1	11.6	26.3	59.0	118.6

Petroleum at $13.00 per barrel.

H = High)
L = Low) market penetration of Electric Cars.

E cars = Electric Cars.
C cars = conventional cars.

2. ELECTRIC CARS AS A COMMUTER SYSTEM

2.1 INTRODUCTION

Development of Electric Cars has been inhibited by the limited energy storage capacity of existing lead-acid batteries, and the difficulty that has been experienced in research and development of advanced battery technology. New high power batteries are feasible, but are still largely experimental. Development work to produce these batteries with characteristics of reliability, operational safety and convenience, low weight, long life and economy of materials and manufacture have not been very rewarding, although there is optimism that a breakthrough in technological development will be available within one or two decades.

The restrictions on vehicle range and performance imposed by the limitations of lead-acid batteries, even the improved variety, have been substantial; although, surprisingly, the Electric Car could probably cope with about 90% of all urban requirements at this time. This demand would however exhaust the batteries and prevent the use of the Electric Car until recharged, usually over a period of eight hours.

The public recognises this defect and, with no confidence in the ability to complete journeys satisfactorily, has not seen the Electric Car as a viable alternative to the conventional car.

With the world's petroleum supplies being restricted, and the introduction of emission control on vehicle exhausts, there are substantially increased costs in using conventional cars. The introduction of Electric Cars is of vital importance to Australia which will, after 1985, be dependent on imported oil supplies.

The "Park and Charge" meter concept of substantially increasing the range of Electric Cars by recharging the batteries at each end of a journey, whenever the cars are idle, overcomes the lag in battery technology to make the Electric Car an attractive means of commuter and business transport in city areas. With an increased public confidence in the ability of the car to complete all required city journeys, and with adequate performance characteristics and economy of operation, the Electric Car should experience a ready market.

2.2 BATTERY TECHNOLOGY

It has been recognised that one of the principal reasons why Electric Cars have not yet been widely accepted is the limited range per battery charge. Throughout the world many different types of battery are under development for vehicle propulsion; some have shown intrinsic promise but no one system meets all the requirements of:

- low cost,
- high energy density (kilowatts / kilogram weight),
- good discharge capacity (ampere-hours),
- long cycle life and reliability,
- operational safety and convenience,
- economy of materials and manufacture,
- abundant material resources throughout the world,
- simple installation procedures,
- ease of recycling or disposal.

Battery types under development are:

- Improved lead-acid,
- Zinc-nickel,
- Zinc-air,
- Zinc-chlorine,
- Sodium-sulphur,
- Lithium-sulphur.

The lithium-sulphur battery is an advanced type with high energy density and operates at very high temperature (600 °C). It is still very experimental.

Sodium-sulphur and zinc-chlorine batteries have good energy densities and are expected to be available commercially within five to ten years, but are more suited to heavy vehicle and industrial application. As the former operates at high temperature (400 °C) and the electrolyte of the latter requires refrigeration, these systems pose substantial development problems in order to achieve a suitable specification for use in Electric Cars, particularly in relation to operational safety and convenience.

Zinc-air batteries operate at ambient temperatures, have good energy density but low power output and cycle life. The batteries must be used in conjunction with lead-acid batteries to allow for peak load application, and are not commercially viable at present.

Zinc-nickel batteries suffer from internal short-circuiting on frequent recharging, and research work is proceeding to overcome this fault in a potentially good type of battery.

The improved lead-acid battery has achieved dominance because of good capacity, reliability, long cycle life and relative economy even though the energy density is only moderately low. Present limitations on energy density, at between 40 to 50 watt-hours per kilogram of total battery weight, severely limit the total charge that can be stored in a vehicle of reasonable size and weight so that for most cars under development the range for city driving conditions is of the order 40 to 70 kilometres. It is expected that the energy density may be improved, for commercial batteries, to about 60 watt-hours/kilogram within the next five years, while maintaining a minimum cycle-life for deep discharge at 500 - 600 cycles. This would allow a probable average life of the order of three years if "Park and Charge" meters are used to keep batteries "topped up" and deep discharges to a minimum.

With the need to establish Electric Cars on the market at the earliest possible date, and given the limitations of alternative battery technology, it will be necessary to accept the lower energy storage capacity of lead-acid batteries and look to other ways by which performance and range may be improved, so that trends in the consumption of petroleum may begin to be reversed. Vehicle design, with an emphasis on weight reduction and transmission improvements, will be an important avenue to improved performance with respect to acceleration and other handling characteristics.

For the purpose of this study, it is assumed that only improved lead-acid batteries will be available throughout the period to the year 2000. It has to be noted , however, that earlier introduction of new types of battery, with substantially higher performance or the successful introduction of fuel cells, would make the Electric Car even more attractive. A higher penetration of Electric Cars could then occur and the subsequent effects would need to be adjusted accordingly.

2.3 CHARGING FACILITIES

Supplementary charging facilities include:

- Battery pack exchange stations,
- Service stations with rapid charge capability,
- Auxiliary power unit trailers, and
- "Park and Charge" meters established conveniently at kerb-side and open parking areas, shopping centres, drive- in theatres, parking stations and office building garages.

2.3.1 BATTERY PACK EXCHANGE STATIONS

Battery pack exchange stations will be necessary to cater for longer journeys, but extensive development of this facility will require a wasteful investment of resources in the duplication of batteries and would impose the need on motorists to undertake extremely expensive funding arrangements whilst experiencing uncertainties relating to valuation of battery property at changeover. Battery rental would assist in this regard, but abuse of the batteries by tenants could lead to high prices for this privilege.

2.3.2 SERVICE STATIONS

The provision of rapid charge facilities at service stations will also be a necessary feature to provide a short-term boost charge in the case of emergencies, however this service has limitations of flexibility and location.

2.3.3 AUXILIARY POWER UNIT TRAILERS

The use of trailers equipped with diesel powered generators to extend the range of Electric Cars sufficiently for rural trips provides an alternative to the need for a second (conventional) car for such purposes. The use of trailers consistently within city areas would be cumbersome and lead to traffic congestion while not assisting the reduction of problems with fuel supplies or the environment, and would be a significant item of capital expenditure for each motorist. However, the hire of auxiliary power unit trailers from local depots when needed for rural journeys, or the recovery of stranded cars, would be a benefit.

2.3.4 "PARK AND CHARGE" METERS

"Park and Charge" meters, established across a city in central business districts (C.B.D.), commercial and industrial areas will add a convenient way to provide a recharging facility with the flexibility of the car maintained as far as practicable. The meters would be capable of providing both "trickle" and "boost" charging, although the latter could not be considered an alternative to the rapid charge obtainable at a service station.

2.4 METER SYSTEMS

"Park and Charge" meters may be installed progressively as the demand develops, with varying degrees of sophistication in marketing the product: electrical power.

- Adaption of existing coin-operated meters by providing separate power dispensing modules adjacent the stems, at low level. The modules would be controlled by low voltage relays, switched in the meters to sense coin insertion and time expiry. Existing meters may be modified for this purpose, but coin capacity is limited, and frequent maintenance and coin collection would be required.

- Advanced coin-operated twin meters, with direct power connection and switching systems; and equipped with large coin storage capacity.

- Magnetic card-operated meters, similar to the previous units, but not needing the coin store. These meters would use cards impressed with consumable magnetic symbols which are systematically cancelled as power is consumed. The cards would be available for purchase in advance as required.

- Magnetic card-operated console controlling a number of power dispensing modules at low level. The system would use permanent identifiable magnetic cards and would be controlled by a central computer for operation and invoicing costs to users by mailed accounts. The consoles would be equipped with a data entry panel and light emitting displays for information on identity, power and cost.

- Punched, printed or magnetic cards with boom gate control at parking stations. Electric Car charging outlets in special areas, separate from parking spaces for conventional cars, could be un-metered if entry into those areas was controlled. Payment would be at the check-out booth.

- Un-metered charging outlets may be provided in some office buildings where the building owners include the cost of power supply in the car space rental.

With the progressive sophistication of the systems, apart from operational convenience and reliability, there are economies in installation, maintenance, fee collection and supervision. The details of meter systems are described in greater detail in Chapter 5.

2.5 COMMUTER MARKET

Battery Electric Cars will normally be charged when not used at night, and the quantity of energy stored may well be adequate for short trips to neighbourhood shopping centres when the vehicle functions as a second family car for this purpose. The large scale introduction of the Electric Car, however, requires the installation of "Park and Charge" meters throughout a city to encourage their use for commuter and business travel. It will then be possible to recharge the batteries of an Electric Car at any time the vehicle is not being used. The ranges of the cars may be increased by a factor of two, or more if boost charges are taken.

"Park and Charge" meters will therefore improve the confidence of the public in the ability of the Electric Car to provide a satisfactory alternative transportation system, and remove the fear of being stranded through inadequate power reserves.

The introduction of Electric Cars to the market, and the satisfaction of the electrical demand which will be applied over a wide time scale during each day, will not require any substantial increase in generating capacity. Generally, traffic peaks occur at similar time periods to the present peaks in electrical demand and at those times the demand for recharging will be at a minimum. The recharging demand will occur after the passage of the peak electrical demands of domestic and industrial supply, and can be catered for the most part by the present off- peak capacity within the supply system. In fact, as discussed in Chapter 7, the provision of the Electric Car demand will tend to reduce the need for the power supply to be temporarily suspended suddenly in the event of rapid system overload, because the buffer storage so provided will allow sufficient time for auxiliary power generation units to be brought on line. Cessation of power supply to this appreciable sector of the system, for several minutes, would have no significant effect on the recharging of car batteries which in effect provides the supply system with effective buffer storage. This storage would help eliminate udesirable irregularities in supply to normal consumers in these circumstances.

3. CAR CHARACTERISTICS

3.1 INTRODUCTION

The characteristics of conventional internal combustion-engined cars presently on the market are changing rapidly in response to energy, economic and environmental factors influencing the community.

The introduction of emission control devices, in accordance with Australian Design Rule 27A in 1976, has had a significant impact on car performance and operational cost. The increased fuel consumption characteristic will be further aggravated if people tend to buy cars with larger engine displacements to compensate for the loss of power; and on its own account this feature is contrary to the requirement to conserve fuel in view of the impending energy crisis in Australia.

Because of economic pressures, it is likely that drivers will forego the demands of the past for those high performance characteristics that are used infrequently or designed for driver appeal. The economic pressures will be exacerbated if legislation similar to that proposed in the U.S. is introduced to force manufacturers to comply with a program to improve fuel consumption by at least 50% during the period 1978 - 1985, with the addition of a graduated scale of taxes on cars which do not comply: and again by the raising of the price of Australian oil to equal that on the world market.

Consequently it is expected that the presently discernible trend to acceptance of smaller cars with proportionately better fuel consumption, will accelerate.

It is into this changing market that Electric Cars will be thrust by events, largely outside our control; that is, by cessation of crude oil supplies in Australia, and subsequently throughout the world.

3.2 CONVENTIONAL CARS

Cars and station waggons are currently classified by size as large, medium or small with sub-classification such as luxury, family, small-medium. Several characteristics, including accommodation, engine displacement and number of cylinders, weight and length influence the classification; however, the boundaries are naturally not specific.

TABLE 3.1: CONVENTIONAL CAR CHARACTERISTICS (New car condition - 1976)

CLASSIFICATION	LARGE		MEDIUM		SMALL	
Type	Luxury	Family	Luxury	Family	Small-Medium	Small
Accommodation	5	5	4-5	4-5	4	4
Weight - kg.	1,560	1,425	1,210	1,140	960	790
Length - metres	4.92	4.81	4.66	4.41	4.19	3.89
No. cylinders	8	6	4-6	4	4	4
Engine Displacement - litres	4.26	4.15	2.33	2.76	1.73	1.32
Power - kw.	158	137	89	100	75	52
Fuel Consumption km/litre	5.5	6.5	8.0	8.2	9.5	11.2
Approximate Price $	17,000	6,700	10,300	5,600	4,700	3,900
Approximate Operating Cost for 16,000 km/$/km	0.11	0.09	0.07	0.07	0.06	0.05

Recent comparative tests on two large family size cars indicate that fuel consumption increases by an average of 23% when exhaust emission control devices are fitted.

The cars were in new condition, and were tested under average driving conditions in city areas.

3.3 ELECTRIC CARS

Extensive experimental development in many countries has explored a variety of concepts regarding Electric Cars, including

- automated captive
- hybrid semi-captive electric/battery electric
- hybrid conventional / battery electric
- battery electric.

3.3.1 AUTOMATED CAPTIVE

Several nations have developed experimental demonstration facilities to examine the operational characteristics of automated captive systems which are in effect public transport services using small four or six seat car modules operating on a network of elevated tracks. The tracks are proposed at a grid of one kilometre centres across a city. The modules are continually moving, and vacant units are sidetracked at stations for entry. The systems are controlled by computers, using magnetic card tickets and computer terminals at the stations for calling up destinations, routes and numbers of passengers, and are capable of centralised invoicing. The inherent disadvantages of such systems are the highly capital intensive establishment cost, the impersonal nature of the service and the need for prospective passengers to walk to each station.

3.3.2 HYBRID SEMI-CAPTIVE

Proposals for hybrid semi-captive electric / battery electric systems envisage the use of privately owned vehicles operating on batteries when travelling on minor roads and drawing power supplies from overhead or underground distribution lines when travelling on major routes. The systems require duplication of some equipment on board the vehicles, and the development of electronic monitoring for adequate traffic control. Some queueing congestion may occur at peak periods. These systems would overcome the impersonal nature of the previous systems, but would require large capital investment by public authorities as well as by individual car owners.

3.3.3 HYDRID CONVENTIONAL/BATTERY ELECTRIC

This concept is a compromise endeavouring to retain the long range and performance of the conventional car while obtaining community benefits, in city areas, of a reduction in pollution. One theme suggests that the use of IC engines would be prohibited within city boundaries, where the electric drive could be used, leaving the IC engine to be used on longer, rural trips. Another theme suggests that a small IC engine running at constant speed (and therefore economically and with low emission problems) would constantly charge batteries providing a reservoir of power for electric drive, so that adequate acceleration and hill-climbing ability would be provided. Each of these themes has been explored experimentally, but unit costs will remain high because of the complex power sources and transmission. It is unlikely that there will be sufficient market penetration to warrant large scale development of this type, or that it will provide any significant reduction in the depletion of liquid fuel reserves.

3.3.4 BATTERY ELECTRIC

This concept has attracted more attention than the previous concepts and extensive development is being undertaken in many countries. Many combinations of battery types, motors, controllers and transmissions have been investigated and gradually the design has evolved to the stage where cars of reasonable performance can be produced. Battery technology is developing at a slow pace and limits cars at this stage to using improved lead-acid batteries which have modest energy storage, but reasonably good cycle life. Range limitation is a direct result of the limited energy storage capability of lead-acid batteries which are unlikely to be displaced for at least one or two decades.

Supplementary recharging of batteries during periods when cars are idle will increase the potential daily range appreciably.

From analysis of conventional cars, and taking into account the increasing cost penalties that will apply in future years to cars with high fuel consumption, and allowing for lead-acid batteries with recharging by "Park and Charge" meters, it is postulated that the ideal urban Electric Car for the Australian market would approximate the following specification:

Accommodation	4-5 persons
Length	4.1 metres
Gross weight	1,300 kg.
Battery weight	350 kg.
capacity	14 kWh
Motor, rated power	20 kw
Max. speed	90 kmph
Range (urban conditions)	70 km min.

It is anticipated that the above car would consume an average of 0.55 kWh/km (battery input) whilst averaging three stops per kilometre, with an intermediate cruise speed of 60 km per hour.

In the event of improved batteries being available, either the range could be increased or the battery weight reduced. If the latter, it is probable that the economics of electric transportation would be better than the comparable conventional car.

Electric Cars would be equipped with on-board chargers, rated at 240 Volt single phase and 15 amp capacity. The chargers would need to monitor the state of charge in the batteries to avoid gassing problems, and the consequent loss of electrolyte when the batteries are nearly fully charged.

Table 3.2 provides some data on several recent experimental Electric Cars.

TABLE 3.2: TYPICAL EXPERIMENTAL ELECTRIC CARS

Country		Australia	Japan			Sweden	U.K.	U.S.A.
Model		Flinders Mark II	Light	Compact	Large	Volvo-Light	Lucas Taxi	Copper Town Car
Accommodation		4	4	5	5	4	5	
Length - metres		3.60	3.17	3.35	4.50	2.68		3.68
Gross Weight - kg.		1150	1128	1650	1920	1000	2500	1500
BATTERY	Weight - kg.	310	340	500		360	1000	450
	Type	ILA	ILA	ILA		Lead-Acid Traction	ILA	Lead-Acid Traction
	Voltage	144	96	192		72		108
	Capacity Ah/5 hr.		200	158.5				
	Cycle Life							
MOTOR	Type	PC	Series DC	Shunt DC			Series DC	Shunt DC
	Rated power - kw	10.2	11.2	20.0		8.0	37.0	30.6
Control System		Battery Switching	Thyristor	Thyristor		Thyristor		Combined Switching & Thyristor
Max. speed - km/hr.		70	80	94	85			90
Acceleration - secs.		0-50 km 17.5 secs.	0-40 km 9 secs.	0-40 km 9 secs.				0-65 km 12 secs.
Max. range at Constant speed - 40 km/hr.		120	175	180	55	70		190
Urban Driving Range - km.		60-70					80-120	Up to 100

P.C. = Printed circuit ; D.C. = Direct current; I.L.A. = Improved lead -acid.

3.4 ON-BOARD BATTERY CHARGERS

It is likely that on-board chargers will be specifically designed for each type of Electric Car. Basically they should fulfill the following operational requirements:

- Ability to withstand frequent charging operation,
- Simple to operate even by laymen,
- Auto-restart of charging after power interruptions,
- Protection against over-voltage and over-current,
- Protection against potential imbalance between the charger and the vehicle body,
- Compact and light weight,
- Ability to withstand mechanical stresses as a result of the motion of the vehicle,
- High reliability,
- Low noise operation,
- Provision of radio interference suppression in order to avoid interference with other consumers,
- Low maintenance.

The power rating of the on-board chargers should be selected to suit the application but at the same time it has to be standardised to match the capacity of power outlets provided at parking spaces and parking stations. The power rating of the on-board charger limits the rate of energy replenishment; therefore the maximum daily travel range is restricted.

It is proposed that standard on-board chargers should be rated at 240 Volt single phase 15 amp for the following reasons:

- they can be plugged into readily available standard 240 Volt single phase 15 amp outlets,
- they require less bulky and less expensive filters,
- lower capital costs are involved in power reticulation to power outlets,
- they produce less voltage disturbance and can be more efficiently utilised as compared to larger chargers.

3.5 BATTERY CHARGER DESIGN ASPECTS

On-board battery chargers are designed to work on several principles:

- constant potential
- constant current
- two step method, i.e. constant current and constant potential.

The last method is very suitable for on-board charging of Electric Cars, especially when the batteries are close to full charge. The initial high current is pulse controlled to keep it constant until the battery temperature or battery voltage reaches the pre-selected value; afterwards the voltage control takes over to hold the battery voltage at constant level. This action is required to avoid gassing as the battery voltage rises, and the consequent loss of electrolyte.

It is envisaged that on-board chargers should incorporate status indicators. In order to permit fast charging to be carried out in charging stations, a changeover switch has to be incorporated to by-pass the on-board charger whenever necessary.

New equipment, recently developed within Australia, monitors the average specific gravity of battery electrolyte in order to assess the state of charge, and it is proposed to adapt this equipment to control the rate of charge to suit exactly the battery's acceptance rate. This system is relatively small and inexpensive and would be ideal as an on-board charger.

4. TRANSPORTATION PROJECTIONS

4.1 GENERAL

The transportation projections for each State and Australia have been derived from studies undertaken in relation to the Modified Sydney Region, and extended on a population basis to cover those metropolitan areas within each State that might reasonably be expected to support the establishment of a market for Electric Cars.

Metropolitan areas considered appropriate for Electric Cars used principally as commuter vehicles are mainly coastal cities with present population exceeding 20,000 persons. Inland cities and growth areas of that order of magnitude have been excluded on the premise that most inhabitants would tend to require vehicles to operate in the adjacent country areas, and would not therefore be attracted by the limited range characteristics of the Electric Car. Canberra, being a city of significantly larger size, has been included because of its extensive commuter traffic.

Population projections for each metropolitan area, based on 1971 and 1976 Census data, have been assessed by reference to the Australian Bureau of Statistics, appropriate State Planning Authorities and the Town Planning Departments of the relevant cities. A market population in each State has been derived for five-year increments to the year 2000; and data on vehicle registrations, gross vehicular distances travelled and parking demand in the central business district (C.B.D.), commercial and industrial areas have been developed for each period.

Penetration of the market available to Electric Cars has been denoted by two exponential growth curves representing low and high levels, commencing with 1.50% and 2.25% in 1980 ranging to 40.00% and 80.00% in 2000 respectively. With due allowance for vehicular type and ownership preferences these figures reduce to approximately 24% and 54% of <u>all</u> cars and waggons in the year 2000.

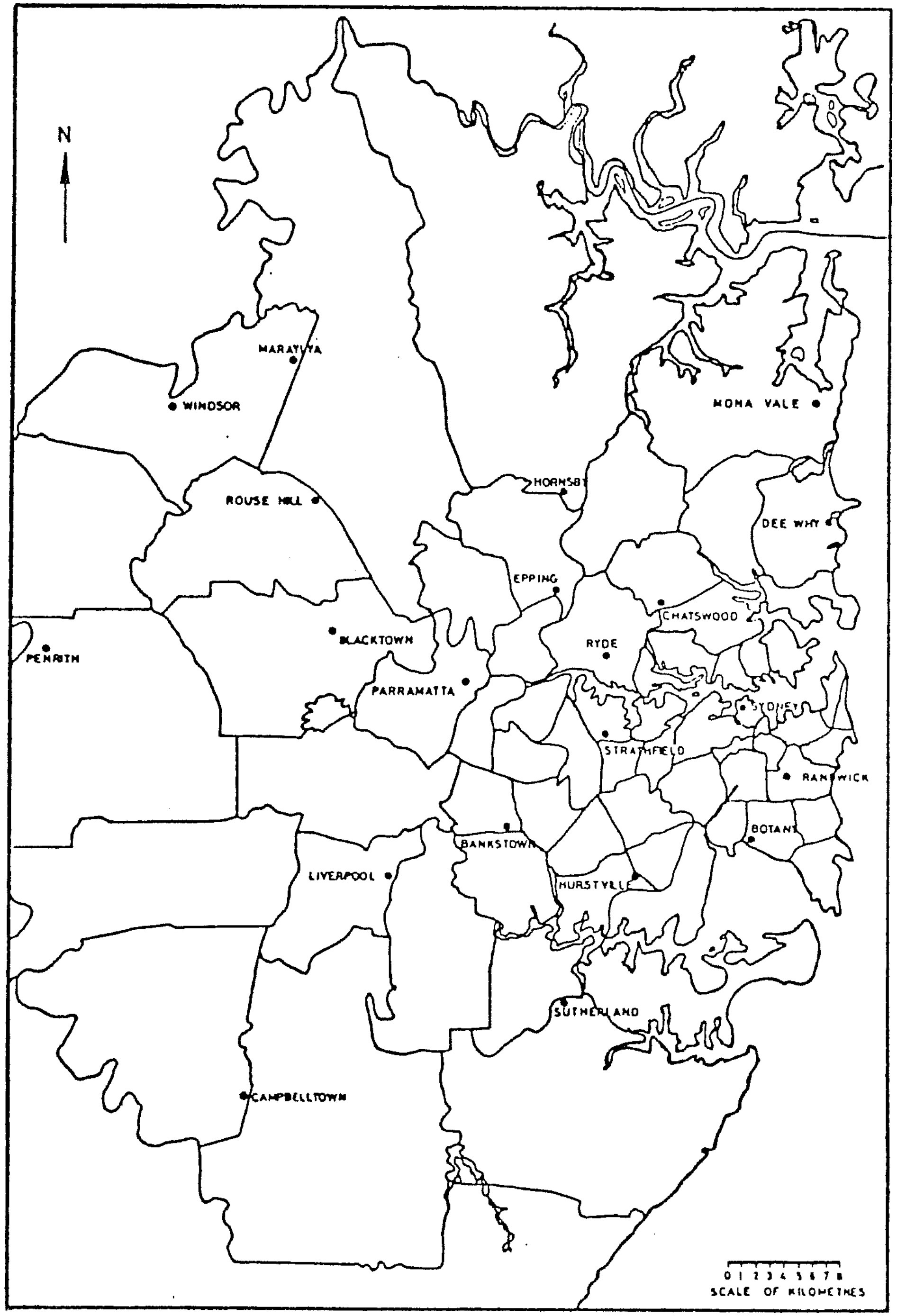


Fig 4·1 MAP OF MODIFIED SYDNEY REGION SATS - 1971

TABLE 4.1: POPULATION PROJECTIONS x 1000 PERSONS

STATE	METROPOLITAN AREA	1971	1975	1980	1985	1990	1995	2000
NEW SOUTH WALES	Modified Sydney Region	2791.0	2900.0	3046.0	3215.0	3370.0	3518.0	3658.0
	Sydney Outer Metro	252.4	291.0	338.5	393.0	460.5	526.5	608.0
	Newcastle	268.4	269.5	279.0	290.0	302.0	313.0	322.9
	Wyong-Gosford	89.3	103.0	120.0	137.0	151.0	175.5	200.0
	Campbelltown	46.7	67.5	108.5	167.0	221.8	280.2	332.5
	Wollongong	160.9	181.5	208.4	222.5	244.5	264.0	282.1
	TOTAL METRO AREAS	3608.7	3812.5	4100.4	4424.5	4749.8	5077.2	5403.5
	TOTAL STATE	4601.2	4810.0	5067.0	5359.5	5649.5	5932.5	6218.0
VICTORIA	Melbourne	2503.0	2580.0	2685.0	2765.0	2820.0	2870.0	2910.0
	Geelong	122.1	129.0	132.0	137.0	140.5	143.0	144.5
	TOTAL METRO AREAS	2625.1	2709.0	2817.0	2902.0	2960.5	3013.0	3054.5
	TOTAL STATE	3539.8	3675.0	3820.0	3925.0	4020.0	4090.0	4140.0

TABLE 4.1: POPULATION PROJECTIONS x 1000 PERSONS (cont'd)

STATE	METROPOLITAN AREA	1971	1975	1980	1985	1990	1995	2000
QUEENSLAND	Brisbane-Ipswich	701.0	732.0	777.0	812.0	865.0	900.0	940.0
	Brisbane Outer Metro	136.0	150.0	167.0	186.0	206.0	227.5	250.0
	Gold Coast	74.2	97.0	127.0	158.0	188.0	219.0	250.0
	Mackay	34.3	38.7	44.9	50.0	57.0	64.0	74.0
	Rockhampton	47.0	50.0	56.0	63.0	69.5	76.0	82.5
	Townsville	71.1	81.5	98.0	117.0	138.0	155.0	170.0
	Cairns	30.1	34.3	40.0	47.8	56.0	64.6	72.0
	TOTAL METRO AREAS	1093.7	1183.5	1309.9	1433.8	1579.5	1706.1	1838.5
	TOTAL STATE	1827.1	1955.9	2144.0	2348.3	2562.2	2784.7	3023.3
A.C.T.	Canberra	144.0	195.0	250.0	306.0	382.0	454.0	540.0
S. A.	Adelaide	842.7	892.0	940.3	990.0	1040.0	1083.0	1127.0
	TOTAL STATE	1160.0	1225.0	1292.0	1358.0	1420.0	1475.0	1520.0
TAS.	Hobart	153.8	160.8	171.4	177.6	185.6	192.8	199.4
	Launceston	62.2	64.9	66.9	68.8	70.6	72.2	74.0
	TOTAL METRO AREAS	216.0	225.7	238.3	246.4	256.2	265.0	273.4
	TOTAL STATE	391.0	397.0					
W. A.	Perth	701.0	787.0	905.0	1030.0	1155.0	1275.0	1400.0
	TOTAL STATE	1030.0	1128.0	1282.0	1422.0	1600.0	1772.0	1940.0
AUST.	TOTAL METRO AREAS	9231.2	9804.7	10560.9	11332.7	12123.0	12873.3	13636.9
	TOTAL AUSTRALIA	12756.0	13400.0	14242.0	15060.0	15892.0	16685.0	17459.0

4.2 POPULATION DATA

Population trends over past years are expected to continue; however, it should be noted that migration, both from overseas sources and internally, could allow noticeable variations to arise if current trends are distorted by political, economic or development factors that may occur in the period under consideration. During this period the population of Australia is expected to grow to 17.5 million persons by the year 2000.

Table 4.1 presents the extent of population data obtained for this study and anticipated projections. The metropolitan areas considered are listed and summed to provide the total population considered as a market for Electric Cars, and is compared to the total State and national populations.

4.3 VEHICLE REGISTRATIONS

Cars and station waggons represented 77% of all vehicles registered in Australia at 31st December, 1975, and approximately 84% of all petrol powered vehicles (Ref. 4.1).

Projections of the distribution of first and subsequent cars between households are tabulated below (Ref. 4.2 and 4.3).

TABLE 4.2: DISTRIBUTION OF FIRST AND SUBSEQUENT CARS BETWEEN HOUSEHOLDS

Proportion of all Households Owning the Number of Vehicles Stated

	Zero	1	2	3	4 or more
1971	21.0	50.2	22.3	4.8	1.7
1981	15.5	48.2	28.1	6.0	2.2
1991	12.0	47.1	31.7	6.7	2.5
2001	9.6	46.1	34.3	7.3	2.7

TABLE 4.3: ESTIMATED STOCKS OF URBAN CARS BY TYPE - 1971 to 2000 - PERCENT

Car Type	1971	1980	1990	2000
1st	68.3	64.6	60.3	55.7
2nd	24.7	27.6	31.0	34.7
3rd	5.5	6.3	7.0	7.8
4 or more	1.5	1.5	1.7	1.8
	100.0	100.0	100.0	100.0

Registration statistics reveal that throughout Australia, during the period 1971 to 1975, new car registrations averaged 9.8% of all existing registrations of that type; and that whilst cars represented 87.5% of this type in 1971, there was a trend to increasing the proportion of station waggons by approximately 0.25% per annum.

Analysis of car size indicated that in the year 1975-76 only 3% of all cars were classified as large.

TABLE 4.4: NEW CAR REGISTRATIONS - 1975-76 - PERCENT

Size	Cars	Station Waggons	Total
Small	45	28	42
Medium	52	27	48
Large	3	45	10
Total	100	100	100

4.4 CAR OWNERSHIP

Car and station waggon ownership per head of population characteristics are tabulated in Table 4.5, and it should be noted that the ownership ratio for the Sydney Region, as determined by the Sydney Area Transportation Study, 1971 (S.A.T.S.), is slightly less than the national average.

TABLE 4.5: CAR AND STATION WAGGON OWNERSHIP RATIO - Vehicles Per Head of Population

	1971	1975	1980	1985	1990	1995	2000
Modified Sydney Region	0.307	0.350	0.390	0.430	0.470	0.4875	0.493
Australia and all States	0.306	0.354	0.410	0.449	0.480	0.502	0.510

4.5 TRAVEL CHARACTERISTICS

Detailed studies of the Modified Sydney Region, which were extended to indicate the situation for the States and the whole Nation, were based on data obtained for the Sydney Area Transportation Study, 1971, and projected in proportion to the market populations projected to the year 2000. Table 4.6 details the journey purpose and mode of travel for both the study area as a whole and the C.B.D.

Figure 4.2, relating to the S.A.T.S. Modified Sydney Region, indicates the distribution for each mode of travel, and it is significant that the average distance travelled per journey is approximately 10 km. with 90% of all journeys less than 25 km.

Figures 4.3 and 4.4 indicate the periodic distribution of the number of journeys by mode of travel and journey purpose.

The daily car trip factor will tend to increase from 2.15 car trips per day, as recorded in S.A.T.S. 1971, to approximately 2.60 in the year 2000, because of the increased availability of cars within each household and the greater decentralisation of city functions.

4.6 ELECTRIC CARS — MARKET PENETRATION

It is anticipated that Electric Cars will penetrate the market slowly in the initial period after introduction, but will experience an exponential growth as greater acceptance occurs as a result of

- improving technology, with better power, range and acceleration,
- improved battery technology, giving longer cycle life,
- the energy crisis, and
- environmental factors.

The growth curves indicating possible market penetration rates are presented in Figure 4.5. The low rate would probably be appropriate to a free market condition, while the high rate may require additional stimulation to the population by way of political or economic pressure.

TABLE 4.6

JOURNEY PURPOSE AND MODE OF TRAVEL, 1971

CATEGORY	A		B		C		D		E		F			
	Home-Based Work		Home-Based School		Home-Based Shopping		Home-Based Social/ Recreational		Home-Based Personal Business		Non Home-Based		All Purposes	
Mode of Travel	Number of Journeys	Per Cent	Number of Journeys	Per Cent	Number of Journeys	Per Cent	Number of Journeys	Per Cent	Number of Journeys	Per Cent	Number of Journeys	Per Cent	Number of Journeys	Per Cent
STUDY AREA														
Private Vehicle	1,161,400	65.1	179,000	31.1	407,100	75.8	688,700	90.5	523,900	87.8	559,200	85.9	3,519,300	71.7
Public Transport	624,500	34.9	396,400	68.9	129,500	24.2	72,400	9.5	72,600	12.2	192,200	14.1	1,387,600	28.3
Total	1,785,900	100.0	575,400	100.0	536,600	100.0	761,100	100.0	596,500	100.0	651,400	100.0	4,906,900	100.0
Percentage of Total	36.4		11.7		10.9		15.5		12.2		13.3		100.0	
CENTRAL BUSINESS DISTRICT														
Private Vehicle	77,000	22.2	1,300	9.9	6,300	17.0	21,200	55.6	17,600	42.1	55,700	58.2	179,100	31.2
Public Transport	270,100	77.8	11,900	90.1	30,600	83.0	17,000	44.4	24,100	57.9	40,100	41.8	393,800	68.8
Total	347,100	100.0	13,200	100.0	36,900	100.0	38,100	100.0	41,700	100.0	95,800	100.0	572,900	100.0
Percentage of Total	60.5		2.3		6.5		6.7		7.3		16.7		100.0	

SATS - 1971

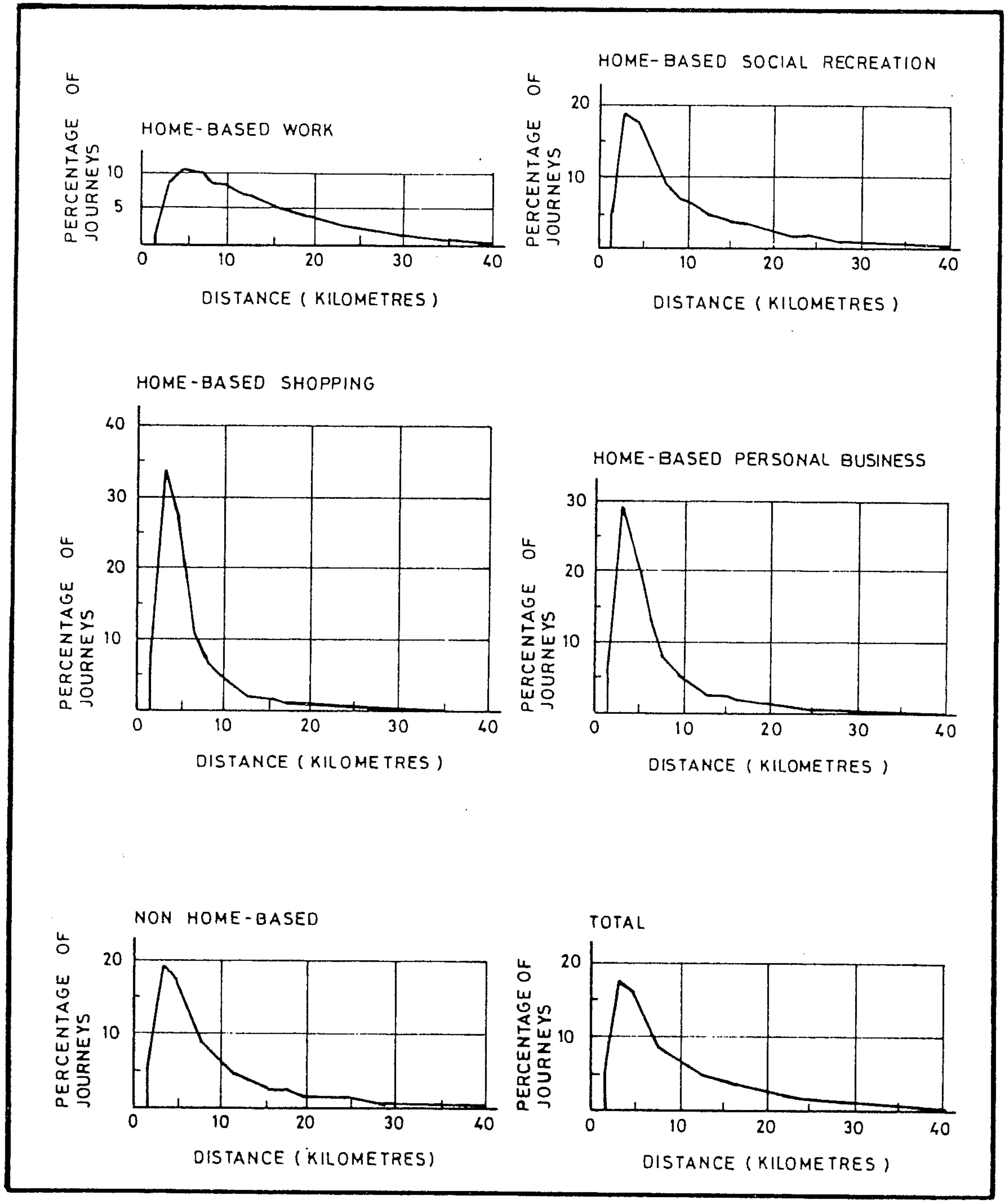


Fig 4·2

Distribution of Interzonal Private Vehicle Driver Journeys by Length of Journey Study Area - 1971

SATS - 1971

BY MAIN MODE OF TRAVEL

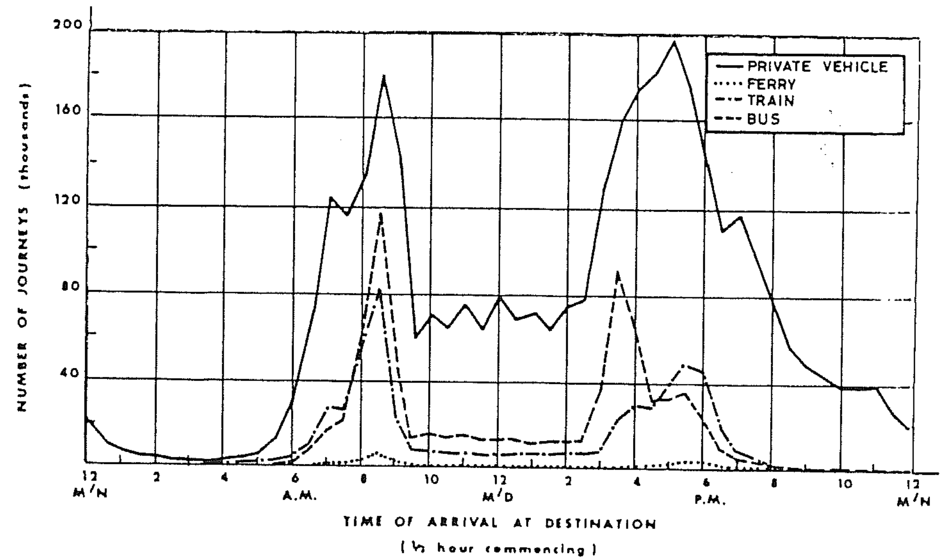


Fig 4-3

BY JOURNEY PURPOSE

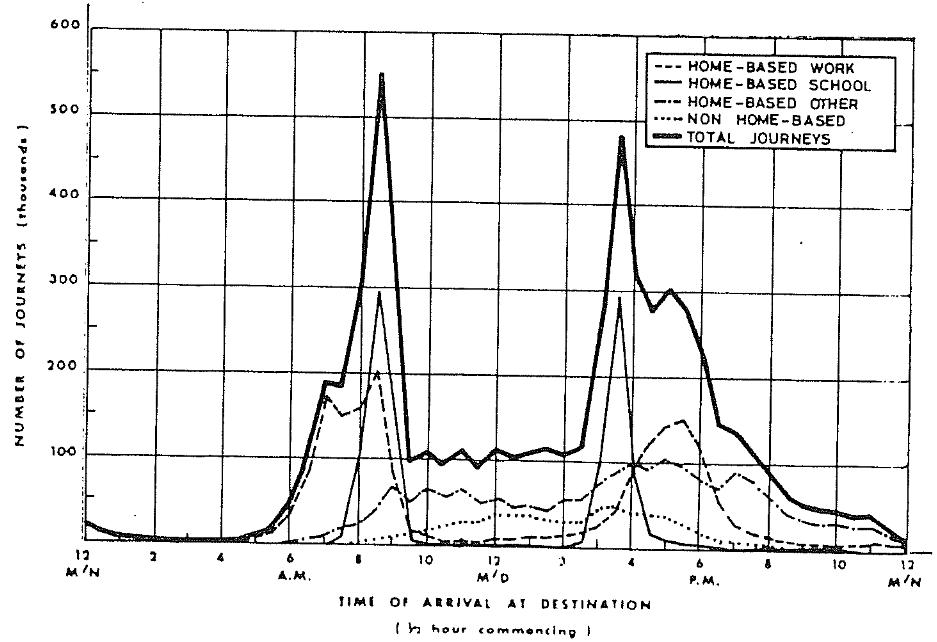


Fig 4·4

SATS - 1971

Distribution of Person Journeys by Time of Day
Study Area - 1971

4.7 TRAFFIC DEMAND — ASSESSMENT

The average weekday journey purpose and mode data for the Modified Sydney Region of S.A.T.S. 1971 is used as a basis for ascertaining the total daily car and waggon trips applicable to each of the five year growth periods to the year 2000. A population growth factor relative to the base year, 1971, together with historical trends in the various vehicle occupancy ratios is used to generate the total car and waggon trips for each of the relevant categories of journey.

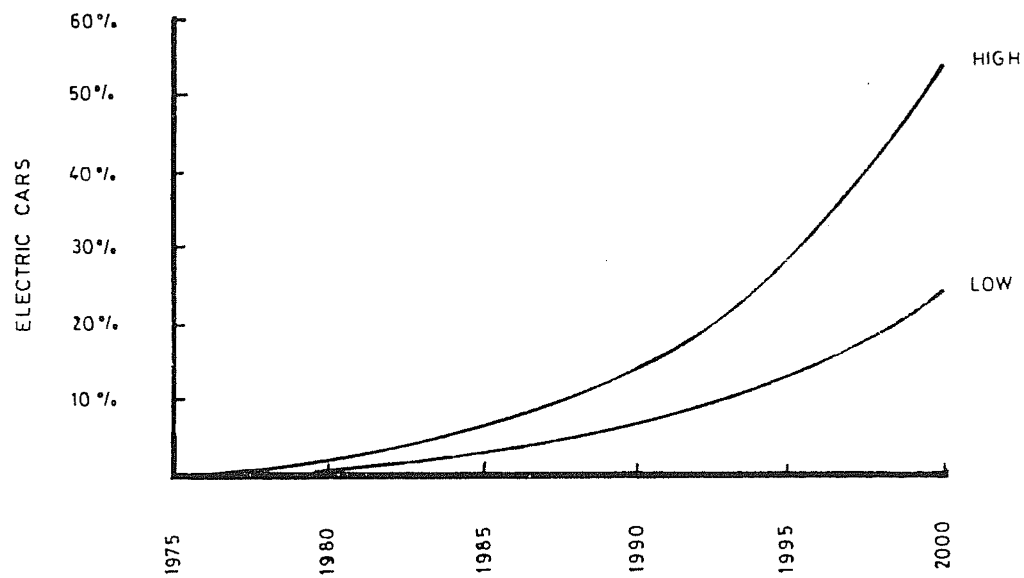
Journey categories relevant to the low market penetration are A, C, E, F, whilst categories relevant to the high market penetration are A, C, half D, E and F. Refer to Table 4.6

It is considered that Electric Cars are not likely to displace either station waggons or larger cars as the former are increasingly used on leisure and other long trips and the latter will remain as status vehicles. The market availability of the vehicle trips generated is adjusted to reflect these conditions, such that the market available to the Electric Car is that which will otherwise be occupied by present day medium and small cars.

A minor reduction in mean distance travelled per trip, from 10 km. in 1971 to 9.4 km. in 2000, coupled with an increasing daily trip factor (2.15 to 2.60 car trips/day) and the appropriate low or high market penetration factor enables the total daily and annual distances travelled by all Electric Cars to be determined for each five year period.

The total distance travelled by cars and station waggons of all types and sizes can similarly be determined when applied to journey categories A, B, C, D, E, F.

Determination of the total number of cars and station waggons, by applying the projected car ownership ratios to the projected population, enables the number of Electric Cars, at low and high market penetrations, to be assessed by comparing the respective vehicular distances travelled. Refer Table 4.7.



ELECTRIC CAR MARKET PENETRATION

Fig 4·5

TABLE 4.7: TOTAL AUSTRALIAN TRAFFIC DATA (cont'd)

			1980	1985	1990	1995	2000
Victoria	State Population x 1000		3,820	3,925	4,020	4,090	4,140
	Market Population x 1000		2,817	2,902	2,960	3,013	3,055
	All Cars * No. x 1000		1,157	1,303	1,421	1,513	1,558
	All Cars * Total Daily Distance - 1000 km		29,838	32,054	33,670	34,872	35,820
	Electric Cars No. x 1000	H	18.3	91.0	195.9	412.0	837.6
		L	10.9	40.2	86.7	187.2	370.5
	Electric Cars Total Daily Distance - 1000 km	H	474	2,238	4,643	9,498	19,260
		L	280	990	2,054	4,201	8,519
Queensland	State Population x 1000		2,144	2,348	2,562	2,785	3,023
	Market Population x 1000		1,310	1,434	1,580	1,706	1,839
	All Cars * No. x 1000		537	644	758	856	938
	All Cars * Total Daily Distance - 1000 km		13,875	15,839	17,972	19,745	21,562
	Electric Cars No. x 1000	H	8.5	44.9	104.6	233.3	504.2
		L	5.0	19.9	46.3	103.2	223.0
	Electric Cars Total Daily Distance - 1000 km	H	220	1,106	2,478	5,378	11,594
		L	130	489	1,096	2,378	5,128
Australian Capital Territory	Population x 1000		250	306	382	454	540
	All Cars * No. x 1000		103	132	183	228	275
	All Cars * Total Daily Distance - 1000 km		2,648	3,380	4,345	5,254	6,332
	Electric Cars No. x 1000	H	1.6	9.6	25.3	62.1	148.1
		L	1.0	4.2	11.2	27.5	65.5
	Electric Cars Total Daily Distance - 1000 km	H	42	236	599	1,431	3,404
		L	25	104	265	633	1,506

* All cars within the market areas.

TABLE 4.7: TOTAL AUSTRALIAN TRAFFIC DATA

			1980	1985	1990	1995	2000
Australia	Total Population x 1000		14,242	15,060	15,892	16,685	17,459
	Market Population x 1000		10,561	11,333	12,123	12,873	13,638
	All Cars * No. x 1000		4,330	5,089	5,819	6,462	6,955
	All Cars * Total Daily Distance - 1000 km		111,852	125,178	137,899	148,989	159,906
	Electric Cars No. x 1000	H	68.8	355.2	802.4	1,760.2	3,739.3
		L	40.7	157.0	358.7	778.4	1,654.0
	Electric Cars Total Daily Distance - 1000 km	H	1,777	8,741	19,017	40,579	85,979
		L	1,048	3,865	8,412	17,947	38,029
Mod. Sydney Region	Population x 1000		3,046	3,215	3,370	3,518	3,658
	All Cars * No. x 1000		1,188	1,383	1,584	1,715	1,803
	All Cars * Total Daily Distance - 1000 km		32,259	33,515	38,336	40,715	42,894
	Electric Cars No. x 1000	H	18.9	96.5	218.4	467.1	969.9
		L	11.1	42.7	96.6	206.6	428.9
	Electric Cars Total Daily Distance - 1000 km	H	513	2,480	5,287	11,090	23,063
		L	302	1,097	2,338	4,905	10,207
New South Wales	State Population x 1000		5,067	5,360	5,650	5,933	6,218
	Market Population x 1000		4,100	4,425	4,750	5,077	5,404
	All Cars * No. x 1000		1,681	1,987	2,280	2,549	2,756
	All Cars * Total Daily Distance - 1000 km		43,427	48,876	54,031	58,760	63,362
	Electric Cars No. x 1000	H	26.7	138.7	314.4	694.2	1,481.7
		L	15.8	61.3	139.1	307.0	655.4
	Electric Cars Total Daily Distance - 1000 km	H	690	3,413	7,451	16,004	34,069
		L	407	1,509	3,296	7,078	15,069

H = High)
L = Low) Levels of market penetration

* All cars within the market areas.

TABLE 4.7: TOTAL AUSTRALIAN TRAFFIC DATA (cont'd)

			1980	1985	1990	1995	2000
South Australia	State Population x 1000		1,292	1,358	1,420	1,475	1,520
	Market Population x 1000		940	990	1,040	1,083	1,127
	All Cars * No. x 1000		385	445	499	544	574
	All Cars * Total Daily Distance - 1000 km		9,956	10,935	11,830	12,534	13,214
	Electric Cars No. x 1000	H	6.1	31.0	68.8	148.1	309.0
		L	3.6	13.7	30.5	65.5	136.7
	Electric Cars Total Daily Distance - 1000 km	H	158	764	1,631	3,414	7,105
		L	93	338	722	1,510	3,143
Tasmania	State Population x 1000		418	440	460**	480**	500**
	Market Population x 1000		238	246	256	265	273
	All Cars * No. x 1000		98	110	123	133	139
	All Cars * Total Daily Distance - 1000 km		2,521	2,717	2,912	3,067	3,201
	Electric Cars No. x 1000	H	1.5	7.7	16.9	36.2	74.9
		L	0.9	3.4	7.5	16.0	33.1
	Electric Cars Total Daily Distance - 1000 km	H	40	190	402	835	1,721
		L	24	84	178	369	761
Western Australia	State Population x 1000		1,282	1,422	1,600	1,772	1,940
	Market Population x 1000		905	1,030	1,155	1,275	1,400
	All Cars * No. x 1000		371	462	554	640	714
	All Cars * Total Daily Distance - 1000 km		9,586	11,377	13,138	14,757	16,415
	Electric Cars No. x 1000	H	5.9	32.3	76.4	174.3	383.9
		L	3.5	14.3	33.8	77.1	169.8
	Electric Cars Total Daily Distance - 1000 km	H	152	794	1,812	4,019	8,826
		L	90	351	801	1,778	3,904

* All cars within the market areas.
** Extrapolation of projections by Bureau of Statistics.

4.8 PARKING DEMAND — ASSESSMENT

The parking demand is related to traffic demand, with variations due to characteristics of

a) employment,

b) shoppers and business visitors,

and is catered for by the provision of parking as follows:

i) kerbside, and

ii) off-street - open areas
- parking stations
- office building garages.

Existing studies of parking demand for the Sydney C.B.D. and Chatswood (N.S.W.) commercial area provide a basis for correlation of projected demand arising from the traffic demand assessed in Par. 4.7, and trends in the development of kerbside and off-street parking are used to establish projections realistically. Parking demand for Electric Cars is determined in proportion to the numbers of Electric Cars penetrating the total car and station waggon market. Refer Table 4.8.

4.8.1 CENTRAL BUSINESS DISTRICT (C.B.D.)

The number of vehicles using the C.B.D. is determined by comparing trip generated distances with those of the Modified Sydney Region and the total number of cars in that region; however, notice must be taken of the variation with time of the number of cars per household as this factor weights the data for the Region with regard to traffic categories B, C, D, and E.

4.8.2 COMMERCIAL AREAS

Analysis of population and employment by industry from the Sydney Outline Plan, 1966, and S.A.T.S., 1971, enables the tertiary employment component (defined as retail, service, public authority, office transport and communication et al) to be established for the Region, C.B.D., and non-C.B.D. areas. Allocation of the tertiary component to non-C.B.D. commercial centres has been taken with a range from 40% to 60% of the total component. From Chatswood area studies, the correlation of the numbers of employees to shoppers and business visitors, with due allowance for the ratio of car drivers, has been extended to represent the total cross section of the Modified Sydney Region. Variation within this relationship is recognised and a range of demand is provided.

The parking demand is a function of the relative proportions of employees and shoppers plus visitors, with the former occupying parking spaces for the major part of the day while the latter group characteristically stay for periods of $\frac{1}{2}$ to $1\frac{1}{2}$ hours.

4.8.3 INDUSTRIAL AREAS

Low and high estimates of the manufacturing industry component of total employment, and the relationship to total population, based on data from the Sydney Outline Plan, 1966, and S.A.T.S., 1971, have been projected to the year 2000. Taking into account the proportion of employees who travel by private transport, and low and high assessments of car occupancy, (Ref. 4.4) the percentage of car drivers and hence number of car drivers, can be determined. Employee parking demand in industrial areas is equated to the number of car drivers, as the parking turnover rate will be very nearly unity.

TABLE 4.8: TOTAL AUSTRALIAN ELECTRIC VEHICLE PARKING DEMAND

					1980	1985	1990	1995	2000
Mod. Sydney Region		Population	x 1000		3,046	3,215	3,370	3,518	3,658
	ALL CARS	Cars	No. x 1000		1,188	1,383	1,584	1,715	1,803
		CBD - Parking Spaces	x 1000		33.4	36.0	38.8	40.3	41.1
		Commercial Areas -	Spaces x 1000	H	448.6	504.8	559.5	595.0	623.0
				L	317.9	357.4	397.0	423.0	443.7
		Industrial Areas -	Spaces x 1000	H	169.0	178.4	187.0	195.3	203.0
				L	131.4	138.7	145.0	151.8	157.8
	ELECTRIC CARS	Cars	No. x 1000	H	18.9	96.5	218.4	467.1	969.9
				L	11.1	42.7	96.6	206.6	428.9
		CBD -	Spaces x 1000	H	0.53	2.51	5.35	10.98	22.11
				L	0.31	1.11	2.37	4.85	9.78
		Commercial Areas -	Spaces x 1000	H	7.14	35.22	77.14	162.06	335.13
				L	2.97	11.03	24.21	50.96	105.55
		Industrial Areas -	Spaces x 1000	H	2.69	12.45	25.78	53.19	109.20
				L	1.23	4.28	8.84	18.29	37.54
New South Wales		Market Population	x 1000		4,100	4,425	4,750	5,077	5,404
	ELECT. CARS	CBD -	Spaces x 1000	H	0.67	3.44	7.61	15.87	32.65
				L	0.40	1.51	3.10	7.07	14.48
		Commercial Areas -	Spaces x 1000	H	9.56	48.59	108.81	233.93	494.90
				L	4.04	15.14	34.11	73.60	155.86
		Industrial Areas -	Spaces x 1000	H	3.63	17.20	36.36	76.78	161.17
				L	1.61	5.92	12.54	26.41	55.40
Victoria		Market Population	x 1000		2,817	2,902	2,960	3,013	3,055
	ELECT. CARS	CBD -	Spaces x 1000	H	0.46	2.26	4.74	9.42	18.46
				L	0.28	0.99	1.93	4.20	8.18
		Commercial Areas -	Spaces x 1000	H	6.57	31.86	67.81	138.83	279.78
				L	2.77	9.93	21.26	43.68	88.11
		Industrial Areas -	Spaces x 1000	H	2.50	11.28	22.66	45.56	91.12
				L	1.11	3.88	7.82	15.67	31.32

TABLE 4.8: TOTAL AUSTRALIAN ELECTRIC VEHICLE PARKING DEMAND (cont'd)

				1980	1985	1990	1995	2000
Queensland	Market Population	x 1000		1,310	1,434	1,580	1,706	1,839
	ELECT. CARS CBD -	Spaces x 1000	H	0.22	1.12	2.53	5.33	11.11
			L	0.13	0.49	1.03	2.38	4.93
	Commercial Areas -	Spaces x 1000	H	3.05	15.75	36.19	78.61	168.42
			L	1.29	4.91	11.35	24.73	53.04
	Industrial Areas -	Spaces x 1000	H	1.16	5.58	12.10	25.80	54.85
			L	0.52	1.92	4.17	8.87	18.85
Australian Capital Territory	Market Population	x 1000		250	306	382	454	540
	ELECT. CARS CBD -	Spaces x 1000	H	0.04	0.24	0.61	1.42	3.26
			L	0.02	0.10	0.25	0.63	1.45
	Commercial Areas -	Spaces x 1000	H	0.58	3.36	8.75	20.92	49.45
			L	0.25	1.05	2.74	6.58	15.57
	Industrial Areas -	Spaces x 1000	H	0.22	1.19	2.92	6.87	16.11
			L	0.10	0.41	1.01	2.36	5.54
South Australia	Market Population	x 1000		940	990	1,040	1,083	1,127
	ELECT. CARS CBD -	Spaces x 1000	H	0.15	0.77	1.67	3.39	6.81
			L	0.09	0.34	0.68	1.51	3.02
	Commercial Areas -	Spaces x 1000	H	2.19	10.87	23.82	49.90	103.21
			L	0.93	3.39	7.47	15.70	32.50
	Industrial Areas -	Spaces x 1000	H	0.83	3.85	7.96	16.38	33.61
			L	0.37	1.32	2.75	5.63	11.55
Tasmania	Market Population	x 1000		238	246	256	265	273
	ELECT. CARS CBD -	Spaces x 1000	H	0.04	0.19	0.41	0.83	1.65
			L	0.02	0.08	0.17	0.37	0.73
	Commercial Areas -	Spaces x 1000	H	0.55	2.70	5.86	12.21	25.00
			L	0.23	0.84	1.84	3.84	7.87
	Industrial Areas -	Spaces x 1000	H	0.21	0.96	1.96	4.01	8.14
			L	0.09	0.33	0.68	1.38	2.80

TABLE 4.8: TOTAL AUSTRALIAN ELECTRIC VEHICLE PARKING DEMAND (cont'd)

					1980	1985	1990	1995	2000
Western Australia	Market Population		x 1000		905	1,030	1,155	1,275	1,400
	ELECT. CARS	CBD -	Spaces x 1000	H	0.15	0.80	1.85	3.99	8.46
				L	0.09	0.35	0.75	1.78	3.75
		Commercial Areas -	Spaces x 1000	H	2.11	11.31	26.46	58.75	128.21
				L	0.89	3.52	8.29	18.48	40.38
		Industrial Areas -	Spaces x 1000	H	0.80	4.00	8.84	19.28	41.76
				L	0.36	1.38	3.05	6.63	14.35
Australia	Market Population		x 1000		10,561	11,333	12,123	12,873	13,638
	ELECT. CARS	CBD -	Spaces x 1000	H	1.73	8.81	19.43	40.25	82.39
				L	1.04	3.88	7.91	17.93	36.54
		Commercial Areas -	Spaces x 1000	H	24.61	124.43	277.71	593.15	1,248.97
				L	10.40	38.78	87.06	186.62	393.33
		Industrial Areas -	Spaces x 1000	H	9.36	44.06	92.81	194.67	406.75
				L	4.16	15.16	32.02	66.96	139.81

H = HIGH)
L = LOW) Levels of market penetration

4.9 PROJECTED FUEL CONSUMPTION — CONVENTIONAL CARS

The average fuel consumption of all internal combustion engined cars and station waggons in the year 1975, based on recorded annual consumption of motor spirit, vehicle registrations and average distance travelled is approximately 6.4 km./litre for urban driving conditions, compared to an average new car performance of approximately 8.8 km./litre, based on independently published performance tests (Ref. 4.5), and market penetration characteristics.

The introduction of emission control equipment required by Australian Design Rule 27A for Motor Vehicles, for reduction of exhaust pollutants into the atmosphere, has penalised conventional cars with regard to acceleration and fuel consumption to the extent that the average fuel consumption figure for 1976-77 is some 18% worse at 5.4 km./litre.

Legislation proposed in the United States of America suggests a major improvement in new car fuel consumption, exceeding 50% during the period 1978 to 1985. The current average figure of 7.6 km./litre is required to improve to 11.6 km./litre for new cars, with severe taxes imposed on the sale of cars not meeting these criteria and tax credits available for the sale of cars with performances exceeding the target figures. This data for new cars must be compared to an urban driving performance in that country of approximately 5.0 km./litre. It should be noted that at present there are approximately three times as many large cars in the U.S. as in Australia.

5. "PARK AND CHARGE" METERS

5.1 INTRODUCTION

"Park and Charge" meters will enable the recharging of car batteries, at trickle or boost rate, whenever the Electric Car is parked at kerbside, in an open parking area, a parking station of an office building garage. These facilities would be established throughout urban areas, as appropriate to the demand, in the central business district and major commercial and industrial areas, and will have an important influence on the successful introduction of Electric Cars in metropolitan areas throughout the nation.

The meters will dispense power and/or parking on a time basis and will indicate the cost involved. While they will be simple to operate, they must also be absolutely safe under all conditions, and will be required to satisfy all codes, and authorities, on operational characteristics, malfunction and accidental occurence. This aspect of meter design will be one of the main requirements, and will contribute to a major portion of the installed cost. The meters and Electric Cars will need to be standardised with regard to battery charging requirements and connections.

5.2 CONCEPTS

In catering for the needs of the short-time shopper, the industrial and commercial traveller and the businessman who would leave his car parked all day, the following metering concepts have been considered and the benefits and costs of each have been explored.

- Existing coin-operated parking meters could be modified quite easily to provide a safe and satisfactory introduction of "Park and Charge" meters in metropolitan areas. Meters of this type, being mechanical, will incur costs for winding, servicing and coin collection; and will in addition need supervision by parking police.

- Magnetic card-operated meters of various designs are currently being used to purchase power for domestic and similar appliances, and could easily be adapted for this purpose. Meters of the type requiring consumable magnetic cards would still require supervision by parking police.

- A development of the magnetic card-operated meter, using permanent identifiable magnetic cards would be connected via Telecom facilities to a central computer, thereby enabling direct billing to an electricity, or similar, account. This system allows flexibility of operation and will accommodate variation in the cost of power, peak demand periods during the day, and the possibility of assessing fines at penalty rates coupled with direct billing, thereby eliminating the need for supervision by parking police.

The electric power facility for each of the various concepts would need to incorporate design features relating to the particular location.

5.3 OPERATION

The system would be simple to operate. After selecting a vacant meter space, with an indicator light advising that power is available, and assessing the charging requirements by reference to the car's instruments indicating the state of charge of its batteries, the driver would withdraw the armoured flexible lead from a well in the car and insert the plug into the power outlet. This action would disconnect the drive circuit within the car to prevent it being driven away with the lead attached to the meter. Insertion of coins or magnetic card as appropriate into the meter, for the amount of power required, would switch power and display lamp on and at the same time lock the plug into the socket to prevent disconnection by unauthorised persons. On completion of the charging period purchased, and after an appropriate delay period, a further ligh would flash to indicate a parking infringement. In the event of an early return, the driver could switch off the power within the car, and then retract the plug and lead thereby also disconnecting the supply to the meter outlet socket while at the same time re-connecting the driving circuit within the car.

The computer controlled magnetic card-operated meters would be operated in a similar manner, but would require identification verification to avoid incorrect billing of accounts. This system lends itself to further development in that a number of charging points may be monitored by one console, situated away from the kerb, thereby improving the street appearance and reducing meter costs.

5.4 ASSUMPTIONS

In determining the safety aspects, electrical demands and cost estimates the following assumptions were made:

- All Electric Cars would meet appropriate electrical requirements as laid down by codes developed by the Standards Association of Australia, particularly in relation to:
  - standard design for an armoured flexible lead and plug outlet socket,
  - the standardisation of the armoured flexible lead location on the left side of all cars, with due consideration being given to the length of the lead to allow satisfactory connection to the "Park and Charge" meters for the various parking modes applicable,
  - the standard overload current limiting features of each car's battery charger with respect to:

    Trickle charge.....maximum supply current 15 amps A.C.

    Boost charge.......maximum supply current 30 amps A.C.
  - a master circuit breaker on the car's battery charger to render the car inoperative while being charged,
  - a micro-action switch on the spring recoil assembly of the car's amoured flexible lead to also render the car's controls inoperative until the lead is wound back into the car and the hatch closed.

- The cost of electricity, Telecom exchange switching, utilisation of computers and computer programming would be recovered through metering and rental charges,

- Boost charge facilities would not be required for the various meter concepts where used in commercial areas because of the increased costs of the electrical reticulation and installation, and the uneconomic effects of imbalance in the electrical network.

5.5 COIN OPERATED "PARK AND CHARGE" METERS

It is considered that the quickest method of introducing kerbside "Park and Charge" meters would be to use the coin operated variety, as existing parking meters could easily be modified to allow the system to operate.

These meters would need to incorporate the following inbuilt features:

- A timing mechanism that is either mechanically spring operated or preferably electrically operated,

- An indicating dial to show the charge time prepaid by the customer,

- A flag to indicate when time has expired,

- A redlight to indicate that power is available. This light would flash if the car is left connected after expiry of the prepaid charging time and an appropriate short delay period,

- A green light to indicate that power is "on" to the car, after insertion of coins and connection of plug,

- Robust construction,
- A large coin store,
- A locking device to prevent disconnection of the plug by unauthorised persons,
- An electric fail-safe feature in the case of vehicle collision or accident,
- The base of the pedestal unit to incorporate a feature which would allow wiring to snap free from a plug receptacle in the concrete base in the event of an accident,
- Dual operation: two meters and plugs, etc., per pedestal stand,
- The electrical distribution sub-circuit breakers would need to incorporate core balance earth leakage protection,
- The armoured flexible lead would need to be impact resistant with
    - a fail safe connection which would break at the connection in the event of an accident,
    - the connecting plug would need to be held captive once supply is "on" to prevent disconnection by unauthorised persons.

Coin operated meters could also be used in parking stations, but they would be much more expensive to supply, install and supervise than a punched card, boom gate operated system.

In assessing the overall economics of this type of meter, the costs of winding, coin collection, servicing and supervision should be taken into account.

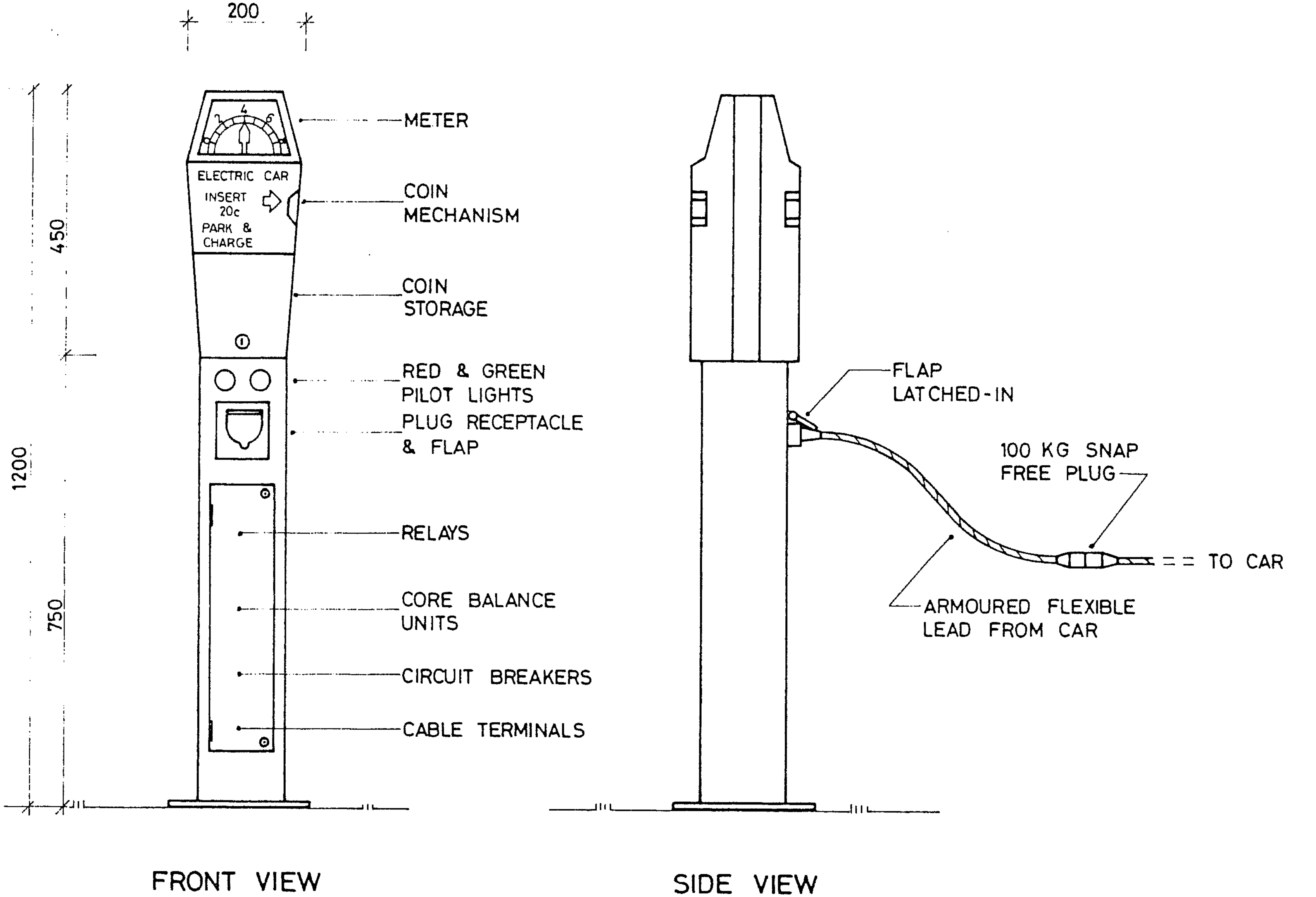


Fig. 5.1 DUAL FACED COIN OPERATED "PARK AND CHARGE" METER

5.6 MAGNETIC CARD "PARK AND CHARGE" METERS

As the increasing penetration of Electric Cars creates a greater demand for "Park and Charge" meters, it will become feasible, from an economic point of view, to produce a completely electronically operated metering system connected to a central computer by telephone line.

The metering system envisaged would be designed to supply electricity to a number of kerb-side "charge points" from a single console which would

- accept instructions from intending purchasers of power,
- communicate data to and from the central computer,
- initiate and monitor the supply of power to the "charge points",
- activate indicator lights and plug latching mechanism at the "charge points".

This concept would reduce substantially the cost of metering per car space and eliminate the need for coin collecting officers and supervision by parking police. "Park and Charge" and "overstay" could be registered automatically and invoiced to the purchaser directly by the central computer.

5.6.1 CONSOLE

The console would need to incorporate the following features:

- Magnetic card operation,
- Push buttons (preferably vandalproof thermal touch type) to acknowledge and register amount of charge time required and "charge point" selected,

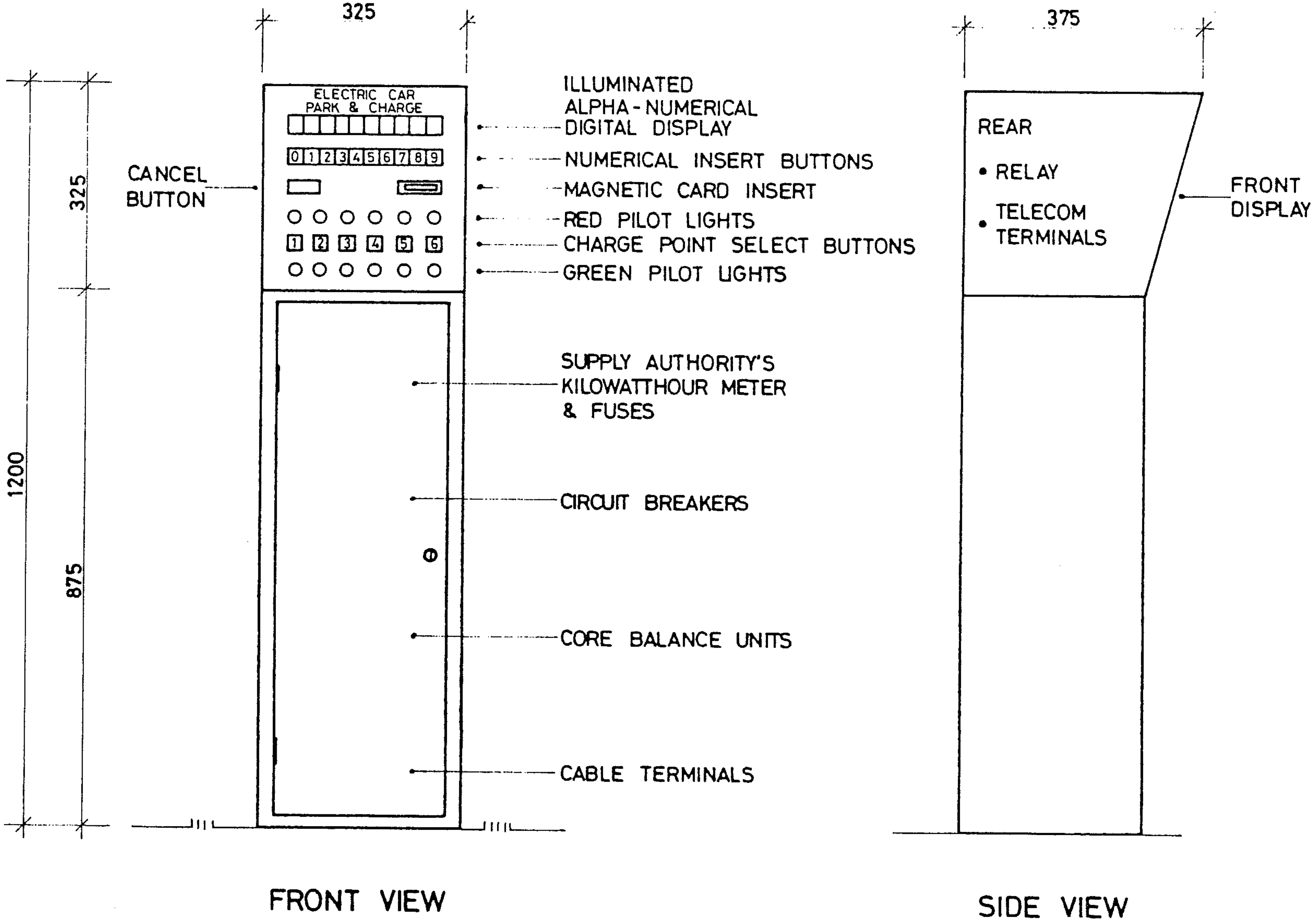


Fig. 5.2 MAGNETIC CARD-OPERATED "PARK AND CHARGE" METERING CONSOLE.

- Digital display to indicate various sequences of operation,

- Illuminated light to show:

  i) Red - power is available, and
  ii) Green - power is on to particular "charge point",

- Distribution cabinet in base to house sub-circuit breakers, each to incorporate core balance earth leakage protection,

- Separate compartment for connection of console to "Telecom" wiring.

5.6.2 CHARGE POINTS

A number of "charge points" established at the kerb-side, with each serving two cars would be connected electrically for power to, and monitored by, the console. The "charge points" would be small units of convenient height for connecting purposes and would need to be of robust construction, securely anchored to the kerb, to prevent damage by vandals and/or accident.

The "charge points" would need to incorporate the following inbuilt features:

- Red light to show that power is available

- Green light to show that, after purchasing instruction data has been entered and accepted at the console, power is being supplied

- Plug receptacle with locking device to prevent disconnection of the plug by unauthorised persons.

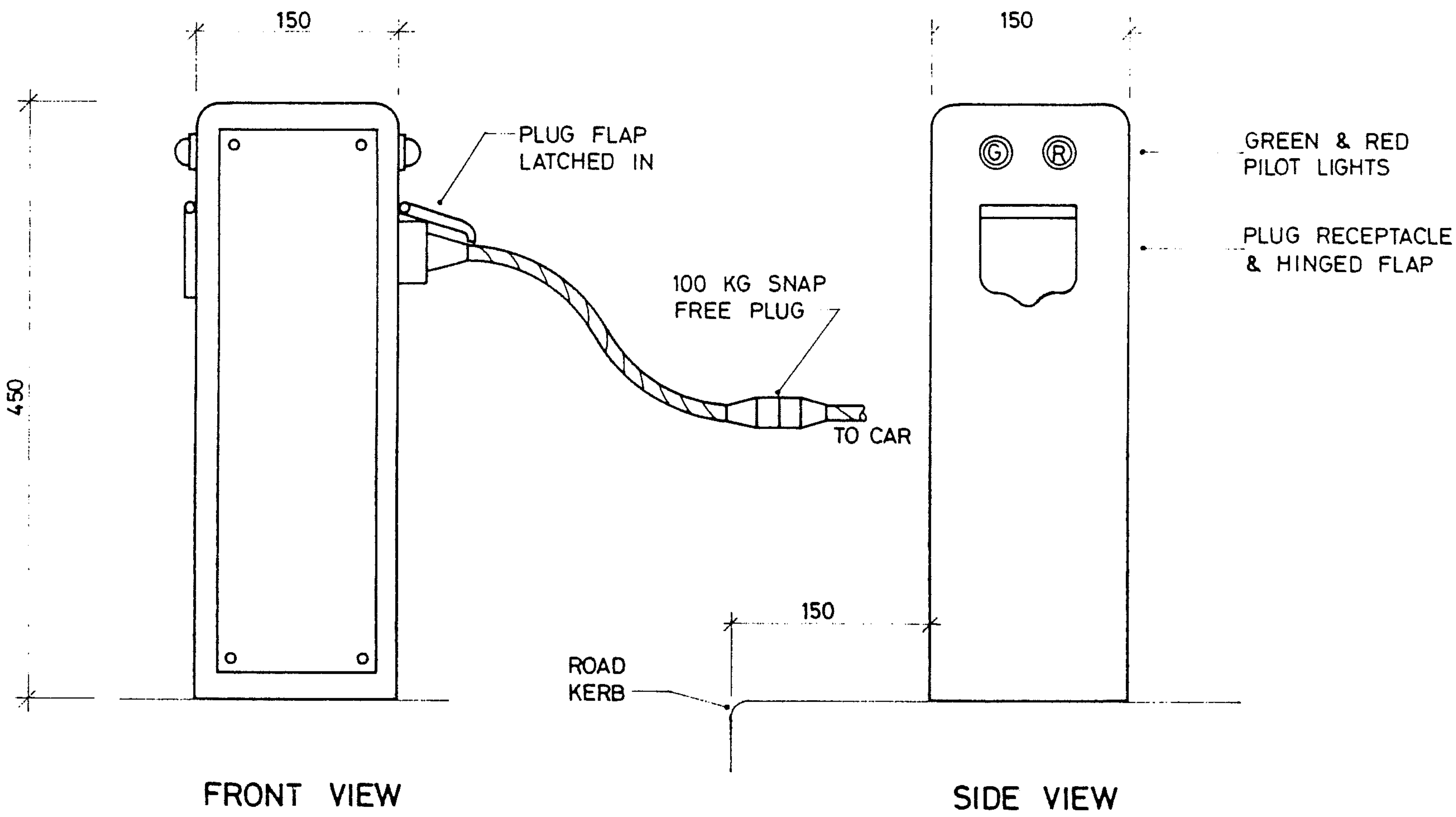


Fig. 5.3 TWO CAR "CHARGE POINT"

5.7 OPERATION OF MAGNETIC CARD METERS

A typical magnetic card "Park and Charge" meter would operate as follows:

After parking the car at a vacant charge point which has a red light "on" indicating that power is available, and determining the duration of charging required, the driver would switch on the car's battery charging unit, thereby rendering the car inoperative, extract the car's armoured flexible lead and plug it into the meter's power outlet. If the plug is left in the charge point for more than 30 seconds without the driver correctly programming the main metering console, the red light at the charge point will commence to flash until either the programme is completed or the plug removed. This feature will deter drivers from parking illegally.

The programming of the console would be initiated by insertion of the driver's magnetic card, and the computer would acknowledge by display of the card number at the console, and indicate next entry. To ensure correct ownership of card the driver would enter date of birth and the computer would display verification by an appropriate signal at the console. If the driver's account is overdue, the computer could refuse to accept the next entry and display at the console accordingly. Following valid acknowledgement, the driver would enter the required charging time and select the appropriate charge point by depressing the relevant push-button. This action would activate a latch on the charge point and lock the plug into position, so preventing disconnection by unauthorised persons.

Removal of the magnetic card from the console would switch on the power which would register by illumination of green lights at the charge point and at the appropriate charge point button on the console.

If the car remains at the charge point after expiry of the purchased charging time, a SCAN signal from the computer will monitor the point and charge a predetermined penalty to the driver's account. Penalty rates may intensify at peak periods, or extended over-stay. While the car remains at an expired charge point, the red light would flash until removal of the car's plug from the socket when the red light would be on constantly.

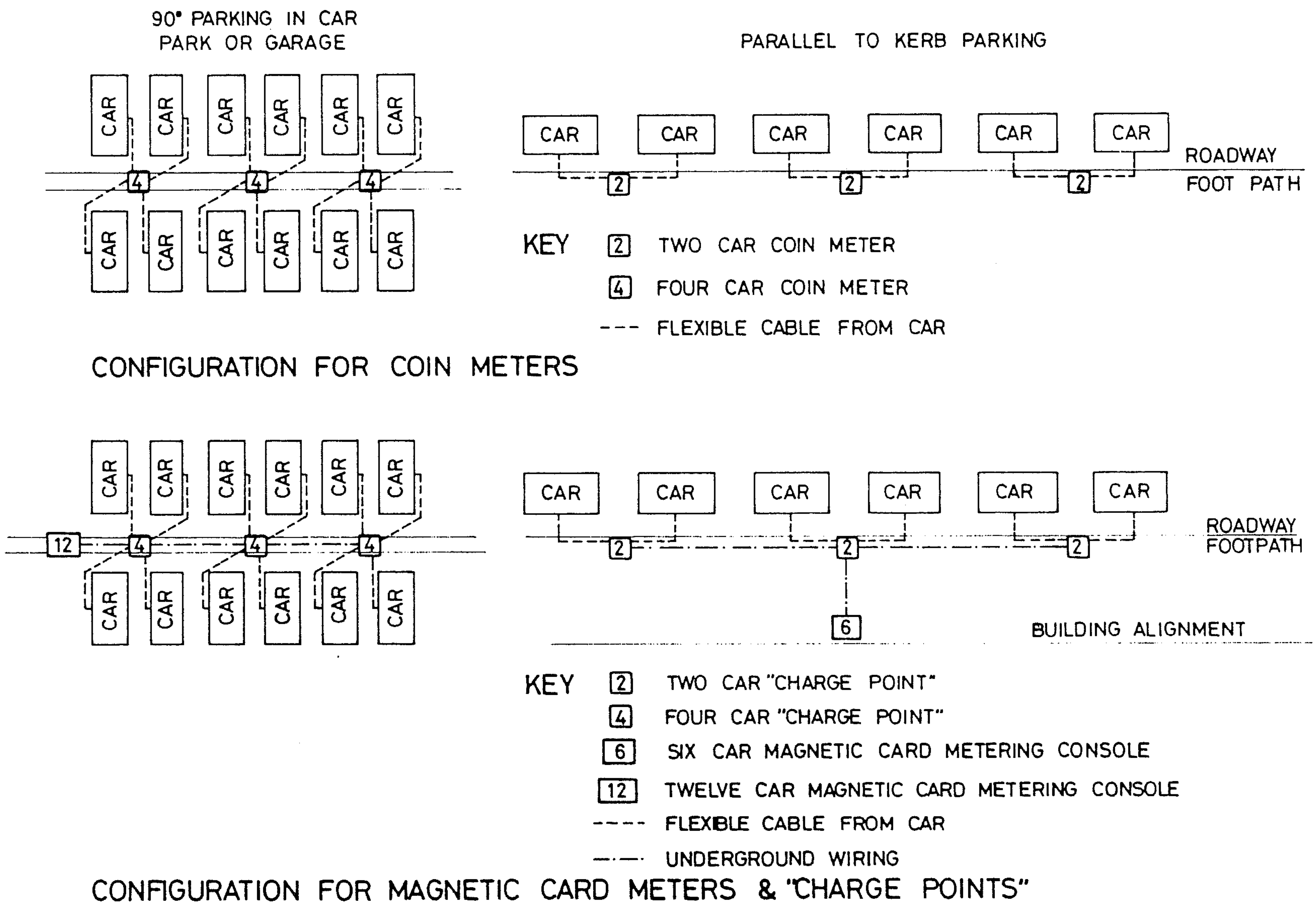


Fig. 5.4 PARKING CONFIGURATION FOR COIN & CARD-OPERATED "PARK AND CHARGE" METERS

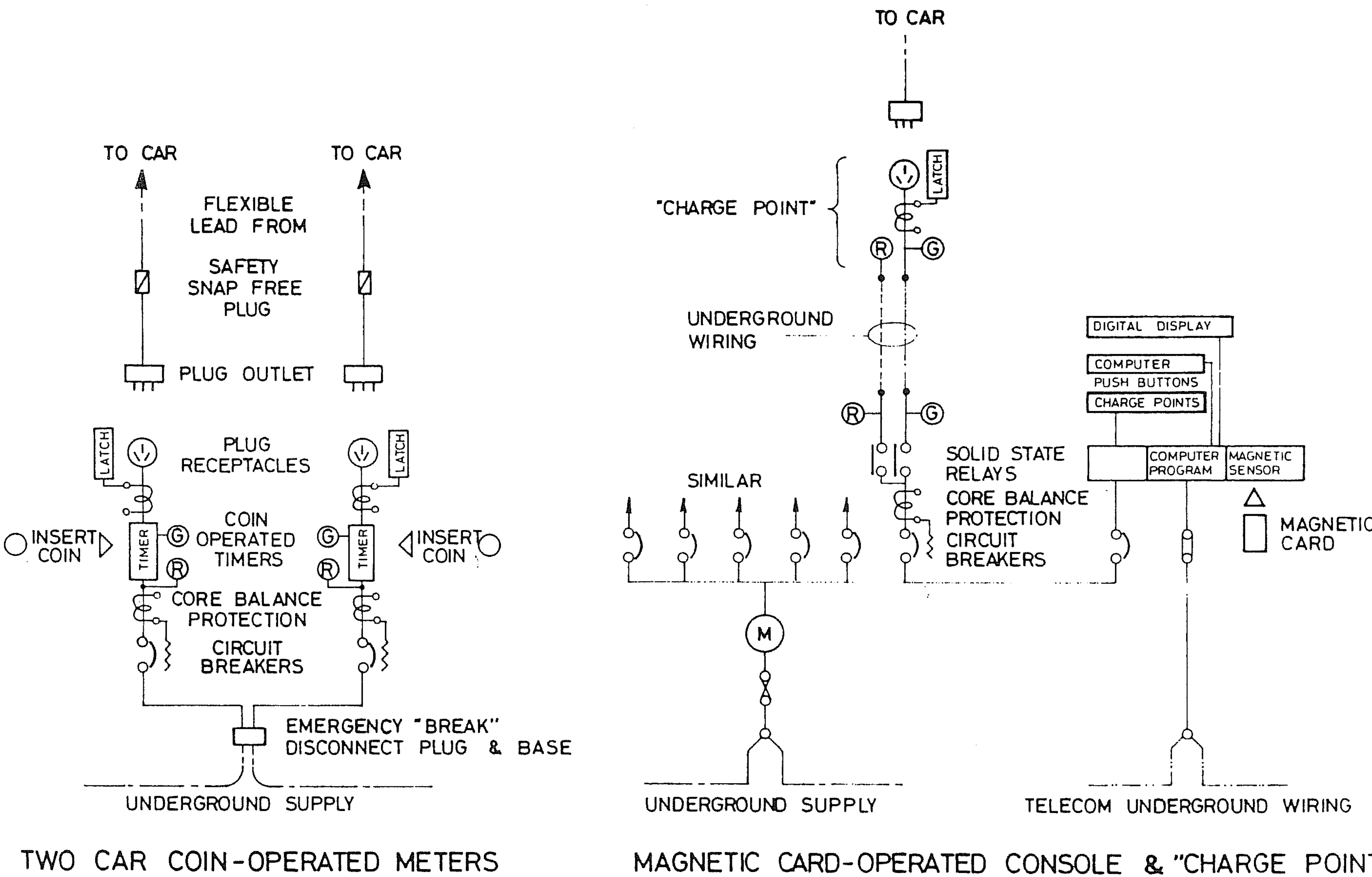


Fig. 5.5 SCHEMATICS FOR METER SYSTEMS

On returning to the car for removal, the driver would re-insert the magnetic card and verify with date of birth to obtain the value of the charge debited to the account, and the console would display the cost for a short period, with recall available while the card remains inserted by repeated entry of the date of birth. Removal of the card would cause the power to be switched off and the plug de-latched.

When the plug has been withdrawn from the charge point socket all systems would be restored to normal. On rewinding the armoured flexible lead back into the car and closing the car's plug cover, a microswitch and relay would re-activate the car's circuitry to enable it to be driven away.

5.8 PARKING STATION AND GARAGE FACILITIES

Power outlets for Electric Cars in commercial parking stations and office garages would probably differ from those utilised at kerb-side and open parking area charge points.

A development of existing car park systems, with the installation of a "Charging Facility Area" entered through a second boom gate controlled by insertion of the parking station entry card into a separate console with time recording and printing capability, would enable drivers to park or park and charge for any length of time and have the cost of power supplied assessed and paid for at the check out booth.

The power outlets would be similar to those normally used in a domestic garage except that it would be necessary to latch the plug to prevent disconnection by unauthorised persons, similar to mechanism described for use with coin-operated meters.

Adaption of existing parking station systems could be undertaken very easily and excessive metering costs could be avoided.

5.9 INVESTMENT

The potential use of meters will vary according to the trip purpose and the journey pattern and distances of the individual commuters, and could be expected to be different for each of the business district, commercial and industrial areas.

The investment of capital required for the installation of meters in each of these areas has been estimated at two levels of potential use: namely, a low of 70% and a high of 100% of the Electric Cars taking advantage of "Park and Charge" metering. At some locations the potential use may well be less than these values, and the level of investment required to cater for the appropriate demand for metered spaces would be correspondingly less.

The estimated investment for coin operated and magnetic card meters is detailed in Tables 5.1 and 5.2 respectively, and have been compiled using the following estimates:

.	Estimated cost per coin-operated two-car meter installed	$ 600.00
.	Estimated cost per coin-operated four-car meter installed	$1,000.00
.	Estimated average installation cost per car space serviced	$ 266.00
..	Estimated cost of magnetic card-operated six-car metering computerised console	$1,150.00
..	Estimated cost of magnetic card-operated twelve-car metering computerised console	$1,900.00
..	Estimated cost per two-car "charge point"	$ 100.00
..	Estimated average cost per magnetic card-operated outlet installed	$ 219.00
...	Estimated cost per annum Telecom connection to each computerised console	$ 50.00
...	Estimated cost per annum for utilisation of computer and program per console	$ 50.00
...	Estimated cost per annum for utilisation of computer and program per car	$ 28.00

7..

TABLE 5.1: ESTIMATED INVESTMENT : COIN-OPERATED "PARK AND CHARGE" METERS INSTALLED PROGRESSIVELY FROM 1980 to 2000 - 1977 Currency

State	% of Electric Cars Utilising Meters		1980		1985		1990		1995		2000	
			1000 ECPS	$ Million	1000 ECPS	$ Million	1000 ECPS	$ Million	1000 ECPS	$ Million	1000 ECPS	$ Million
New South Wales	100%	High	13.86	3.69	69.23	18.42	152.8	40.65	326.6	86.88	688.7	183.2
		Low	6.06	1.61	22.57	6.00	49.75	13.24	107.1	28.49	225.7	60.1
	70%	High	9.7	2.58	48.46	12.89	107.0	28.45	228.7	60.82	482.1	128.3
		Low	4.24	1.13	15.78	4.20	34.83	9.27	75.00	19.95	158.0	42.03
Victoria	100%	High	9.53	2.53	45.4	12.08	95.21	25.33	193.8	51.56	388.4	103.40
		Low	4.16	1.11	14.8	3.94	31.01	8.25	63.55	16.91	127.6	33.95
	70%	High	6.67	1.77	31.78	8.45	66.65	17.73	135.7	36.09	271.9	72.32
		Low	2.91	0.78	10.36	2.76	21.71	5.78	44.49	11.84	89.32	23.76
Queensland	100%	High	4.43	1.18	22.45	5.97	50.82	13.52	109.7	29.18	234.4	62.35
		Low	1.92	0.51	7.32	1.95	16.55	4.41	35.98	9.58	76.82	20.44
	70%	High	3.10	0.82	15.72	4.18	35.58	9.47	76.79	20.43	164.1	43.65
		Low	1.34	0.36	5.13	1.36	11.59	3.09	25.19	6.7	53.78	14.31
Australian Capital Territory	100%	High	0.84	0.22	4.79	1.28	12.28	3.27	29.21	7.77	68.82	18.31
		Low	0.37	0.10	1.56	0.42	4.0	1.07	9.57	2.55	22.56	6.00
	70%	High	0.59	0.16	3.36	0.89	8.6	2.29	20.45	5.44	48.18	12.82
		Low	0.26	0.07	1.09	0.29	2.8	0.75	6.7	1.79	15.80	4.20
South Australia	100%	High	3.17	0.84	15.49	4.12	33.45	8.90	69.67	18.54	143.6	38.20
		Low	1.39	0.37	5.05	1.35	10.9	2.90	22.84	6.08	47.07	12.52
	70%	High	2.22	0.59	10.85	2.89	23.42	6.23	48.77	12.98	100.6	26.74
		Low	0.97	0.26	3.54	0.94	7.63	2.03	15.99	4.26	32.95	8.77
Tasmania	100%	High	0.8	0.21	3.85	1.03	8.23	2.19	17.05	4.54	34.79	9.26
		Low	0.34	0.09	1.25	0.34	2.69	0.72	5.59	1.49	11.4	3.04
	70%	High	0.56	0.15	2.7	0.72	5.77	1.54	11.94	3.18	24.36	6.48
		Low	0.24	0.06	0.88	0.24	1.89	0.50	3.92	1.04	7.98	2.13
Western Australia	100%	High	3.06	0.81	16.11	4.29	37.15	9.90	82.02	21.82	178.43	47.47
		Low	1.34	0.36	5.25	1.40	12.09	3.22	26.89	7.16	58.48	15.56
	70%	High	2.14	0.57	11.28	3.00	26.01	6.92	57.42	15.28	124.91	33.23
		Low	0.94	0.25	3.68	0.98	8.47	2.26	18.83	5.01	40.94	10.89
Australia	100%	High	35.7	9.50	177.3	47.17	389.9	103.8	828.1	220.3	1738.0	462.4
		Low	15.6	4.15	57.82	15.38	127.0	33.79	271.5	72.22	569.7	151.6
	70%	High	24.99	6.65	124.2	33.02	273.0	72.60	579.7	154.2	1216.0	323.7
		Low	10.92	2.90	40.48	10.77	88.9	23.65	190.1	50.56	398.8	106.1

ECPS = Electric Car Parking Spaces

TABLE 5.2: ESTIMATED INVESTMENT : MAGNETIC-CARD "PARK AND CHARGE" METERS INSTALLED PROGRESSIVELY FROM 1980 to 2000 - 1977 Currency

State	% of Electric Cars Utilising Meters		1980		1985		1990		1995		2000	
			1000 ECPS	$ Million	1000 ECPS	$ Million	1000 ECPS	$ Million	1000 ECPS	$ Million	1000 ECPS	$ Million
New South Wales	100%	High	13.86	3.04	69.23	15.16	152.8	33.46	326.6	71.53	688.7	150.8
		Low	6.06	1.33	22.57	4.94	49.75	10.89	107.1	23.45	225.7	49.43
	70%	High	9.7	2.12	48.45	10.61	106.9	23.42	228.6	50.07	482.1	105.6
		Low	4.24	0.93	15.79	3.46	34.83	7.63	74.97	16.42	158.0	35.60
Victoria	100%	High	9.53	2.09	45.4	9.94	95.21	20.85	193.8	42.44	388.4	85.06
		Low	4.16	0.91	14.8	3.24	31.01	6.79	63.55	13.92	127.6	27.94
	70%	High	6.67	1.46	31.78	6.96	66.65	14.60	135.7	29.71	271.9	59.54
		Low	2.91	0.64	10.36	2.27	21.71	4.75	44.49	9.74	89.32	19.56
Queensland	100%	High	4.43	0.97	22.45	4.92	50.82	11.13	109.7	24.02	234.4	51.33
		Low	1.92	0.42	7.32	1.60	16.55	3.62	35.98	7.88	76.82	16.82
	70%	High	3.10	0.68	15.71	3.44	35.57	7.79	76.79	16.82	164.1	35.93
		Low	1.34	0.29	5.12	1.12	11.58	2.54	25.19	5.52	53.77	11.78
Australian Capital Territory	100%	High	0.84	0.18	4.79	1.05	12.28	2.69	29.21	6.40	68.82	15.07
		Low	0.37	0.08	1.56	0.34	4.0	0.88	9.57	2.10	22.56	4.94
	70%	High	0.59	0.13	3.35	0.73	8.60	1.88	20.45	4.48	48.17	10.55
		Low	0.26	0.06	1.09	0.24	2.80	0.61	6.70	1.47	15.79	3.46
South Australia	100%	High	3.17	0.69	15.49	3.39	33.45	7.33	69.67	15.26	143.6	31.45
		Low	1.39	0.30	5.05	1.11	10.9	2.39	22.84	5.00	47.07	10.31
	70%	High	2.22	0.47	10.84	2.37	23.42	5.13	48.77	10.68	100.5	22.01
		Low	0.97	0.21	3.54	0.77	7.63	1.67	15.99	3.50	32.95	7.22
Tasmania	100%	High	0.8	0.18	3.85	0.84	8.23	1.80	17.05	3.73	34.79	7.62
		Low	0.34	0.07	1.25	0.27	2.69	0.59	5.59	1.22	11.4	2.50
	70%	High	0.56	0.12	2.69	0.59	5.76	1.26	11.94	2.61	24.35	5.33
		Low	0.24	0.05	0.87	0.19	1.88	0.41	3.91	0.86	7.98	1.75
Western Australia	100%	High	3.06	0.67	16.11	3.53	37.15	8.14	82.02	17.96	178.43	39.08
		Low	1.34	0.29	5.25	1.15	12.09	2.65	26.89	5.89	58.48	12.80
	70%	High	2.14	0.47	11.28	2.47	26.0	5.70	57.41	12.57	124.9	27.35
		Low	0.94	0.21	3.67	0.80	8.46	1.85	18.82	4.12	40.94	8.96
Australia	100%	High	35.7	7.82	177.3	38.83	389.9	85.39	828.1	181.4	1738.0	380.6
		Low	15.6	3.42	57.82	12.66	127.0	27.81	271.5	59.46	569.7	124.8
	70%	High	24.99	5.47	124.1	27.18	272.9	59.77	579.7	126.9	1216.0	266.4
		Low	10.92	2.39	40.47	8.86	88.9	19.50	190.0	41.62	398.8	87.34

ECPS = Electric Car Parking Spaces

5.10 RECOMMENDATIONS

1. A S.A.A. select sub-committee be formed to investigate all aspects of the electrical design of Electric Cars to ensure basic standardisation particularly in regard to:

- Safety.
- Master control switch on battery charger in car.
- Current limitation on -

  i) Trickle Charge.
  ii) Boost Charge.

- Armoured flexible lead and plug connection to external 240 volt A.C. supply.
- Location of connection of armoured flexible lead to car.
- Automatic control switch to prevent car from moving until flexible lead and plug are completely rewound into car.
- Metering facilities to provide driver with "easy to read" indication of:

  i) State of battery.

  ii) Reserve ampere hours.

  iii) Hours required to fully recharge battery on -
  trickle charge
  boost charge.

  iv) Adjustable scale to show reserve capability of car to travel (in kilometres) at various speeds over flat or hilly terrain. This could be by simple electric calculator or rotating or sliding scale on meter similar to a slide rule.

2. An Electricity Supply Authority select sub-committee be formed to investigate:

- The safety features required at metering points.
- Acceptable kW/hr metering arrangements.
- The feasibility and method of charging accounts via computer.
- The cost factors involved in utilising their computer for parking meter operation and charging.

3. A Government select sub-committee be formed comprising members from the Standards Association, Electricity Supply Authorities, Telecom Australia, and Local Government engineers to co-ordinate the responsibilities for design, funding, installation, policing, electricity supply and accounting.

6. POWER DEMAND AND DISTRIBUTION

6.1 INTRODUCTION

From the number of Electric Cars estimated to be in service throughout the various States and in Australia as a whole to the year 2000, an assessment has been made of the total quantity of electrical energy which will be consumed. The estimated energy consumption has been compared with the generating capacity currently anticipated in year 2000 to assess the capability of the electric power supply industry to service this new load.

As Electric Cars are introduced, it is apparent that batteries for most Electric Cars would be charged overnight at home. With the installation of on-board chargers, it would be possible to recharge the battery at any time when the car is not being driven, provided electricity is made available. The effects of providing charging facilities at the on-street and off-street parking meters on the daily power demand load curve for different areas, namely central business district, commercial, industrial and residential areas, have been studied. The result of the analysis does not necessarily apply to all other cities and other regions in Australia, but would help to provide some basis for comparison.

With the introduction of Electric Cars, increasing numbers of battery chargers incorporating thyristors (or power semi-conductors) would be connected to the medium/low voltage supply system. It appears that the establishment of a specific standard is most urgent. The standards should set out the permissible limits of disturbances that could be generated from an appliance such as a battery charger. The specific requirements in such a standard would govern the design criteria of the battery chargers and therefore would have direct influence on the development of the Electric Car.

6.2 TOTAL ENERGY CONSUMPTION

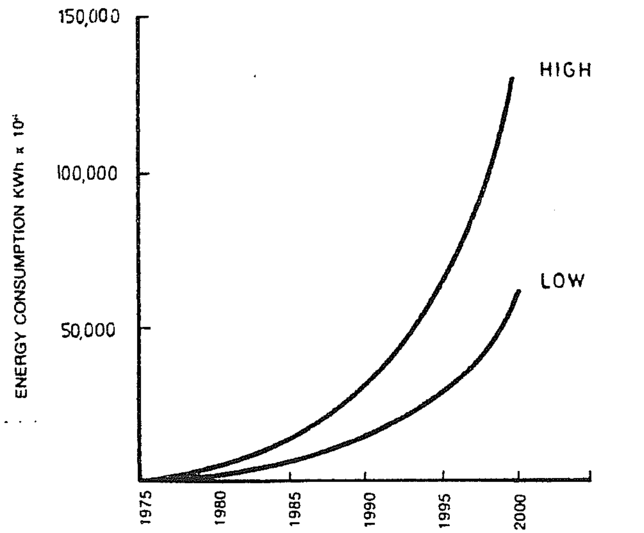
From figures obtained for the average daily distance travelled by all Electric Cars at five year increments from 1975 to 2000, assuming the average vehicle consumption of 0.55 kWh/km and an average usage of 280 days per annum, total operational electrical energy consumed by all Electric Cars in the corresponding years for the various States has been calculated and tabulated in Table 6.1

It can be seen from Fig. 6.1 to Fig. 6.8 inclusive that the total energy consumption increases exponentially with time beyond the year 1980. The rate of increase varies within each State.

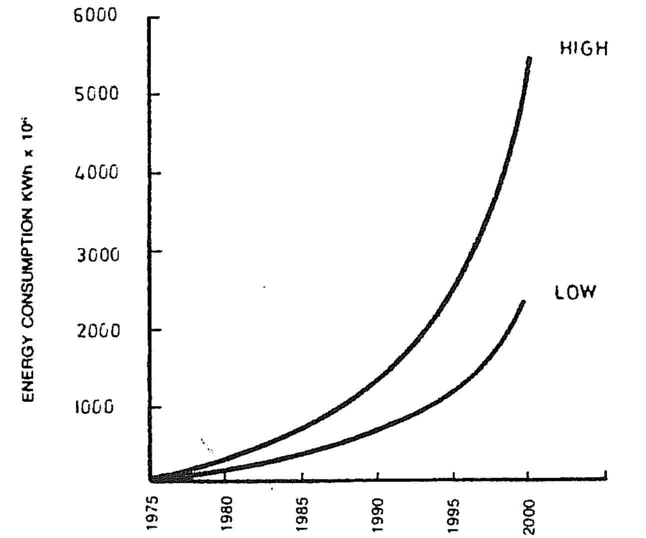
TABLE 6.1 ESTIMATED TOTAL ENERGY CONSUMED BY ELECTRIC CARS (1975-2000 - x 10^6 kWh)

		1980	1985	1990	1995	2000
Australia	H	273.65	1345.96	2928.62	6249.17	13240.77
	L	161.39	595.21	1295.45	2625.24	5856.47
New South Wales	H	106.26	525.60	1147.30	2464.62	5246.62
	L	62.68	232.38	507.58	1090.01	2320.62
Victoria	H	72.99	344.65	715.02	1462.69	2966.04
	L	43.12	152.46	316.32	646.95	1311.93
Queensland	H	33.88	170.32	381.61	828.21	1784.48
	L	20.02	75.30	168.78	366.21	789.71
South Australia	H	24.33	117.66	251.17	525.76	1093.86
	L	14.32	52.05	111.19	232.54	484.02
Western Australia	H	28.41	112.28	279.05	618.93	1359.20
	L	13.86	54.05	123.35	273.81	570.42
A.C.T.	H	6.47	36.34	92.25	220.22	524.22
	L	3.85	16.02	40.81	97.48	231.92
Tasmania	H	6.16	29.26	61.98	125.59	265.03
	L	3.69	12.94	27.41	56.83	117.19

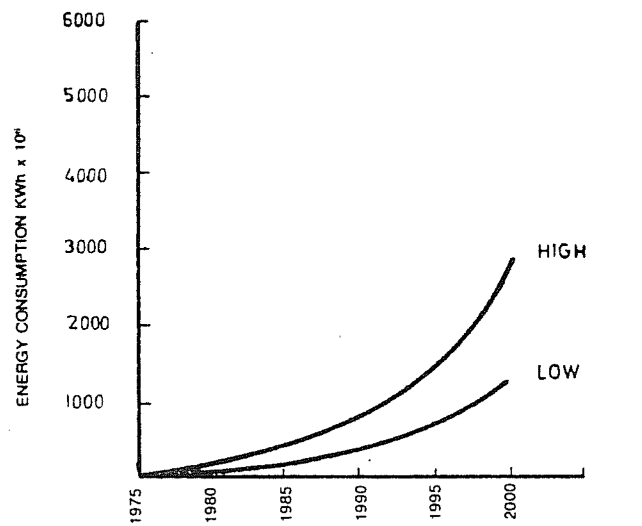
H = HIGH)
L = LOW) Levels of market penetration of Electric Cars.



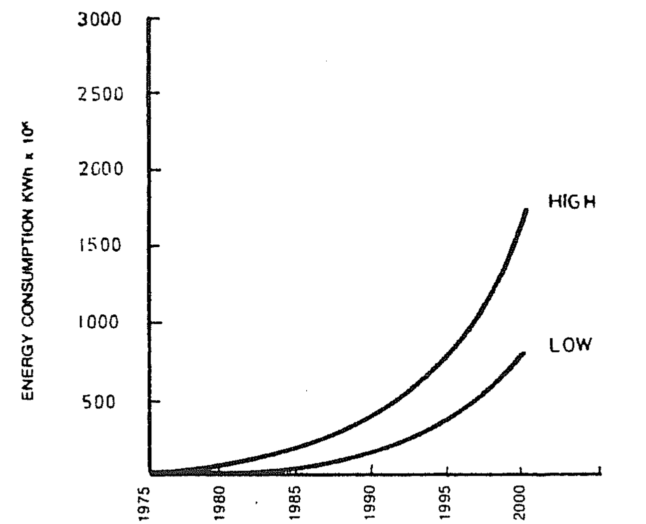
TOTAL ENERGY CONSUMED BY ELECTRIC CARS
Fig 6.1 AUSTRALIA



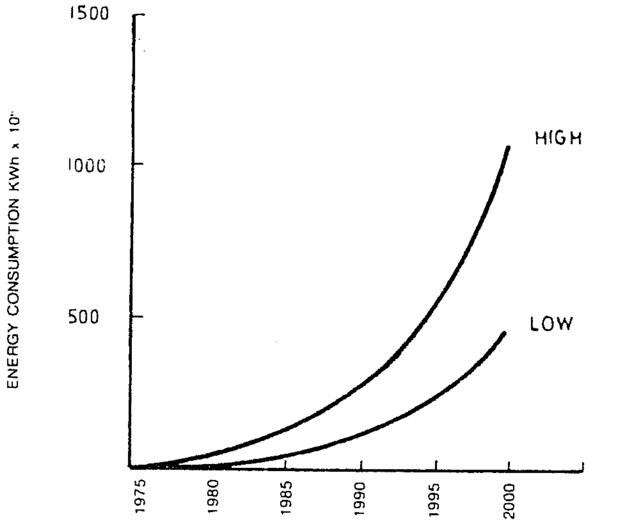
TOTAL ENERGY CONSUMED BY ELECTRIC CARS
Fig 6.2 N.S.W.



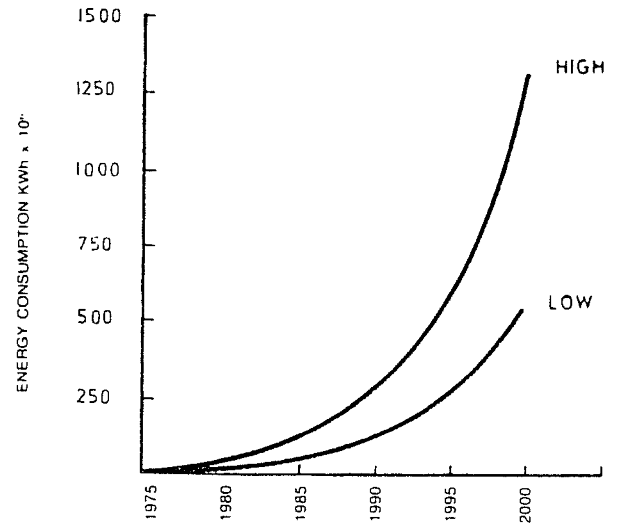
TOTAL ENERGY CONSUMED BY ELECTRIC CARS
Fig 6.3 VICTORIA



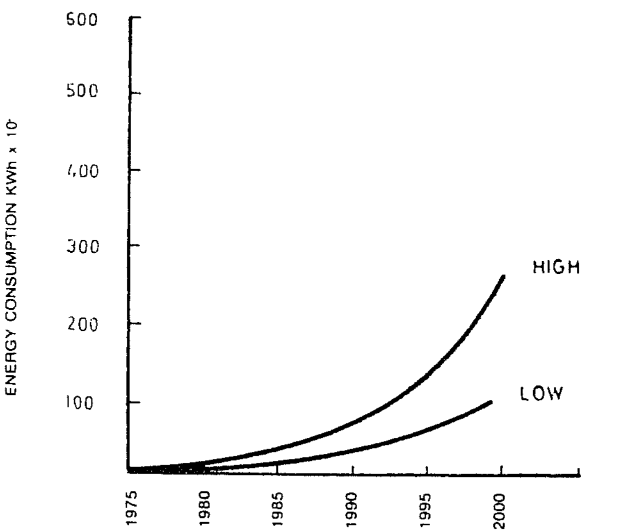
TOTAL ENERGY CONSUMED BY ELECTRIC CARS
Fig 6.4 QUEENSLAND



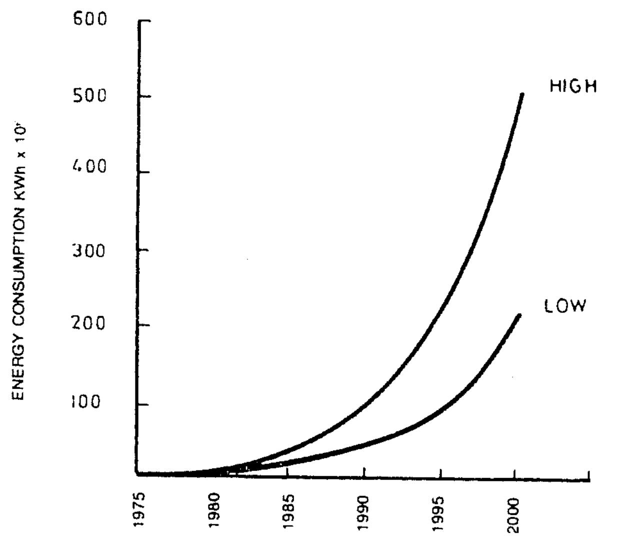
TOTAL ENERGY CONSUMED BY ELECTRIC CARS
Fig 6.5 SOUTH AUSTRALIA



TOTAL ENERGY CONSUMED BY ELECTRIC CARS
Fig 6.6 WESTERN AUSTRALIA



TOTAL ENERGY CONSUMED BY ELECTRIC CARS
Fig 6.7 TASMANIA



TOTAL ENERGY CONSUMED BY ELECTRIC CARS
Fig 6.8 A.C.T.

An attempt is made to compare the estimated total energy consumption by cars in the year 2000 against the postulated energy generated in the same year. The results are tabulated in Table 6.2.

Referring to Table 6.2 (column 1) the total energy in kilowatt hours (kWh) generated in the year 1976 has been obtained from the Annual Report (1975-76) published by the Electricity Supply Association of Australia. It must be noted that figures for New South Wales and Victoria have included the energy generated by the Snowy Mountains Authority, which has been imported into these States.

Figures for the percentage increase in energy generated in the past 14 years have been obtained from similar reports as tabulated in Table 6. 3 It can be seen that the percentage-increase has tapered off in recent years. This was perhaps due to the slowing down in industry as a result of changes in the economic climate. Some States were more significantly affected than others. While increases in electricity consumption by domestic consumers can be related to the projected population growth, it must be remembered that a larger portion of the electricity consumption is used by the commercial and industrial sectors. The growth of commerce and industry is more likely to be influenced by economic policies and government decisions. Therefore, more conservative figures have been assumed for the average percentage-increase of energy generated per year to the year 2000.

It must be noted that as electricity supply to the A.C.T. is fed from the N.S.W. network, figures for energy consumption in kilowatt hours by Electric Cars in A.C.T. and N.S.W. have been added together.

As shown in Table 6.2 (column 5), the energy consumed by Electric Cars expressed as a percentage of the postulated energy generated in the year 2000 varies in each State depending on the State population, the future population growth rate and the extent of industrialisation. The percentage figure gives an indication of the extra burden on the generating system as a result of wider use of Electric Cars. In all cases, the advancement by 12-18 months of programmes for generation in the year 2000 would cope with this new load. The normal lead time required for the planning, construction and putting into operation of large thermal generating stations is approximately five years. A shorter lead time is required for expanding the transmission and distribution system.

Power generating authorities should have no major problems in handling this additional electricity energy consumption.

TABLE 6.2 TOTAL ENERGY CONSUMED BY ELECTRIC CARS/ESTIMATED TOTAL ENERGY GENERATED to Year 2000

	(1) Total kWh Generated in 1976 (x 10^6 kWh)	(2) Average % Increase Per Annum	(3) Estimated kWh Generated in 2000 (x 10^6 kWh)	(4) kWh Consumed By Electric Cars (x 10^6 kWh)	(5) kWh Consumed By Electric Cars - kWh Generated (%)
Australia	68,477	5%	220,838	H 13240.77 L 5856.47	6.0 2.6
New South Wales	25,902**	5%**	83,533**	H 5770.22* L 2552.54	6.9 3.0
Victoria	18,898**	6%**	76,518**	H 2966.04 L 1311.93	3.9 1.7
Queensland	8,501	7%	43,120	H 1784.48 L 789.71	4.1 1.8
South Australia	5,551	5%	17,901	H 1093.86 L 484.02	6.1 2.7
Western Australia	4.055	9%	32,079	H 1359.20 L 570.42	4.2 1.9
Tasmania	5,909	2%	9,489	H 265.03 L 117.19	2.7 1.2

H = HIGH)
L = LOW) Levels of market penetration of Electric Cars

* Combined figure for New South Wales and A.C.T.

** Included energy generated by Snowy Mountain Authority imported to New South Wales and Victoria.

TABLE 6. 3 PERCENTAGE INCREASE IN kWh GENERATED

Year	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Australia
1962-63	-	-	8.4	7.1	11.3	17.6	11.6
1963-64	14.5	12.1	11.9	9.3	6.8	6.0	11.1
1964-65	7.8	11 5	8.4	12.5	12.0	11.2	10.0
1965-66	4.9	6.2	10.8	13.4	11.7	3.1	7.5
1966-67	7.8	8.9	10.0	5.6	13.0	5.4	8.2
1967-68	9.6	6.4	13.1	13.6	7.8	10.2	7.3
1968-69	7.4	7.7	8.9	6.1	18.5	27.3	9.2
1969-70	10.5	4.4	7.2	8.0	14.2	9.0	8.8
1970-71	8.1	4.7	8.7	4.1	11.8	6.1	7.4
1971-72	4.3	3.3	10.2	1.7	7.5	5.6	4.6
1972-73	3.1	4.5	10.0	8.8	10.6	2.2	5.8
1973-74	5.8	8.2	8.5	4.5	9.9	1.9	6.0
1974-75	6.9	7.3	8.7	4.2	7.6	1.6	5.1
1975-76	2.6	7.0	2.8	6.2	9.8	0.7	4.0
ACTUAL Average % Increase	6.2	7.9	9.1	7.5	10.9	6.2	7.8
FUTURE Assumed % Increase Per Annum	5	6	7	5	9	2	5

6.3 POWER DEMAND — DISTRIBUTION SYSTEM

The impact of Electric Cars on the distribution system is quite different from that on the generating and transmission systems. A distribution system is specific to the consumers served by it. Power demand depends largely on the type of connected load and consumption habits in the district.

Typical load curves for the different districts in the metropolitan area are shown in Figure 6.9 to Figure 6.12 inclusive.

6.3.1 CENTRAL BUSINESS DISTRICT (C.B.D.)

In the central business district the demand is high and fairly constant between 8 a.m. and 6 p.m., with a small dip during lunch time, both in summer and winter. There have been plans for gradual phasing-out of kerb-side parking spaces within the CBD in the near future to avoid traffic jams. The majority of parking spaces would therefore be concentrated in parking stations. Reinforcement of the distribution network would be necessary for supplying additional power to these locations when power outlets for charging are provided.

In the CBD parking spaces usually have a high turnover rate, hence power outlets provided for charging would usually be highly utilised.

In the built-up areas, as the load density (MVA/sq. kilometre) increases, the capital costs for distribution equipment per KVA decreases. The cost outlay for each power outlet point is anticipated to be less compared to that provided in other districts.

6.3.2 COMMERCIAL AREAS

In Fig. 6.10, it can be seen that the demand is high and fairly constant from 8 a.m. to 10 p.m., with a dip between 4 to 6 p.m. The extended high demand over the evening as compared to the load curve for the CBD is due

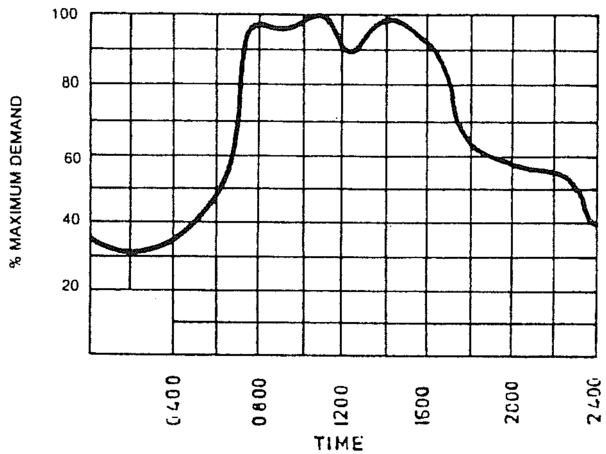


Fig 6.9 TYPICAL DAILY LOAD CURVE — C.B.D.

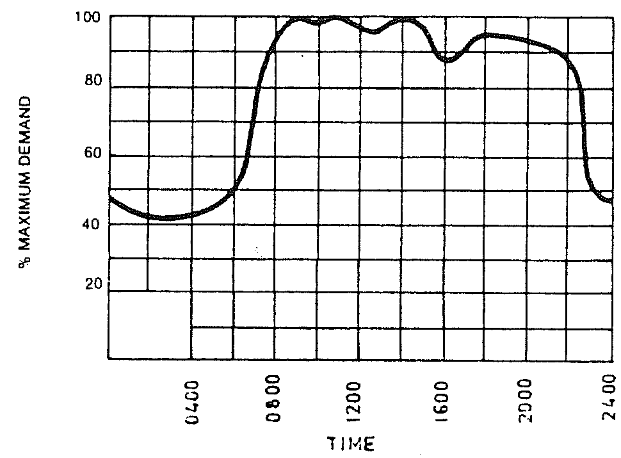


Fig 6.10 TYPICAL DAILY LOAD CURVE — COMMERCIAL

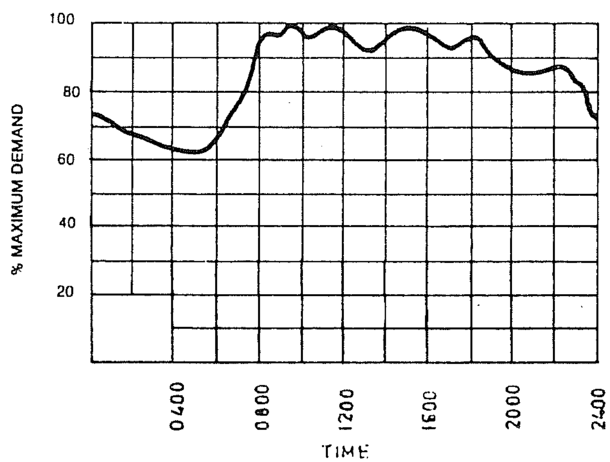


Fig 6.11 TYPICAL DAILY LOAD CURVE — INDUSTRIAL

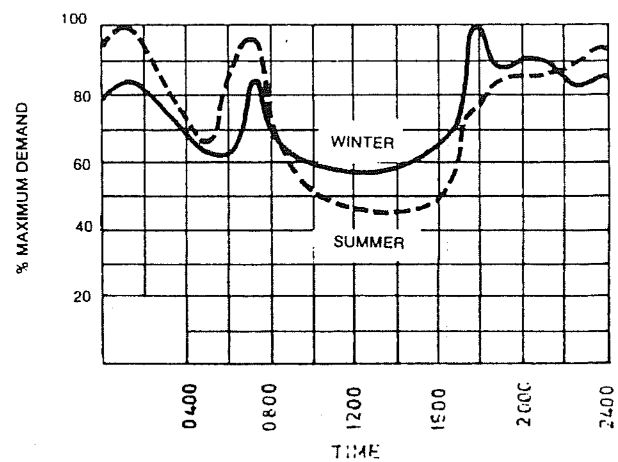


Fig 6.12 TYPICAL DAILY LOAD CURVE — RESIDENTIAL

to the substantial demand by domestic consumers during the early evening.

The weekday car park accumulation in such a district is shown in Fig. 6.13. Assuming that charging of Electric Cars is directly related to the car parking accumulation, there would be a new demand peak between 11 a.m. and 1 p.m.

Overnight charging of Electric Cars in domestic homes in the same area would fill in the existing 'valley' substantially.

Overall, there would definitely be requirements for reinforcement of the distribution network but it is envisaged that growth in the load on the existing low voltage system could be met largely by increasing the number of infeeds from the 11KV/33KV system. The need for reinforcing the sub-transmission and transmission system is unlikely.

6.3.3 INDUSTRIAL AREAS

As seen in Fig. 6.11, the demand is high and fairly constant between 6 a.m. and 6 p.m. The demand during the early and late evening depends mainly on the type of industries in the district, whether they operate on a two or three shift basis.

The majority of parking spaces are provided by industries in close proximity to the factories or plants. Reticulation of power to outlet points for Electric Cars can be conveniently fed from the nearby substation supplying the existing factories and plants.

From Fig. 6.13, it can be seen that the car parking accommodation is very constant during the working hours of between 6 a.m. to 5 p.m. Average parking duration is usually long, namely over 7 hours. Thus, it is anticipated that power demand by Electric Cars charging has its peak in the initial 2-3 hours when all cars arriving are charged at the same time. Therefore, to avoid this peak, load control is necessary.

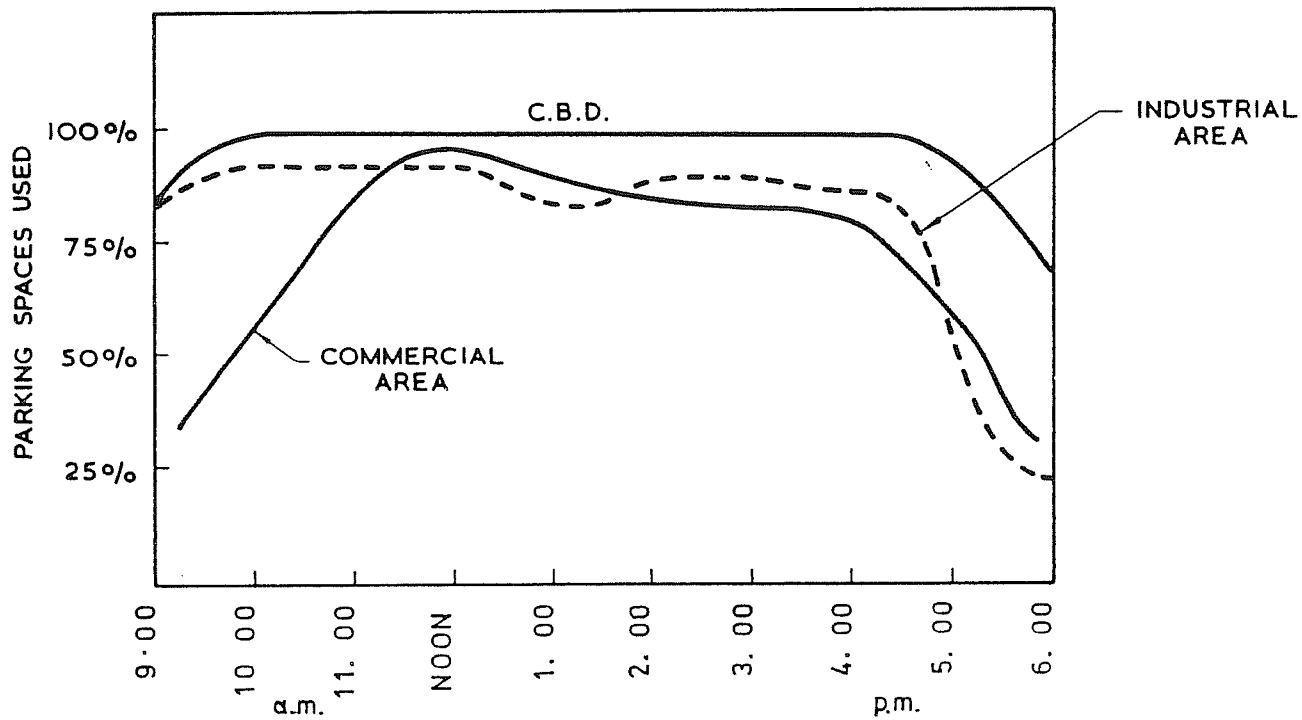


Fig 6·13 CAR CHARGING DISTRIBUTION

By short interruption of supply to each parking-power outlet at selected intervals over an average parking period, the peak load can be contained without causing noticeable inconvenience to the motorists.

If parking spaces actually are within the plant premises and power supply to the power outlets for charging Electric Cars is fed from the sub-station in the plant, local load control can be carried out to suit the particular load characteristic of the plant in order to achieve optimum results.

6.3.4 RESIDENTIAL AREAS

From Fig. 6.12, it is seen that the typical demand curve changes with the seasons. Distribution equipment is more heavily loaded during the evening than during the day.

With the introduction of Electric Cars, when charging is basically carried out overnight new demand peaks will occur. It is anticipated that quite substantial reinforcement of the distribution system will be necessary. Furthermore, as the load density in these areas is relatively low, the cost of reinforcing the distribution network per KVA is higher than that in other areas.

In recent years, supply authorities have already had the continuous task of reinforcing the distribution network in domestic areas in order to meet the rapid trend of home electrification. Wider use of storage heaters is a significant contribution to the increase in consumers' demand. It is therefore anticipated that by general application of ripple control, the power demand by battery charging and water heating could be programmed and even higher utilisation of distribution equipment would be achieved.

6.3.5 COMMENTS

It appears that reinforcement of the M.V./L.V. network would be necessary in all cases, but it is more important that once an area is electrified, an increase in load in the area would only require less than proportionate increase in the circuit route-length of mains. While the increase in power demand would require new low-voltage mains, growth in load on an existing low-voltage network could be met largely by increasing the number of infeeds from the next voltage system. Thus while the capacity of the distribution transformer must keep pace with the load, the number of circuit length of H.V. mains would rise more slowly. Usually the total cost per KVA of transformer and M.V./L.V. cabling would only be about 20% of the total cost per KVA of the entire generation, transmission and distribution network. Therefore the additional cost in reinforcement of M.V./ L.V. equipment is more than offset by higher utilisation of generating, sub-transmission and transmission equipment.

6.4 LOAD CONTROL

'Off-peak' or 'restricted hour' supply has been well utilised by consumers both to their advantage and to the advantage of the generating and supply authorities.

In the past, time-switch control had been most commonly used because of its simplicity and minimum cost of installation.

In recent years, ripple control has become more extensively used both in Australia and overseas. It would normally involve the installation of a transmitter located at a central point of an electricity distribution network and the installation of a larger number of receivers connected to the low voltage mains throughout the area covered. The transmitter would inject audio frequency signals into the network and the signal would travel through the power lines and transformers to the receivers which would perform switching functions according to the signal received. Recent techniques allow as many as 200 switching programmes to be stored. There is great flexibility for changing the control pattern in the course of the days, the seasons and the years. Ripple control has proven to be reliable and effective, easy to install and easy to operate.

Electric Cars, being basically an energy storage system, could cope with short interruptions of power supply during charging without causing noticeable inconvenience to the motorists.

In homes where ripple control has already been installed for domestic water heating, the additional installation of power outlets for battery charging would not involve much extra cost. By adding a simple programmer, operation of the water heater and battery charger could be staggered and upgrading of the consumers' mains would not be necessary. Nevertheless, even if consumers' mains had to be upgraded in size, the additional cost involved would be more than offset by the deferment of a high voltage reinforcement scheme which would become necessary if ripple control to battery charging were not implemented. In the cases of "Park and Charge" meters and parking stations, power supply to as large a number of power outlets as possible would be grouped together and the benefits of ripple control could be conveniently achieved.

During the peak load periods, power supply could either be interrupted altogether for a short period of time or for short intervals over a certain period, e.g. several minutes in an hour. By staggering the on/off programmes for different groups of battery chargers, the most efficient and effective result could be achieved.

In contrast with water heating, energy requirements for battery charging would remain constant throughout the year, i.e. there are no seasonal changes but the overall power demand by each charger would not be constant over the charging period. The load current actually would vary throughout the charging period depending on the state of charge of each battery.

In the case of the coin-operated "Park and Charge" meters where the energy supplied would only be related to the time of operation of the meter, there could be difficulties in providing a fair service to motorists if power could be interrupted at times. This problem of course could be eliminated if a compact and economical device could be incorporated into the meter to measure the actual energy consumed.

In view of the potential rapid increase in power demand due to charging of Electric Cars beyond 1995, supply authorities would soon have the task to study in greater detail the full implications of the additional demand so that overall load management policies could be formulated. Since Electric Cars have not yet come into use in significant number, it should be easier to establish a pattern of use, metering and rates in advance than it would be to attempt to shift pattern of use of existing appliances later.

Beyond the year 2000, as the number of Electric Cars increases more rapidly, the existing 'valley' in the load curve could well be filled in. Load peak could occur at a different time during the day. The entire off-peak tariff structure would then have to be reviewed The abolition of the off-peak tariff in its present form is probable and a new system of tariffs could be introduced.

6.5 POWER SYSTEM DISTURBANCE

With the increasing application of thyristors and power semi-conductors, supply authorities have become very concerned about the adverse effects of voltage and current disturbances on the system operating equipment and on the consumers' equipment connected to the same mains.

In the case of battery chargers, thyristors or power semi-conductors are commonly used in order to achieve a highly sophisticated degree of control at minimum costs and minimum space requirement.

While Electric Cars remain small in number, battery chargers would not contribute serious disturbance to the power system. Nevertheless, as the number of battery chargers in use increases rapidly, a significant increase in the level of disturbance would be probable.

6.5.1 ADVERSE EFFECTS

Thyristors (or power semi-conductors) using phase control are likely to generate voltage and current harmonics which could cause the following adverse effects:

- Risks of resonance and overheating of capacitors,
- Irregularity in operation of centralised remote control,
- Additional losses in transformers,
- Causing overheating of the neutral conductor in a 3 phase 4 wire system,
- Irregularity in operation of computers and data gathering equipment,
- Error in energy meters as they are calibrated on a purely sinusoidal wave form.

As thyristors using 'burst' control are not likely to be used in the battery charger application, adverse effects due to 'burst' control have not been considered.

6.5.2 STANDARDS

While it is possible to analyse the magnitude of voltage disturbances generated by individual appliances with knowledge of their characteristics, it is extremely difficult to analyse the resulting disturbances when a large number of appliances are connected to the system. The resulting disturbances depend not only on the characteristics of individual appliances but also on the connection point to the network, on the value of the impedance at fundamental and harmonic frequencies and on the actual connected load at the point of time.

In European countries, draft specific standards have already been prepared in setting limits of permissible disturbance in the power supply network. It has been recognised that unlike industrial applications, disturbances caused by household appliances can hardly be solved at the level of installation requirements as supply authorities have practically no control over their use. It is considered that action at the stages of design and manufacture by means of a standard should make it possible to obtain equipment having such characteristics that within normal operation, disturbances caused would not exceed tolerable levels. Furthermore, by setting limits of disturbance in individual appliances, allowable disturbance level in a network would not be exceeded for the following reasons:

- When several appliances are connected the connection impedance is lower than the conventional impedance (a statistical value used to represent the impedance between an infinite power source and the connected load) on which the permissible disturbance level is derived,

- Appliances do not all operate at one time, i.e. diversity,

- Asychronous operation reduces total disturbance compared to that which would occur with synchronous operation.

In Australia, specific standards on limits of permissible disturbance in power systems have yet to be established but they would be essential to assist the design and development of battery chargers which in turn definitely affect the development of Electric Cars.

6.5.3 HARMONICS REDUCTION

Several common methods of reducing voltage and current harmonics are listed as follows:

- Filter circuits to be provided for the most important harmonics. Very often in addition to limiting harmonics, they also perform part of the power factor compensation function.

- Smoothing circuits to be provided in the charging circuit. These, in addition to producing a correspondingly low level of current harmonic, also mean a reduction in the connected load on the system.

- Increase in the pulse number by extending the circuit arrangement, e.g. a full wave three phase rectification with a pulse number of 6 would not produce the 3rd, 9th and 15th harmonics which are produced by a single phase rectification with a pulse number of 2. The amplitude of the remaining harmonics will however, not be affected.

In battery charging stations, it would be more economical and feasible to build larger central battery chargers to take care of a large number of vehicles. It would be easier for the supply authority to evaluate the potential or actual level of disturbances. Agreement could be reached with the proprietor involved to keep the disturbances within limits acceptable for network operation and the neighbouring users.

In the case of single phase on-board chargers, by using pulse modulating control combined with suitable reactors and capacitors, it could be possible to obtain a mains current consisting only of fundamental and high frequency harmonics. Low order harmonics could be virtually absent and the fundamental of the current would be in phase with the system voltage. The limitation to this technique would be its special demand on the power semi-conductor which would mean that it could only be used for smaller rating chargers, e.g. 3-4 kW.

6.6 POWER RETICULATION — "PARK AND CHARGE" METERS

The method of power reticulation to each "Park and Charge" meter depends largely on the local situation.

The basic requirement is the standardisation of both equipment and equipment layout so that the benefit of mass production can be achieved.

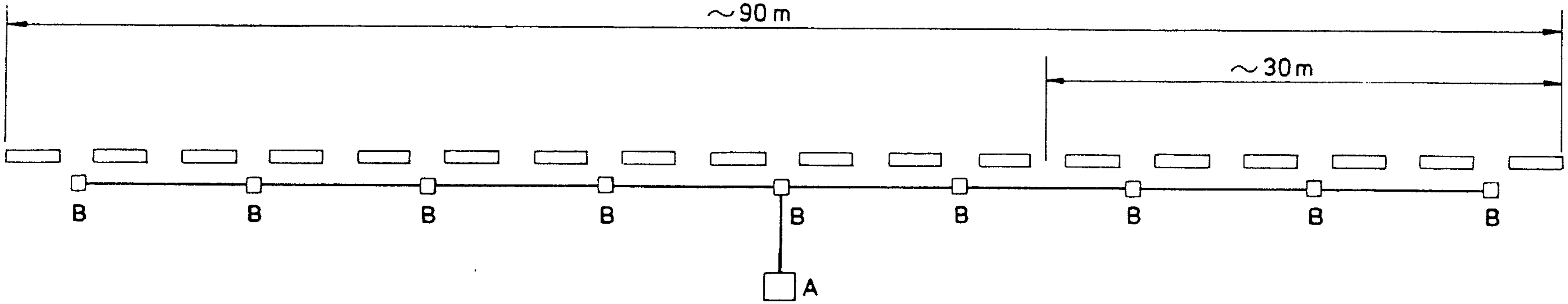
Four different schemes of power reticulation are compared; two for each type of "Park and Charge" meters, namely coin-operated type and magnetic card-operated type.

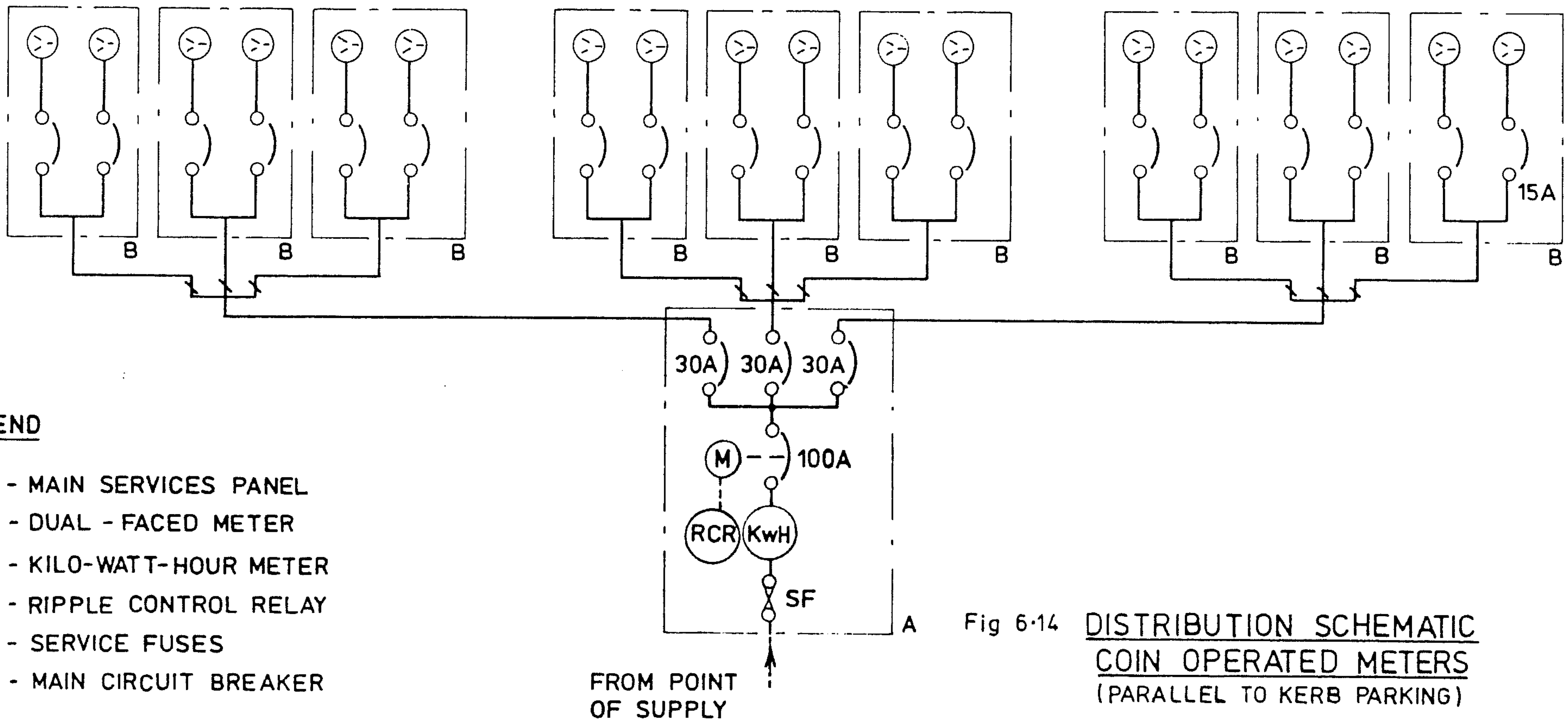
It must be pointed out that in all schemes, plug receptacles are single phase, rated 240 volt 15 amp. It is probable that the provision of 30 amp outlets on "Park and Charge" meters would require high cost in power reticulation and may not be justified.

6.6.1 COIN-OPERATED METERS

Scheme A - Parallel kerb side parking (Fig. 6.14) - Power supply to a group of 18 meters would be obtained from one main services panel which could either be incorporated into the pedestal stand of the "Park and Charge" meter or mounted in a separate free-standing pillar. The main services panel would accommodate all sub-circuit circuit breakers, a ripple control relay and a kilowatt hour meter. On each dual-faced meter, one circuit breaker would be provided for each plug receptacle circuit. For safety reasons, single phase supply should be reticulated to each dual-faced meter.

Scheme B - Off-Street Parking - This particular scheme would be applicable to open car parks or public parking stations. A group of 24 meters would be supplied from one main services panel. The main services panel would accommodate all sub-circuit circuit breaker, and the main circuit breaker. Depending on the size and layout of the car park, several main service panels could be centrally located and only one kilowatt hour meter and one or more ripple control relays would be required.





GEND

A - MAIN SERVICES PANEL

3 - DUAL - FACED METER

vh - KILO-WATT-HOUR METER

CR - RIPPLE CONTROL RELAY

F - SERVICE FUSES

1 - MAIN CIRCUIT BREAKER

Fig 6·14 DISTRIBUTION SCHEMATIC COIN OPERATED METERS (PARALLEL TO KERB PARKING)

6.6.2 MAGNETIC CARD METERS

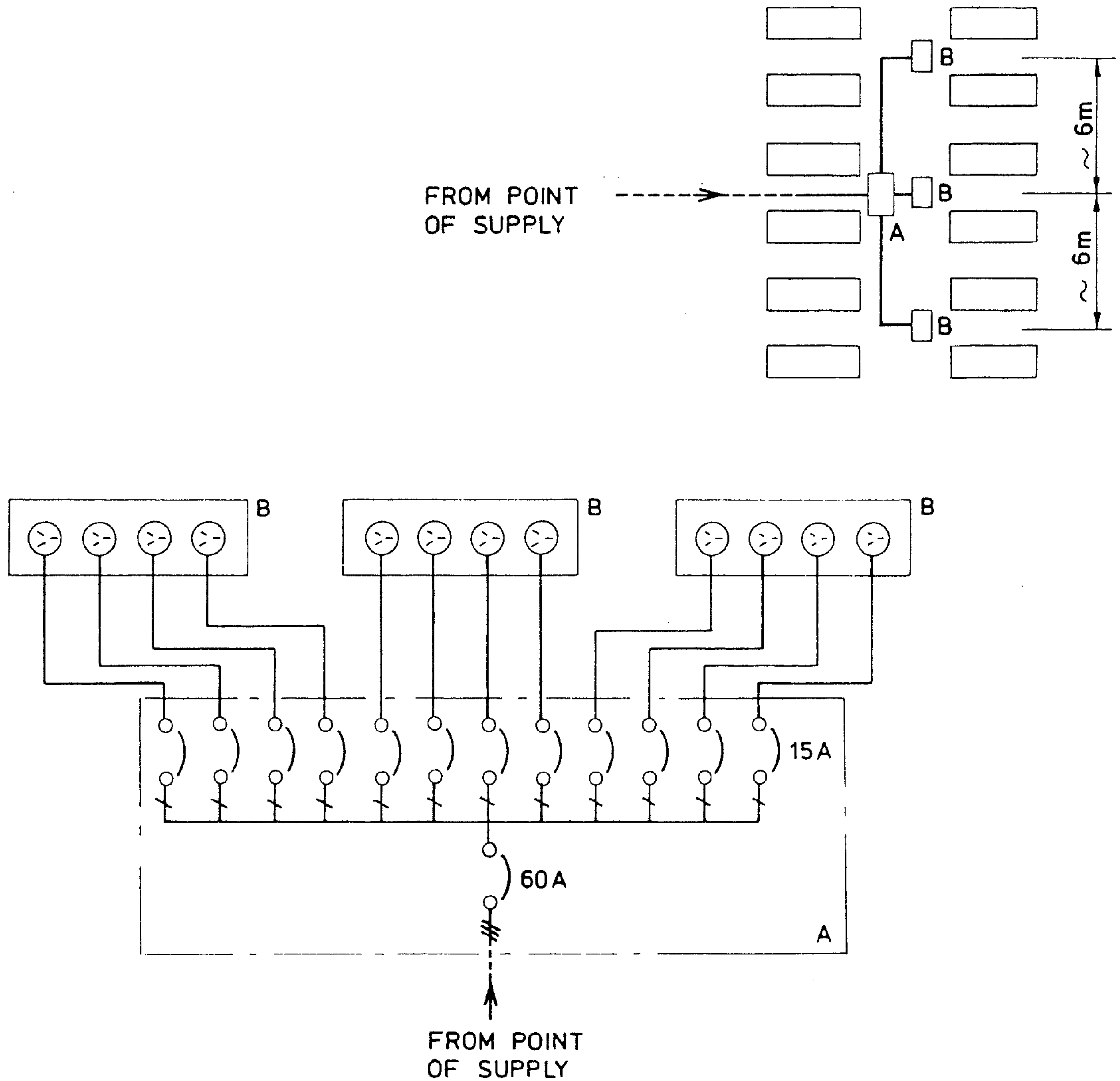
Scheme A - Parallel Kerb Side Parking - An auxiliary services panel would be mounted in a segregated compartment in the metering console refer to Fig. 5.4, Chapter 5). The auxiliary service panel would accommodate circuit breakers for individual plug receptacles to be housed in a separate compartment in the meter console. The main services panel would be provided with extra space for the mounting of the main switch, the kilowatt-hour meter and the ripple control relay. Wiring to plug receptacles on the same "charge point" should be connected to the same phase.

Scheme B - Off Street Parking (Fig. 6.15) - For each group of 12 cars, supply to the plug receptacles would be obtained from the main services panel which would be incorporated into the twelve-car meter console. The main service panel would accommodate the twelve sub-circuit circuit breakers. Again depending on the size and the layout of the car park, several main service panels could be centralised. Only one kilowatt-hour meter and one or more ripple control relays would be required.

6.6.3 COST ESTIMATES

An estimated average cost of work for power reticulation to each meter plug receptacle is tabulated as shown in Table 6. 4

It must be pointed out that figures in Table 6.4 only cover all underground cable reticulation including trenching and the supply and installation of the main services panels, auxiliary service panels and associated equipment mounted on them including the sub-circuit circuit breakers, service fuses, kilowatt-hour meter and ripple control relay. Nevertheless, the circuit breaker for each meter plug receptacle has not been included because it had already been included in the costing of the "Park and Charge" meter.



LEGEND

A - MAIN SERVICES PANEL

B - 4 CAR 'CHARGE POINT'

Fig 6·15 DISTRIBUTION SCHEMATIC MAGNETIC CARD METERS

(90° OFF STREET PARKING)

It should be noted, also, that the cost of reticulation from the sub-station or nearest point of supply to each main services panel has not been included. Realistic cost figures could be worked out with knowledge of the site situation. Depending on the location, the point of supply to each group of meters could be from an existing overhead line, an underground mains, or from a transformer in a substation.

TABLE 6.4 COST ESTIMATES - POWER RETICULATION TO "PARK AND CHARGE" METERS

Scheme	Estimated Average Cost per Meter Point
1. Coin-operated meters:	
a) Parallel to kerb, on-street parking	$64
b) 90° parking, off-street	$38
2. Magnetic-card meters:	
a) Parallel to kerb, on-street parking	$75
b) 90° parking, off-street	$32

6.6.4 COMMENTS

In connection with the "Park and Charge" meter application, it is recommended that further investigation should be carried out at a later date by appropriate State and local authorities with regard to:-

i) Sharing of capital cost in connection with power distribution,

ii) Statutory obligations,

iii) Maintenance and management of electrics associated with the meter,

iv) Policy on tariff or charges on electricity supply.

7. POWER GENERATION AND ENERGY SUPPLIES

7.1 CONSUMPTION OF ENERGY RESOURCES

As large energy demands are reducing the available energy resources, it is important that energy resources are used efficiently. As stated in Chapter 6 on "Power Demand and Distribution" the average energy required to drive an electric vehicle in urban areas a distance of 1 kilometre is 0.55 kWh. This is the energy supplied to the input terminals of the car battery charger.

To make this energy available at the car, assuming coal as the energy resource, then the following steps have to be made:-

	Efficiency
• Mine the coal and transport it to the power station	99%
• Convert the energy in the coal to electrical energy	31%
• Transmit the electrical energy from the power station to the electric vehicle	89%

Therefore the energy in the coal in the ground required to drive an electrical vehicle 1 kilometre is 2.01 kWh or 7.25 megajoules. This amounts to about .25 kg of good black coal, .5 kg of poor black coal and .75 kg of brown coal.

The conventional car in urban traffic will have a petrol consumption of 5.4 kilometres/litre (1.74 kWh per kilometre) with exhaust emission controls and 6.4 kilometres/litre (1.47 kWh per kilometre) without exhaust emission controls.

To make this energy available at the car, the following operations are required:-

	Efficiency
• Transport crude oil from oil well to refinery	96%
• Refine the oil	85%
• Transport and distribute petrol	90%

Therefore the energy in the oil in a well required to drive a conventional car 1 km. is 2.38 kWh or 8.55 megajoules if it is fitted with exhaust emission devices, and 2.00 kWh or 7.2 megajoules if no such devices are fitted.

From the above it can be seen that the conventional car with exhaust emission devices consumes 18% more energy than the Electric Car in terms of fuel in its natural state. Without exhaust emission devices the energy consumptions of conventional and Electric Cars are about the same.

Fig. 7.1 shows the total energy of the resources (oil or coal in the ground) required for cars in urban areas, comparing zero penetration of Electric cars and maximum penetration of Electric Cars. It has been assumed that conventional cars will have exhaust emission devices. The introduction of Electric Cars does not bring about a significant saving in energy until about 1995.

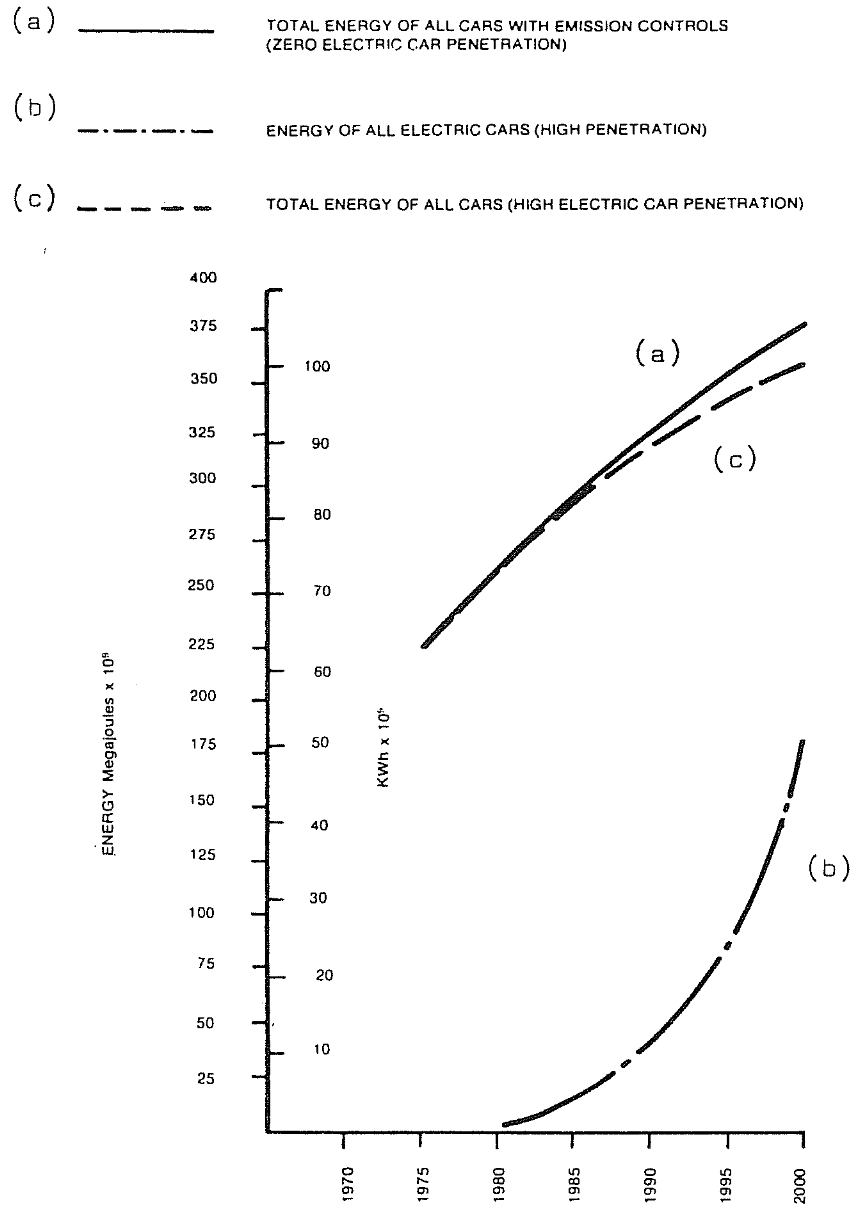
7.2 RESERVES OF ENERGY RESOURCES

Reserves of oil are limited on a world wide basis. In Australia there are 10×10^{12} megajoules of energy in the form of oil compared with 500×10^{12} megajoules of black coal and 350×10^{12} megajoules of brown coal.

The Electric Car therefore consumes less energy than the conventional car with emission controls and also consumes coal of which there are ample reserves.

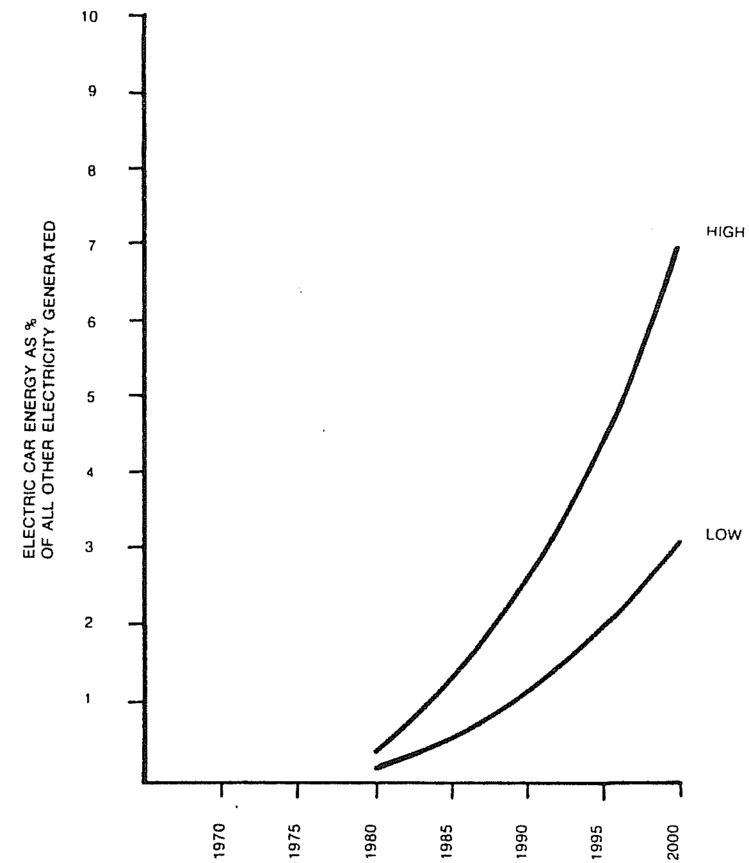
7.3 POWER STATION FUEL

In Australia at present all the major power stations in New South Wales, Victoria, Queensland and South Australia burn coal. In Tasmania, except for an oil fired power station which would only be used in a drought, all power generation is hydroelectric and in Western Australia there are both oil and coal fired power stations. As oil becomes scarcer and more expensive, Western Australia is reverting to coal.



ENERGY RESOURCES REQUIRED

Fig 7.1



GENERATED ENERGY REQUIRED FOR
ELECTRIC CARS HIGH & LOW PENETRATION

Fig 7.2

Should there be inadequate coal in Western Australia or insufficient water available in Tasmania, nuclear power stations may be introduced; however nuclear fuel will be both cheap and plentiful in contrast to oil.

7.4 ELECTRICAL ENERGY REQUIREMENTS

The introduction of Electric Cars would require increased generation of electricity. This increase as a percentage of the total electricity generated in power stations for all purposes is shown on Fig. 7.2 for both low and high projected rates of introduction of Electric Cars. It can be seen that for all Australia this increase at the highest projected rate will amount to approximately 7% of the total electricity generated by the year 2000. The actual increase would vary from State to State as shown in Table 7.1. It should be noted that these figures are total power generated and include losses in the power station auxiliaries and all transmission losses to the point of supply to the Electric Car.

TABLE 7.1: ELECTRICAL GENERATION REQUIREMENTS

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Australia
Generated energy required by Electric Cars in the year 2000 Gwh	6862	3527	2122	1300	1615	298	15722
% Electric Car energy of total Electrical Generation in year 2000	8.2	4.6	4.9	7.3	5	3.1	7.1

7.5 DEMAND REQUIREMENTS

Up until 1995 when the electrical energy increase for Electric Cars is less than 5% of the total electrical energy generated, it will not be necessary to install extra generating plant as it should be possible to interrupt battery charging loads during periods of peak demand. Beyond 1995 when the Electric Car energy load becomes a greater percentage of the total electrical energy load, it will be necessary to install additional generating plant to meet the greater demands placed on the system. To meet these demands in the year 2000, approximately 5% increase in generating plant should be installed during the period 1995-2000. This amounts to an advancement of programs for installation of generating plant by about one year.

7.6 ENERGY REQUIREMENTS

The additional energy requirements for each State vary according to the number of Electric Cars. The amount of fuel used is dependent on the calorific value of fuel used which is different in each State. The energy source and its calorific value are shown in Table 7.2 for each State.

TABLE 7.2: CALORIFIC VALUES OF FUEL

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania
Energy Source	Black Coal	Brown Coal	Black Coal	Black Coal	Black Coal	Water
Calorific MJ/kg value	24	10	27	16	19	Not Applicable

The additional fuel required in each State to meet the energy requirements of the Electric Cars is shown on Table 7.3.

TABLE 7.3: COAL REQUIREMENTS

		Tonnes x 10^3				
		1980	1985	1990	1995	2000
New South Wales	High	62	209	681	1470	3168
	Low	37	136	301	650	1400
Victoria	High	96	454	943	1928	3909
	Low	57	201	417	854	1728
Queensland	High	16	83	186	404	872
	Low	10	37	82	179	386
South Australia	High	20	97	207	433	901
	Low	12	43	92	192	399
Western Australia	High	16	85	194	429	943
	Low	10	37	86	190	417

7.7 ADDITIONAL INVESTMENT

In the period 1995-2000 for the maximum projected growth of Electric Cars, the additional energy and demand requirements of the electric vehicles will necessitate additional investment in power generating and coal mining plant. The investment in present day values to meet the maximum loads in the year 2000 would be as shown in Table 7.4.

TABLE 7.4: COAL MINING AND POWER PLANT INVESTMENT

$million

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Australia
Coal Mining Investment	110	137	31	32	33	-	343
Power Plant Investment	375	214	137	94	153	29	1002
Total Investment	485	351	168	126	186	29	1345

This increased investment will be offset by a reduction in investment in petroleum refining plant.

7.8 LOAD INTERRUPTIBILITY

Most large interconnected systems are operated with a proportion of the generating plant running as "spinning reserve", i.e. plant running unloaded. This provision is made to allow for minimisation of the consequences of sudden loss of generating capacity anywhere on the system which, without spinning reserve to take the load, could result in a cascade collapse of the system.

Spinning reserve is however not without substantial cost. With units of 660MW now being installed in New South Wales it follows that spinning reserve requirements must approach this figure to cater for the loss of such a unit when on full load.

There are two approaches to the problem. The first is to retain generating capacity equivalent to the load on the largest set operating as spinning reserve. The second is to arrange that a segment of the overall system load may be interrupted (that is, disconnected) without notice for sufficient time for additional generating capacity to be brought on line or for other sections of the system to be disconnected or for load to be shared in any other way.

System emergencies are usually catered for by a combination of the above two factors. Nevertheless, the capability of load interruption is considerably more attractive and economic. Some attempt has been made with hot water systems, which are clearly interruptible, to control these on a so-called off-peak system. Under this system the hot water load is provided through a separate meter with a frequency controlled relay arranged so that the supply authority can control the hours under which 'off-peak' electricity may be supplied. To compensate for the inconvenience to the consumer such energy is provided at a lower tariff.

In New South Wales the Electricity Commission has an agreement with an aluminium smelter at Kurri Kurri to supply electricity at a favourable tariff with the proviso that the smelter will accept interruptions of supply for limited periods. These periods are of sufficient time to start up reserve generating sets (usually hydro). Once the reserve sets are running the supply to the smelter can be re-connected.

It is believed that the Electric Car load comes into this category. Clearly short-term disconnection of the Electric Car charging load is of little consequence since batteries by their very nature will generally have stored energy while those that are drained will, by definition, have just completed a journey and could not in any event expect to be driven again until adequate charge has been received. At worst the consequences of a brief interruption would be to limit marginally the subsequent journeys of very few cars.

Thus it may be concluded that the load offered by electric cars, although of no significant proportions, is nevertheless of some value in development of the system of supply.

7.9 LOAD FACTOR IMPROVEMENT

Fig. 7.3 shows typical winter and summer daily load curves which are generally applicable to generating authorities in Australia. The Load Factor (ratio of average load to peak load) will vary but an average will probably be approximately 50%.

Electricity systems throughout the world have adapted themselves to the problem of low load factor and have optimised plant selection accordingly. Capital equipment is installed both to meet the predicted system peak, with an allowance for planned and forced outage of generation or transmission equipment, and is also optimised to operate to suit the system load factor. While at times away from the system peak there may appear to be under-utilisation of invested capital, such periods are of value in providing for maintenance. Furthermore, with coal fired power stations, much of the coal plant from the coal mine through to coal in bunkers and including grinding mills is related more to energy than to demand and the level of installation is related to predicted energy consumption.

Electricity supply undertakings have approached the problem arising from low system load factor in a number of ways. These include pumped storage, off-peak tariffs to displace system peak, and provision of relatively cheap but inefficient generating plant such as gas turbines which consume premium fuel. Electrical energy is both expensive and difficult to store although most undertakings have made, as mentioned above, some effort to use the energy storage and interruptible capability of hot water systems to improve the system load factor. Battery driven cars represent an attractive means of storing energy at one time for use at another apart from any other attractions that are dealt with elsewhere in this report.

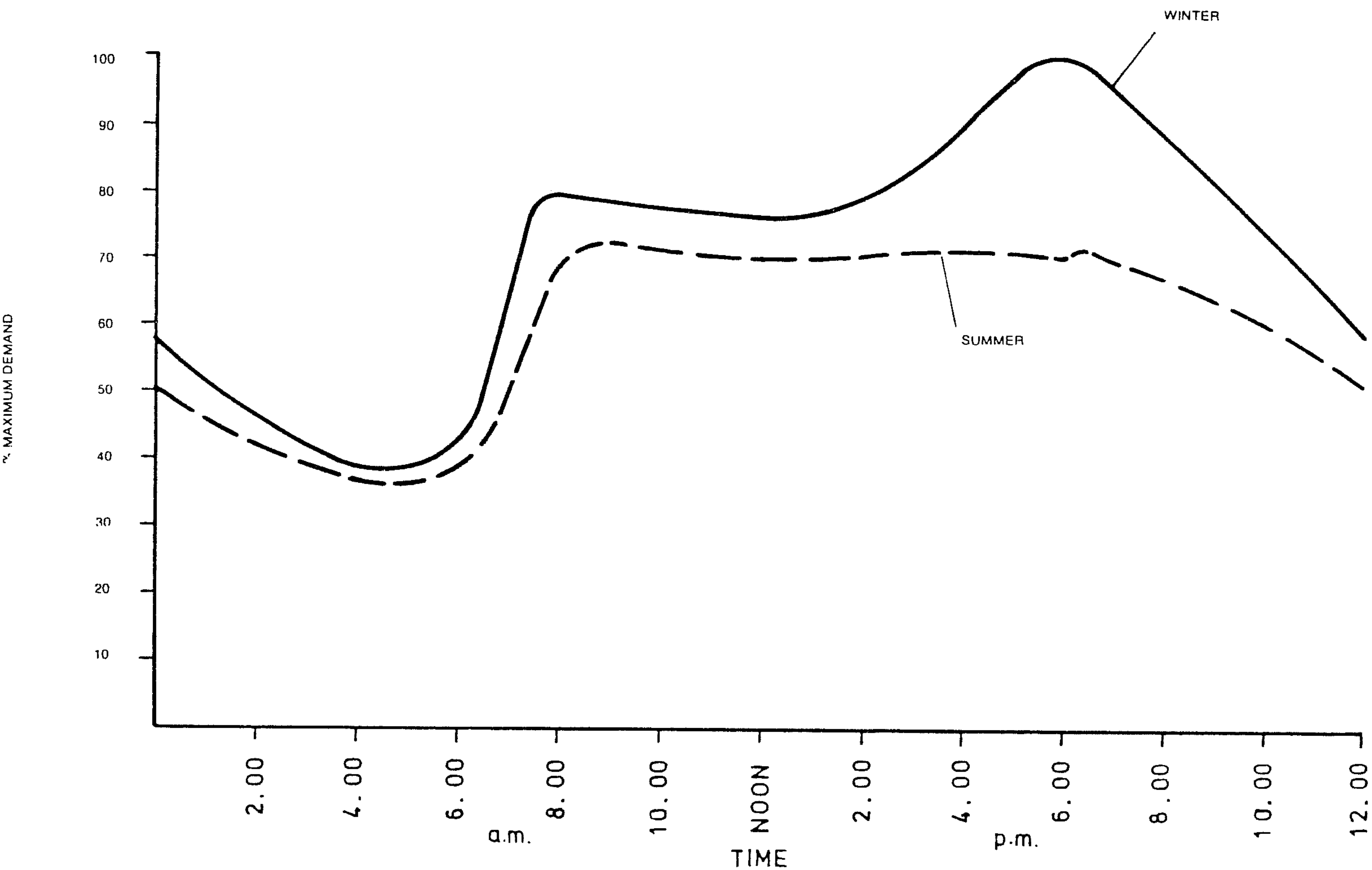


Fig 7.3 DAILY LOAD CURVES

8. ENVIRONMENTAL IMPACTS

8.1 INTRODUCTION

It is widely thought that the introduction of large numbers of Electric Cars into urban areas would have a marked effect on several aspects of the environment. The most obvious of these is the reduction in emissions of the major sources of oxidant pollution, and of carbon monoxide. There is also the expectation that traffic noise generation will be considerably less and that on major roads there will be a consequent improvement in the environment. Other environmental consequences of using Electric Cars are less clear.

Assuming that Electric Cars find wide acceptance and that their introduction is encouraged by government action, an estimate has been made that 54% of all urban passenger cars would be electric by the year 2000. At that time, there would still be more conventional cars in city areas than there are at present. Thus any environmental effects are likely to be related to reduction in effects which would occur, rather than in changes from the present effects as modified by the progressive introduction of emission control devices.

8.2 GENERAL

The potential environmental effects of progressively replacing conventional internal combustion engined cars with Electric Cars are related to changes in:

- the type and quantity of fuel used,
- location and distribution of combustion emissions,
- waste disposal problems, particularly those related to water quality,
- resource use and national balance of payments,
- noise generation characteristics,
- patterns of employment, particularly in relation to car manufacture and energy distribution.

The direction in which these changes will affect the environment can be foreseen although in some cases it is difficult to assess their magnitude. Projections indicate that Electric Cars will be present in large numbers only in urban areas up to the year 2000, and so their effects on the environment will be limited to these areas. Local exceptions to this will arise from new mines and electricity generating stations and a few country factories.

The magnitude of effects will be related to population and vehicle numbers, so the major changes will occur in Sydney and Melbourne and they will be similar in both. Lesser changes will occur in the smaller cities.

8.3 IDENTIFICATION OF POTENTIAL ENVIRONMENTAL EFFECTS

8.3.1 FUEL USE DIFFERENCES

With present technology both Electric and conventional cars ultimately depend on fossil fuels for their power. However, there are basic differences in the nature of the fuels used and the location of their combustion which in turn affect the environment.

In the Modified Sydney Region there are presently over one million conventional cars, and the numbers there and elsewhere in Australia will increase to approximately:

Total No. of cars. (millions).

	1975	1980	1985	1990	1995	2000
Modified Sydney Region	1.01	1.19	1.38	1.58	1.72	1.80
New South Wales	1.70	2.08	2.41	2.71	2.98	3.17
Australia	4.74	5.84	6.76	7.63	8.38	8.90

The interaction of the emissions from these cars, and the products formed from them by photodissociation by sunlight generate secondary pollutants, such as ozone and various toxic organic chemicals, including peroxyacetylnitrate (PAN).

The major impact of producing Electric Cars would be to reduce the present diffuse area-source emission listed above in favour of increased local point sources of sulphur dioxide, particulates and nitrogen oxides. The latter would be at locations remote from densely populated areas, with control and dispersal being more readily achieved. Overall, it could be expected that hydrocarbon emissions will decrease substantially with a smaller decrease in nitrogen oxides. In New South Wales sulphur oxide emissions could increase by up to 8% although for Australia as a whole the increase would be less , at about 6%.

8.3.2 RESOURCE CONSERVATION

The widespread introduction of Electric Cars would aid in the conservation of petroleum. Based on estimates of Electric Car market penetration nominated in Chapter 4. The expected reduction in petrol consumption in the Modified Sydney Region is 3606 kilolitres (with emission controls) daily by the year 2000, but this depends upon the degree of emission control in use at the time and on improvements in consumption. A corresponding reduction in refinery operations, storage and distribution of petroleum would occur thereby reducing evaporative and spillage losses of this fuel, which would also be beneficial from an air and water pollution viewpoint.

The introduction of Electric Cars would increase demand for battery components, although high recycling rates could satisfy most of this demand once the increased production required initially had been achieved.

The first generation of Electric Cars is likely to use a conventional lead-acid battery system but with an increasing car population the utilisation of advanced battery technology should be expected.

Possible alternatives to present batteries are zinc-nickel, zinc-chlorine, sodium-sulphur and lithium-sulphur, which promise to provide from 3 to 10 times the specific energy storage of lead-acid batteries. However, significant increases in the demand for scarcer materials such as lithium may arise.

8.3.3 NOISE

The significance of the effect of Electric Cars on community noise levels will depend on their inherent noise generation relative to the conventional vehicles they displace and the relative penetration of the market that occurs.

The general conclusion that Electric Cars will be quieter under normal traffic conditions may lead to a reduction in background traffic noise, but they may be unable to replace those vehicles, such as diesels and sports cars, which are responsible for the more disturbing, intrusive noises.

Overseas studies have shown that Electric Cars will be about 12 dB quieter under normal running conditions than conventional cars. Once large numbers enter the traffic streams noise generated by major roads will decrease. The continued presence on the roads of large commercial vehicles will reduce the importance of this change in noise level.

8.3.4 SAFETY

With only a few Electric Cars on the road, differential acceleration and other variations in the traffic stream may increase the likelihood of accidents. This factor will disappear as numbers increase. Other safety problems may arise from the presence of greater quantities of battery electrolyte and increased sparking hazard, but design advances will reduce these to acceptable levels. Electric Cars will probably have a safer weight distribution than conventional cars; safer braking by the use of regenerative braking, as well as conventional means,and could readily be designed to be less dangerous in vehicle-pedestrian impacts.

8.3.5 SOCIO-ECONOMICS

Because there will be changes in the fuel service industry and the car manufacturing and accessories supply industries, a potential for work force dislocation and industry structure changes will exist. However, even with the higher of the two rates of market penetration of Electric Cars, the number of vehicles using internal combustion engines will still increase above the present number. Restricted growth opportunities for these sectors of present industry are therefore likely, but not with major or sudden changes.

Manufacturing changes should be slow enough to allow existing manufacturers and suppliers to switch to Electric Car production and parts work; thereby creating other opportunities for employment.

Australia has adequate supplies of coal but present predictions are that it will be short of petroleum resources before 1990. The use of Electric Cars in large numbers will provide some assistance towards reducing oil imports and hence to maintaining a favourable balance of payments, which will assist in stabilising employment patterns for a broad spectrum of the nation's workforce.

8.3.6 WASTE DISPOSAL

. **ELECTROLYTE**

Spent battery electrolyte may become a disposal problem unless economic recycling methods can be developed. At low and high levels of Electric Car penetration of the market in the year 2000, and assuming that disposal of all acid is required, it is estimated that disposal of between 49.6 million and 112.2 million litres will be required for the whole nation.

. **LEAD**

Conventional cars at present discharge lead in an uncontrolled manner to the atmosphere. Without emission controls on vehicle exhausts, lead discharge for Australia would rise from 4560 tonnes in 1975 to 9440 tonnes in the year 2000; with emission controls at the present state of development, the lead discharge will rise to 11,150 tonnes per annum.

Overseas studies indicate that a 90% recycle level on battery lead can be maintained, and on a three year battery life this would generate controlled disposal requirements for low and high Electric Car market penetration of up to 14,000 tonnes and 31,500 tonnes respectively. Additionally, for each of the demands, the remaining conventional cars will discharge the following amounts of lead to the atmosphere by the year 2000:

- without emission controls 7,700 tonnes and 5,500 tonnes
- with emission controls 9,100 tonnes and 6,500 tonnes,

respectively.

8.4 AIR POLLUTION

Sydney and Melbourne already have air pollution problems arising largely from motor vehicle emissions. The control strategy adopted in Sydney is to limit hydrocarbon emissions so that the present "mix" of pollutants will be shifted away from one suitable for the production of ozone. To achieve this with the expected increase in conventional cars will call for extremely stringent emission controls. With the depletion of known Australian reserves of liquid fuel within 10 years, and world reserves early in the next century, it is doubtful whether such controls can be imposed because there is a high fuel consumption penalty. Use of Electric Cars would reduce both air pollution and fuel supply problems.

Photochemical pollution in Sydney rose to levels in excess of WHO recommended values on more than 80 days in 1972 and 1973. Major sources of photochemical pollution are hydrocarbon and nitrogen oxides emitted by cars. In 1973 carbon monoxide concentrations in the ambient air in Sydney CBD exceeded WHO recommended values on 85 days. These high values have continued to be recorded since that time. Similar atmospheric pollution is recorded in Melbourne, while lesser effects appear in the smaller cities.

It is well known that conventional cars are the major source of this problem. They contribute approximately 66 % of the hydrocarbons emitted daily in Sydney, 55 % of the nitrogen oxides, almost 100 % of the carbon monoxide, and 85 % of the lead.

Under certain meteorological conditions the nitrogen oxides and non-methane hydrocarbons can react in the atmosphere to produce secondary photochemical pollution or "smog", made up of toxic oxidants of which, in Sydney, 90 % or more is normally ozone; the remainder consisting of nitrogen dioxide, organic peroxy compounds and small particles (aerosols).

Additional pollution attributable directly to these cars results from odourous and smokey emissions, tyre abrasion and braking which releases asbestos to the atmosphere.

Of the pollutants mentioned above only those resulting from tyre abrasion and braking would be produced directly by Electric Cars.

In an effort to control the rising level of air pollution caused by motor cars, the State Pollution Control Commission (SPCC) N.S.W., has introduced controls on new motor car weighing between 0.5 and 2.5 tonnes operative from the 1st. July, 1976, limiting the emission emission of carbon monoxide, hydrocarbons and nitrogen oxides to the values shown below:

Carbon monoxide	CO	24.2 grams per kilometre
Hydrocarbons	HC	2.1 grams per kilometre
Nitrogen oxides	NO_x	1.9 grams per kilometre.

Furthermore, from the 1st January, 1977 the lead (Pb) content of petrol sold in Sydney, Newcastle and Wollongong was limited to 0.45 gram per litre maximum, and it is proposed to further reduce it to 0.40 grams per litre in 1980.

The effect on the emission rates of carbon monoxide, non-methane hydrocarbons and nitrogen oxides of the introduction of Electric Cars can be gauged on the basis of the introduction rates assumed in this report (Chapter 4).

8.4.1 CENTRAL BUSINESS DISTRICT (C.B.D.)

Table 8.1 shows the progressive change in emission rates between 1975 and 2000 for assumed low and high rates of introduction of Electric Cars for the Sydney CBD. The figures also take account of the progressive effects of post-1976 cars with emission controls and of the proposed reduction in lead emission rates. Comparative figures for the situation with no Electric Cars are also shown. It must be emphasised that the figures shown are not for all conventional cars, but only for those which are likely to be replaced by Electric Cars.

If present conditions continue, the conventional car population will consist entirely of controlled vehicles by 1990. Before that time a decreasing percentage of conventional cars with uncontrolled emissions will remain.

8.4.2 THE MODIFIED SYDNEY REGION

Air pollution reaches its most serious forms for large urban regions, of which the Sydney Metropolitan area is one. Such large urbanised regions have a high density of conventional cars and are of sufficient area that mesoscale atmospheric processes can lead to the accumulation of several days' emissions before dispersing conditions become dominant. The effects of the introduction of Electric Cars on emission rates within the "Modified Sydney Region" are shown in Table 8.2, which was prepared on the same basis as Table 8.1.

TABLE 8.1: PROJECTED POLLUTANT EMISSIONS FOR THE SYDNEY CBD, WITH AND WITHOUT THE INTRODUCTION OF ELECTRIC CARS

(CO, NMHC, NO_x - kg/day x 10^4, Pb - kg/day)   Conventional cars with emission controls.

	1971	1975	1980			1985			1990			1995			2000		
Total Daily Distance Travelled (km x 1000)	1308.0	1366.2	1463.1			1553.0			1636.8			1717.6			1796.3		
Percentage Electric Cars (Low and High Estimate)	0	0	0	0.9	1.5	0	3.1	5.8	0	6.1	13.8	0	12.0	27.2	0	23.7	53.8
Carbon Monoxide (CO)	7.1	7.4	6.1	6.0	6.0	4.8	4.7	4.5	4.0	3.8	3.4	4.2	3.7	3.1	4.3	3.3	2.0
Non Methane Hydrocarbons (NMHC)	0.7	0.7	0.6	0.6	0.6	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.3	0.4	0.3	0.2
Nitrogen Oxides (NO_x)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.1
Lead	130.8	136.6	91.4	90.5	90.0	97.0	94.0	102.3	102.3	96.1	88.2	107.3	94.4	78.1	112.2	85.6	51.8

ABLE 8.2: PROJECTED POLLUTANT EMISSIONS FOR THE MODIFIED SYDNEY REGION WITH AND WITHOUT ELECTRIC CAR INTRODUCTION

(CO, NMHC, NO_x - kg/day x 10^4, Pb - kg/day) Conventional cars with emission controls.

	1971	1975	1980			1985			1990			1995			2000		
Total Daily Distance Travelled (Km x 1000)	25834	27742	32259			35515			38336			40715			42894		
Percentage Electric Cars (Low and High Estimate)	0	0	0	0.9	1.5	0	3.1	5.8	0	6.1	13.8	0	12.0	27.2	0	23.7	53.8
Carbon Monoxide (CO)	139.5	149.8	133.7	132.5	131.7	110.3	106.9	103.9	92.7	87.1	79.9	98.5	86.7	71.7	103.8	79.1	47.5
Non Methane Hydrocarbons (NMHC)	24.8	15.0	12.9	12.8	12.7	10.2	9.8	9.6	8.1	7.6	6.9	8.6	7.5	6.5	9.0	6.9	4.15
Nitrogen Oxides (NO_x)	5.7	6.1	6.7	6.6	6.6	7.0	6.8	6.6	7.3	6.8	6.3	7.7	6.8	5.6	8.1	6.2	3.7
Lead (Pb)	2583	2774	2016	1998	1986	2220	2151	2091	2396	2250	2065	2545	2239	1853	2681	2046	1239

The Sydney Area Transport Study (SATS - 1971) estimated emissions and resultant concentrations of carbon monoxide, non-methane hydrocarbons and nitrogen oxides for 3.2 km square areas covering the Sydney region. These estimates did not anticipate the introduction of Electric Cars, but did allow for the effect of emission controls. These estimates were used to prepare Table 8.3 which illustrates the resultant concentrations for selected areas within the region in the year 2000.

TABLE 8.3: AVERAGE 8 HOUR CONCENTRATIONS FOR SELECTED 3.2 KILOMETRE SQUARE GRIDS - 2000

		SATS Predictions (0% Electric Cars, Max. Controlled Values)	24% Electric Cars	54% Electric Cars
CO ppm	CBD	15	12.3	8.9
NMHC ppm		1.5	1.2	0.9
NO_x ppm		0.3	0.25	0.18
CO ppm	Parra-matta	1.5	12.3	8.9
NMHC ppm		1.5	1.2	0.9
NO_x ppm		0.2	0.16	0.12
CO ppm	N.W. Suburban	5.0	4.1	2.95
NMHC ppm		0.50	0.4	0.3
NO_x ppm		0.05	0.04	0.03

(Ref.: SATS (1971), February, 1974)

Any such reduction in the emission of primary pollutants is likely to be beneficial in curtailing the production of secondary pollutants. There is an optimum ratio of NMHC to NO_x for oxidant formation and that control strategy should aim to remove the ratio as far as possible from the optimum. This can be attempted by reduction of either NMHC or NO_x levels. In Sydney emphasis has been placed on hydrocarbon control because the technology for hydrocarbon control is more advanced and generally cheaper than NO_x control. The precise degree of hydrocarbon control necessary for oxidant control cannot be calculated at this time but reductions of the order of 80% from base year (1971) levels are indicated. (Ref.: Iverach, D. "Planning for Oxidant Control in Sydney").

Even with a low rate of growth of motor vehicle distance travelled, of the order of 4% between 1980-1990, and with the most optimistic assumptions regarding emission control, hydrocarbon emissions will be reduced by only 65% from base year levels.

A more realistic projection is for an increase of about 18% in vehicle distance travelled in the Sydney region between 1980-1990. If all this arose from conventional cars there appears to be little hope of achieving even a 65 % reduction in hydrocarbons.

In fact, with existing technology and projections for vehicle numbers in the Sydney region, even the introduction of 54% Electric Cars by the year 2000 will not achieve the required 80% reduction in non-methane hydrocarbons. However, such a large population of Electric Cars would leave the goal attainable.

Further measures to reduce stationary source hydrocarbon emissions are planned. For example, member companies of the Australian Institute of Petroleum (AIP) are at present installing floating covers on 89 large storage tanks to prevent evaporative losses of hydrocarbons. AIP estimate that hydrocarbon losses will be reduced, as a result, by over 4,900 tonnes annually, or about 42% of hydrocarbons presently emitted from all facilities used by oil companies in storing, distributing and retailing in the Sydney/Wollongong/Newcastle regions.

In the petrol-handling stages after bulk storage, the annual loss of hydrocarbon vapours in the region is estimated to be in the order of 6,500 tonnes annually, principally from service station operations. If no controls are introduced to reduce this loss, and petrol consumed in urban New South Wales increases 45% up to 2000, this loss might be as high as 9,425 tonnes annually in the year 2000 without the introduction of Electric Cars.

Table 8.4 presents various estimates of petrol consumption up to the year 2000, given various rates of introduction of Electric Cars. Assuming that a 54% introduction of Electric Cars to the urban New South Wales region by 2000 would result in a similar decrease in the transport and transferral of hydrocarbons, the 9,425 tonne loss mentioned above could be reduced to 4,354 tonnes, and this refers only to evaporative loss. We would also expect reduced spillage losses.

8.4.3 NEW SOUTH WALES, URBAN

Table 8.5 lists the pollution emission rates for carbon monoxide, non-methane hydrocarbons and nitrogen oxides for urban New South Wales (as defined by this study). The figures are dominated by those of the Sydney Modified Region, but serve to describe the overall effect which can be expected in New South Wales.

8.4.4 AUSTRALIA

Similar data to those for urban New South Wales are shown in Table 8.6 for the whole of urban Australia. Again, the figures are dominated by those for Sydney and Melbourne. Air pollution resulting from these emissions is a major city phenomenon because of the concentration of emission sources which exist.

TABLE 8.4: PROJECTED PETROL CONSUMPTION IN CITY AREAS WITH AND WITHOUT ELECTRIC CARS - NO EMISSION CONTROLS

AREA	1971	1975	1980			1985			1990			1995			2000		
	% EC	% EC	% EC			% EC			% EC			% EC			% EC		
CBD (1)	0%	0%	0%	0.2%	1.5%	0%	3.1%	6.9%	0%	6.1%	13.8%	0%	12.0%	27.2%	0%	23.7%	53.8%
Petrol Consumption K/litres/daily	204	213	228	225	225	242	235	225	255	239	220	268	236	195	281	215	130
Total Daily Distance kms x 1000	1308.0	1366.2	1463.1			1553.0			1636.8			1717.6			1796.3		
SYDNEY REGION (2)	0%	0%	0%	.9%	1.5%	0%	3.1%	6.9%	0%	6.1%	13.8%	0%	12.0%	27.2%	0%	23.7%	53.8%
Petrol Consumption K/litres/daily	4,036	4,334	5,040	4,995	4,964	5,549	5,377	5,166	5,990	5,624	5,163	6,361	5,598	4,630	6,702	5,113	3,096
Total Daily Distance kms x 1000	25,834	27,742	32,259			35,515			38,336			40,715			42,894		
URBAN N.S.W. (6 cities) (3)	0%	0%	0%	.9%	1.5%	0%	3.1%	6.9%	0%	6.1%	13.8%	0%	12.0%	27.2%	0%	23.7%	53.8%
Petrol Consumption K/litres/daily	5,219	5,738	6,785	6,724	6,683	7,637	7,400	7,110	8,442	7,927	7,277	9,181	8,079	6,684	9,900	7,554	4,574
Total Daily Distance kms x 1000	33,403	36,725	43,427			48,876			54,031			58,760			63,362		

TABLE 8.5: PROJECTED AVERAGE DAILY POLLUTANT EMISSIONS FOR URBAN NEW SOUTH WALES (6 CITIES) WITH AND WITHOUT THE INTRODUCTION OF ELECTRIC CARS

(CO, NMHC, NO_x - kg/day x 10^4, Pb - kg/day) Conventional cars with emission controls.

	1971	1975	1980			1985			1990			1995			2000		
Total Daily Distance Travelled (km x 1000)	33403	36725	43427			48876			54031			58760			63362		
Percentage Electric Cars (Low and High Estimate)	0	0	0	0.9	1.5	0	3.1	6.9	0	6.1	13.8	0	12.0	27.2	0	23.7	53.8
Carbon Monoxide (CO)	180.4	198.3	180.2	178.6	177.5	151.8	147.1	141.3	130.7	122.8	112.7	142.2	125.1	103.5	153.3	117.0	70.8
Non Methane Hydrocarbons (NMHC)	18.0	19.8	17.4	17.2	17.1	14.0	13.6	13.0	11.3	10.6	9.7	12.3	10.8	8.9	13.3	10.1	6.1
Nitrogen Oxides (NO_x)	7.3	8.1	9.0	8.9	8.9	9.6	9.3	8.9	10.3	9.6	8.9	11.2	9.8	8.1	12.0	9.2	5.5
Lead (Pb)	3340	3672	2714	2690	2673	3055	2960	2844	3377	317	2911	3672	3232	2613	3960	3021	1829

In the Australia wide context, several other potential air pollution effects may occur, e.g. coal fired power stations.

For New South Wales, the increased energy consumption due to use of Electric Cars in the year 2000 is unlikely to be greater than 4,500 Gwh. This represents a 7.1% increase on the planned capacity for the year 2000. Assuming this increase will be derived from the combustion of coal, the major air pollutants will be particulates, nitrogen, oxides and sulphur dioxides.

A 7.1% increase in coal consumption is likely to result in a much smaller percentage increase in the emission of particulates due to modern control technology.

By contrast, most of the sulphur contained in coal combines with oxygen in the combustion process and is emitted to the atmosphere. Assuming an average sulphur content of New South Wales coal to be 0.6% by weight and that all this sulphur is released to the atmosphere in the form of SO_2, the combustion of 2.25 million tonnes of coal would release 267,000 tonnes of SO_2 to the atmosphere annually, and assuming that no attempt to arrest the emissions of SO_2 will be introduced before the year 2000. Pilot schemes, using wet scrubbers to remove SO_2 are being introduced in the U.S.A. at present, so these emissions could be reduced given technological advances in pollution control.

Other pollutants likely to be released by coal, oil or gas-fired electric generating stations are nitrogen oxides and carbon dioxide. Table 8.6 below shows a comparison of the relative amounts of some pollutants which would be emitted on account of an Electric Car and a conventional car.

TABLE 8.6: OVERALL AIR POLLUTION EMISSIONS.

ELECTRIC versus CONVENTIONAL CAR SYSTEMS

kg/ car/year.

Air Pollutants	Electric Cars	Conventional Cars.
Total particulates	5.23	2.19
SO_2	36.83	10.93
NO_x	18.23	28.49
CO	0.83	136.08
HC	0.64	30.26
CO_2	6.81	9.77

Ref: Stenhouse 1975.

In the above table, it should be noted that emissions from electric power stations usually occur in country areas away from major centres of population as point sources subject to control. Disposal and dispersal are readily chieved at these locations without serious effect to large populations. Emissions from conventional cars occur in major urban areas in uncontrolled circumstances, so that adverse effects on health and visibility are more likely.

A further potential source of air pollution would occur with the increased lead refining and treatment required for battery manufacture, the major pollutants again being sulphur dioxide and particulate matter. This possible increase in air pollution due to increased lead use may well be lessened by high recycling rates.

At present, a high percentage of battery lead is recycled. Data published in 1969 by the Battery Council International showed a 90 % effective recycling rate for lead in the U.S.A.

TABLE 8.7: PROJECTED POLLUTANT EMISSIONS FOR AUSTRALIAN CITIES, WITH AND WITHOUT THE INTRODUCTION OF ELECTRIC CARS

(CO, NMHC, NO_x - kg/day x 10^4, Pb - kg/day) Conventional cars with emission controls.

	1971	1975	1980			1985			1990			1995			2000		
Total Daily Distance Travelled (km x 1000)	85446	94447	111852			125178			137899			148989			159906		
Percentage Electric Cars (Low and High Estimate)	0	0	0	0.9	1.5	0	3.1	5.8	0	6.1	13.8	0	12.0	27.2	0	23.7	53.8
Carbon Monoxide (CO)	463.8	510.0	463.6	459.4	456.6	388.8	376.8	366.2	333.5	313.3	287.4	360.4	317.3	262.4	387.0	294.9	177.1
Non Methane hydrocarbons (NMHC)	46.4	51.0	44.7	44.4	44.0	36.0	34.5	33.8	29.1	27.3	24.8	31.5	27.4	23.8	33.6	25.8	15.5
Nitrogen Oxides (NO_x)	19.6	20.8	23.2	22.9	22.8	24.7	24.0	23.3	26.3	24.5	22.7	28.2	24.9	20.5	30.2	23.1	13.8
Lead (Pb) Greater than	8545	9445	6991	6928	6886	7823	7581	7369	8619	8093	7429	9312	8194	6779	9994	7625	4617

Allowing for 0.25 tonnes of lead per vehicle, and an estimated Electric Car population of 970,000 in the Modified Sydney Region by the year 2000, the total lead requirement in service would be 242,500 tonnes. For urban New South Wales the requirement would be 370,400 tonnes and for urban Australia as a whole, 934,700 tonnes. By comparison, Australia's total identified lead resources in 1976 were estimated at 26.4 million tonnes.

Assuming an average battery life of three years and a recycling rate of 90%, Australia would suffer an annual loss to the environment of approximately 31,150 tonnes. This amount can be compared to losses to the atmosphere, as well dispersed fine particles, of approximately 7,000 tonnes p.a. in 1975 rising to approximately 14,000 tonnes p.a. by the year 2000 if present trends continue, and if there are no Electric Cars.

If Electric Cars penetrate the market at the high rate, the annual quantity of lead dispersed in finely divided form to the atmosphere in the year 2000 is likely to be comparable to the current quantity.

8.5 WATER POLLUTION

The replacement of conventional cars by Electric Cars will have some effect on the type and degree of water pollution, resulting from manufacture, service and use of vehicles. At the present time cars cause pollution in the following ways:

- pollution from mining and processing of raw materials,
- pollution from manufacturing processes,
- spillage and run-off from the fuel processing and distribution industry,
- spillage from the service industry, washing and disposal of spent lubrication.

Electric Cars would provide similar sources of water pollutants.

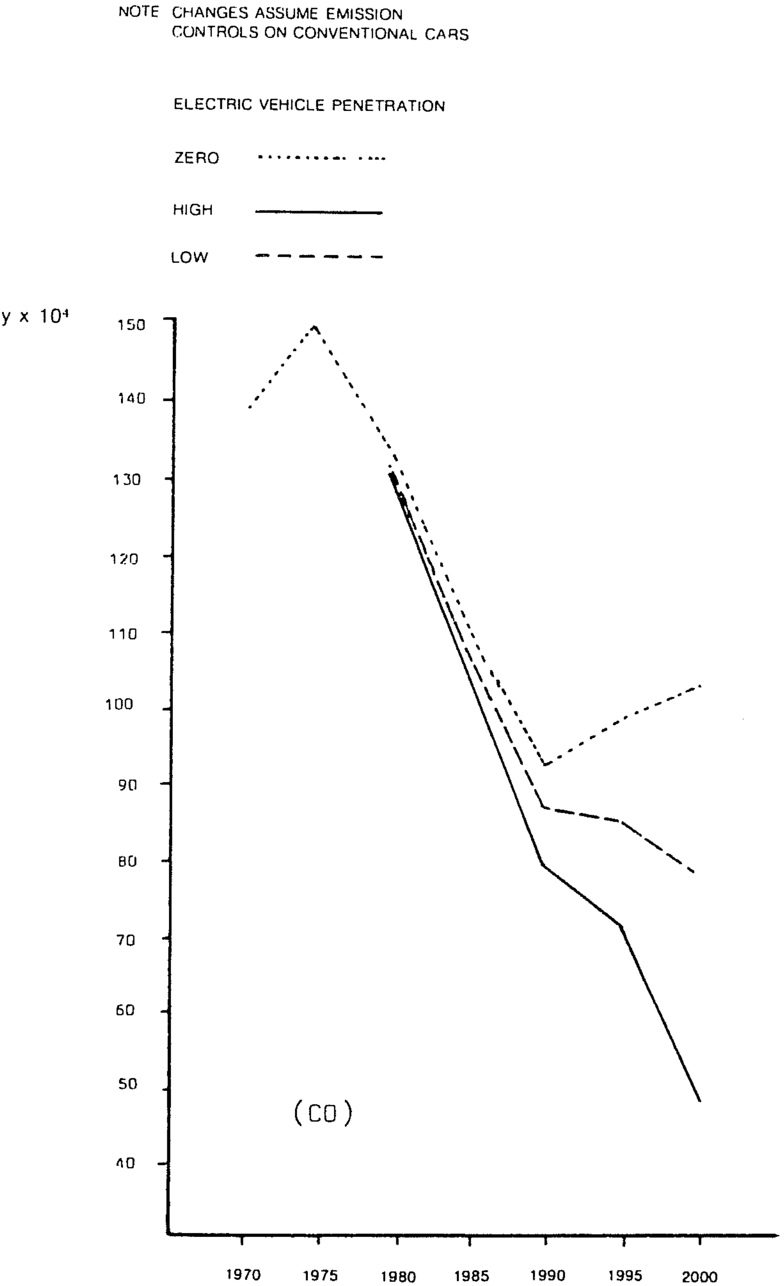


Fig 8.1 CHANGE IN EMISSION RATE CARBON MONOXIDE

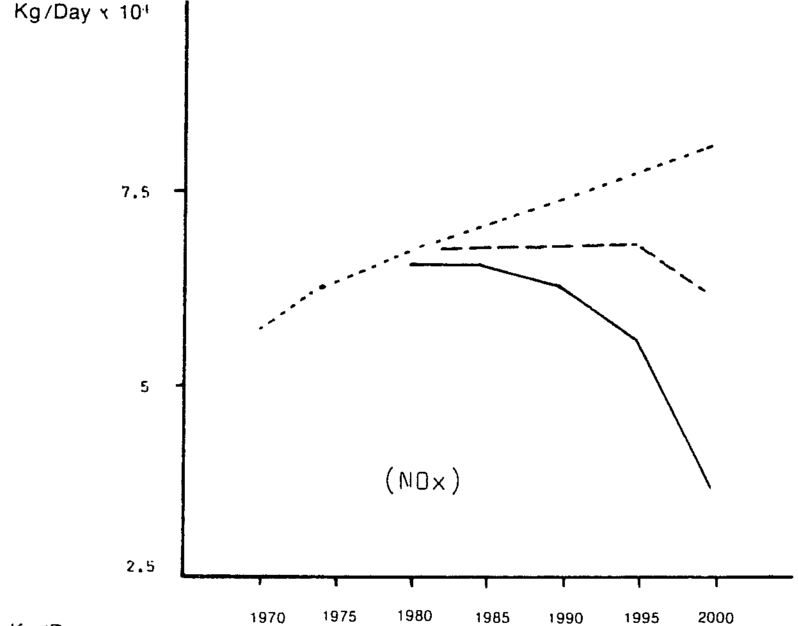


Fig 8.3 CHANGE IN EMISSION RATE NITROGEN OXIDES

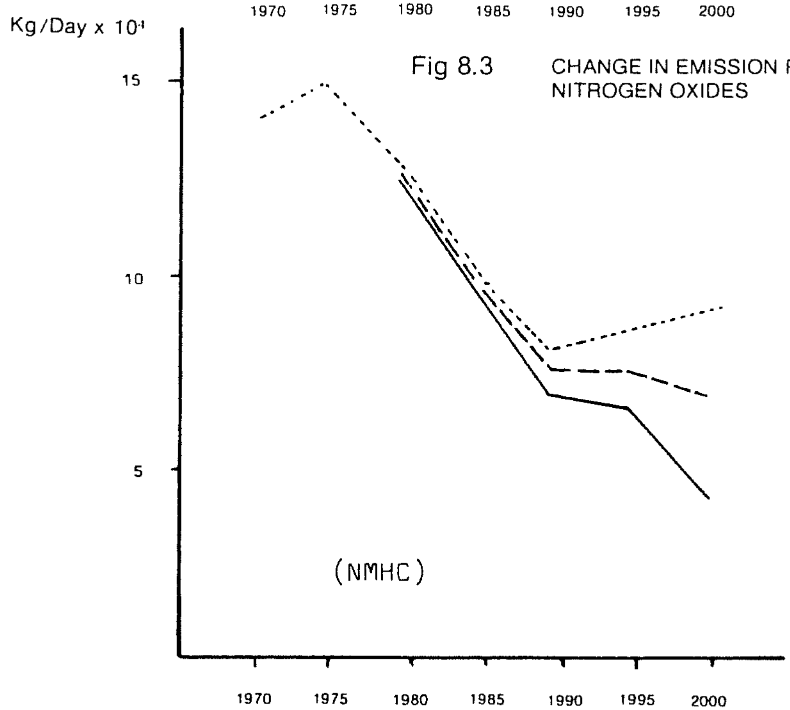


Fig 8.2 CHANGE IN EMISSION RATE NON-METHANE HYDROCARBONS

Mining, processing and manufacturing sources of pollution are not likely to be very different from those presently existing. Pollution of water from the fuel supply industry would be greatly reduced since only lubricants and similar petroleum based products would be required. In the same way spillage losses from the services industry, wastage from car washing and lubricant disposal will be much less than for conventional cars.

These gains in pollution control will be offset by the need to dispose of considerable quantities of spent electrolyte. Unless economic reprocessing methods can be developed, this liquid disposal problem could become the most significant adverse effect arising from the introduction of Electric Cars.

8.6 NOISE POLLUTION

Concern over increasing noise levels in communities is rising, as evidenced in the recent legislation passed in New South Wales.

The major sources of noise emanating from conventional cars are:

- engine noise, caused by combustion and valve, pump and fan operation,
- exhaust system noise,
- transmission system noise,
- braking noise,
- vibration and resonances within chassis and structure,
- coasting noise, caused by tyre/road contact and aerodynamic effects,
- door slamming and horns.

Conventional cars are noisy because firstly , the engine idles while the vehicle is not in motion, and secondly because the engine noise increases with power. Other major noise sources increase with speed. The high power often experienced at low speeds during acceleration makes low speed operation inherently noisy.

The effects of traffic noise generally range from annoyance to interference with an activity. Noise from individual cars is probably not a significant cause of danger to health, but aggregated traffic noise may approach danger levels.

Typical urban noise patterns show a residual or background noise level that is low at night and increases in the morning to a level that holds throughout the day and early evening. Superimposed upon the residual level are many random instances of significant noise intrusions, the most prevalent being caused by aircraft and motor vehicles. For example, the noise from a rapidly accelerating vehicle is distinct from the general background noise generated by continuous traffic.

The significance of the effect of Electric Cars on community noise levels will depend on their inherent noise generation relative to the conventional vehicles they displace, and the relative usage they obtain.

A study by Vargovick of Ford Motor Co., showed that for a lower powered car (the most likely candidate to be replaced by Electric Cars) cruising at 60 kph on a smooth concrete surface roughly half the noise occurs from tyre/road contact. Exhaust and engine noise contribute the remainder. In cases of heavy acceleration, exhaust noise was dominant.

Under traffic conditions, with speeds likely to be near 60 kph, general traffic noice would be expected to be the result of frequent acceleration, with exhaust noice dominant. Electric Cars will not have exhaust noises but tyre/road, and drive train noise sources which will remain. The electric motors may be a significant noise source due to bearing noise, friction, airflow or magnetic factors, but these will be less than noise from reciprocating engines.

The 1972 Urban Vehicle Design Competition compared noise emissions (measured at 7.6 metres sideline distances) from the Cornell Electric Car and 35 other experimental cars employing variously fuelled internal combustion engines. The Electric Car was shown to be 12 dB quieter in terms of overall sound pressure level. It was measured at 64 dB while the

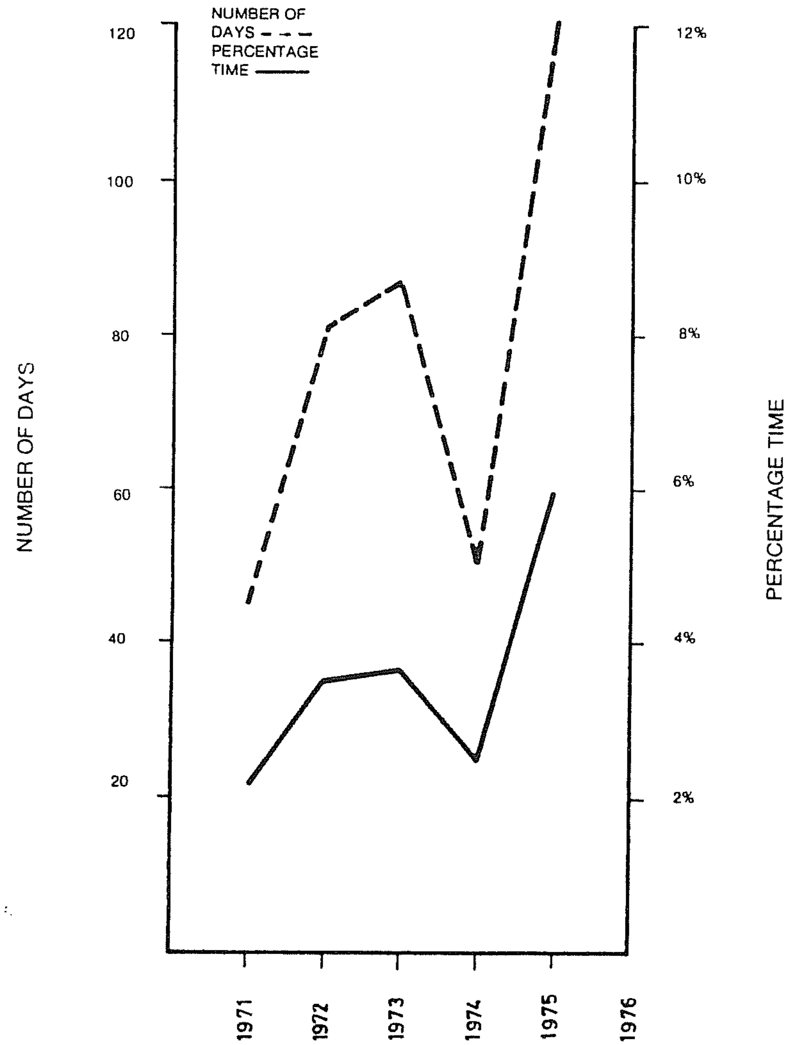


Fig 8.4 EXCEEDANCES, WHO ONE HOUR GOALS FOR OZONE, LIDCOMBE. (FROM STATE POLLUTION CONTROL COMMISSION N.S.W. ANNUAL REPORT, JUNE 1976)

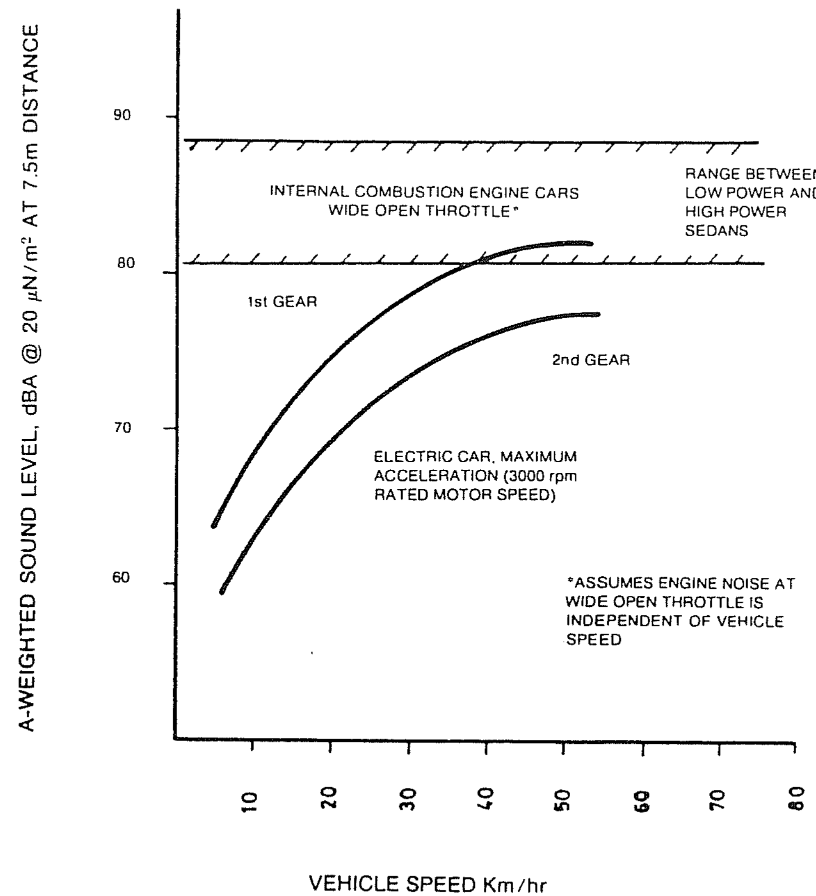


Fig. 8.5 COMPARISON OF ELECTRIC AND CONVENTIONAL CAR NOISE. (MAXIMUM ACCELERATION AT LOW SPEEDS) (FROM HAMILTON, 1974)

average of the other 35 vehicles was 76.3 dB. Measurements were taken at a cruise condition of 50 kph.

The total effect will depend on the number of Electric Cars in the vehicle population. It also appears they will not be capable of replacing diesel trucks, for example, which in many instances make significant contributions to noise levels, particularly of an intrusive nature. Electric Cars may not appeal to motorists seeking 'sporty' performance vehicles which are also blamed for noise intrusions.

8.7 SAFETY

There is a lack of experience with the operation of Electric Cars and therefore no clear understanding of their effects on the safety of their occupants and other road users.

Their potential impacts can be divided into:

- Pre-accident factors,
- During accident factors, and
- Post-accident factors.

8.7.1 PRE-ACCIDENT FACTORS

Pre-accident factors are those which might make Electric Cars more or less likely to be involved in an accident.

- A vehicle operating on 60-100 volts introduces the risk of insulation failures leading to shocks and fires.

- The batteries will contain considerable quantities of acid constituting a potential hazard.

- It is likely they will have a low centre of gravity, meaning lower weight transference in braking and cornering, and thus implicitly an improvement in safety.

- The high tare weight of Electric Cars and reduced variation in gross running weight should lead to a reduction in head lamp aiming variation.

- The low noise level associated with Electric Cars is a potential safety threat because no audible indication is given as to when the vehicle will start from rest, representing a hazard particularly to pedestrians.

- Acceleration and hill-climbing performance of Electric Cars is likelv to be less than that of conventional cars, introducing into the traffic stream some slower vehicles. There is some evidence (Cosgrove 1975) that frequent speed changes caused by slower vehicles are conducive to accidents. This impact, of course, would diminish if large numbers of Electric Cars appeared on the roads, and also if preferential lanes were provided on roads.

- The general design of an Electric Car could be substantially different from a conventional car; possible redesign aspects, such as simplified foot-pedal arrangements and improved field of view, would aid safety. Any new Electric Car would have to satisfy the Australian Design Rules for Motor Vehicle Safety.

8.7.2 DURING-ACCIDENT FACTORS

Electric Cars are likely to have heavy central cores containing the batteries, but in line with modern trends in car design will probably be constructed of light materials. This may provide problems for accident shock absorbtion and maintenance of structural integrity.

There is scope for innovative design of shape and materials which could lead to safer interior design and an external shape less likely to injure pedestrians or to penetrate another vehicle on side impact.

8.7.3 POST-ACCIDENT FACTORS

Although the larger battery load raises the potential for hazards from spilled electrolyte and electric shock, provision of automatic circuit breakers and isolation of the battery pack in a central tunnel in the Electric Car reduces post-accident risk factors to a level at most no greater than present risks of fire from petrol.

The use of exotic batteries such as the sodium-sulphur unit, which must operate at 400°C, would provide extra risk. Care must be taken in introducing such power units that the hazards involved in collisions between Electric Cars and conventional cars, occuring as a result of chemical reactions, are no greater than might occur during collisions between similar types of cars.

8.8 CONCLUSIONS

The major environmental effects of the progressive introduction of Electric Cars into the Australian market will be confined to the urban areas, particularly Sydney and Melbourne. In these locations the principal effects will be reduction in the air pollution potential and in noise generated by major traffic flows. However, these effects will be in the nature of containing the existing problems rather than their marked reduction from existing levels. This comes about because even with optimistic estimates of the rate of introduction of Electric Cars, there will be more internal combustion-engined vehicles operating in the year 2000 than at present. This fact also means that other problems such as industry and employment dislocation are not likely, rather a period of reduced or no growth will occur.

On presently foreseen technology Electric Cars will not be suitable for long distance travel or haulage, so that large numbers will not be used in the smaller cities and towns of Australia. Some related effects on air and water pollution may arise from decentralised car manufacture or electric power generation. These will be isolated and capable of control by existing technology so that non-urban effects will be small.

3.1 NRMA - N.S.W.
New Car Characteristics and Performance Tests.

3.2 Department of Economic Development, South Australia
'The Status of the Flinders University Electric Vehicle Development'
A Report to the Director General of Transport, South Australia, May 1977.

3.3 Parliamentary Paper No. 221 - 1974
Electric Cars - Report by B.T.E., July 1974.

3.4 Darke, B.C.
Electric Vehicles: An Overview
Electric Cars, Their Future Use in Urban Transport
B.T.E. and A.E.V.A. Conference, Canberra, February 1975.

3.5 Allan, J.R.
Developments in Battery Cars World Wide
Electric Cars, Their Future Use in Urban Transport
B.T.E. and A.E.V.A. Conference, Canberra, February 1975.

3.6 Pocobello, M.A. and Armstrong, D.A.
The Copper Electric Town Car
Fourth International Electric Vehicle Symposium, Dusseldorf, 1976.

3.7 Friedman, D., Andon, J. and Hamilton, W.F.
Characterisation of Battery Electric Cars for 1980-2000
Task Report 1: The Impact of Future Use of Electric Cars in The Los Angeles Area.

3.8 Society of Automotive Engineers of Japan, Inc. and Agency of Industrial Science and Technology, M.I.T.I., Japan
Research and Development of Electric Vehicles in Japan, 1977.

4.1 Australian Bureau of Statistics
Motor Vehicle Registrations, 1975 76
Reference No. 14.1, Canberra.

4.2 Parliamentary Paper No. 221, 1974
Electric Cars, Report by B.T.E., July 1974.

4.3 Reid, G.K.
Potential Market and Demand for Electric Vehicles
Electric Cars, Their Future Use in Urban Transport
B.T.E. and A.E.V.A. Conference, Canberra, February 1975.

4.4 Sydney Area Transportation Study,
Volume 1, Base Year (1971) Data Report: January 1974.

4.5 NRMA - N.S.W.
New Car Characteristics and Performance Tests.

4.6 Sydney Area Transportation Study
Volume 2, Travel Model Development and Forecasts: February 1974.

4.7 The Council of the City of Sydney
City of Sydney Parking Policy and Control Code for New Development
July 20, 1971.

4.8 The Council of the City of Sydney
Action Plan No. 4,
Car Parking Stations on the Western Perimeter of the Central Business District (CBD), July 3, 1972.

4.9 The Council of the City of Sydney
City of Sydney Strategic Plan, The 1974-77 Statement of Objectives, Policies and Action Priorities, December 2, 1974.

4.10 Development Planning and Research Associates
Chatswood Centre Basic Data Report, January 1972.

4.11 Development Planning and Research Associates
Chatswood Centre Redevelopment and Transportation Study, Final Report
September 1972.

4.12 N.S.W. Planning and Environment Commission
"Population Projections for New South Wales, 1975-2000"
Technical Bulletin No. 8, August 1976.

4.13 Arnot, R.A.
"Research Papers: 2" Population Resources
A National Spatial Ordering Concept Plan
Town and Country Planning Board, Melbourne, Victoria, 1973.

6.1 Electricity Supply Association of Australia
Annual Reports 1963-64 to 1975-76 inclusive.

6.2 Electricity Authority of N.S.W.
Annual Report 1975-76.

6.3 Bureau of Transport Economics
Electric Cars, Their Future Use in Urban Transport
B.T.E. and A.E.V.A. Conference, Canberra, February 1975.

6.4 Institution of Engineers, Australia
National Conference Publication No. 75/8
Conference on Electrical Transportation, Adelaide, October 1975.

6.5 Parliamentary Paper No. 221
Electric Cars, Report by Bureau of Transport Economics, July 1974.

6.6 Sjovold, A.J.
Parametric Energy, Resource and Noise Impacts of Electric Cars in Los Angeles, Task Report 8, The Impact of Future Use of Electric Cars in the Los Angeles Region, General Research Corp., L.A.

6.7 Hotopp, R. and Klein, F.
Charging Equipment for Electric Road Vehicles:
Basic Requirement as Seen by the Utilities with Special Emphasis on Harmonics
4th International Electric Vehicle Symposium, Dusseldorf, Aug.-Sept. 1976.

6.8 Griffin, J.T.
The Effect of Recharging Rate on the Daily Range of An Electrical Van
4th International Electric Vehicle Symposium, Dusseldorf, Aug.-Sept. 1976.

6.9 Society of Automotive Engineers of Japan, Inc.
Research and Development of Electrical Vehicles in Japan, 1977.

6.10 Gallot, J.
Development of Electrical Vehicles and Energy Supply for Them in Countries of the E.E.C.
4th International Electric Vehicle Symposium, Dusseldorf, Aug.-Sept. 1976.

6.11 Elliot, M.B.
Looking Ahead to Sydney's Future Electricity Needs
'The Contactor', Vol. 42, No. 3, Nov. 1976
Sydney County Council.

6.12 Kniel, R.
Economics of Ripple Control Installations for Consumer Load Control
I.E.E. Symposium on Metering Tariffs.

7.1 Institution of Engineers, Aust.
Energy Use and Conservation in Industry
Report of Working Party 10, National Conference on Energy
Publication No. 77/6, Canberra, July 1977.

7.2 Chapman, R.G.
Electricity Generation and Supply
Electric Cars, Their Future Use in Urban Transport
B.T.E. and A.E.V.A. Conference, Canberra, February 1975.

7.3 Parliamentary Paper No. 221
Electric Cars, B.T.E. Report, July 1974.

7.4 Thomas, M.H.
Energy Utilization in Industry
Institute of Fuel, Sydney, 3rd August, 1977.

8.1 Australian Institute of Petroleum Ltd. 1976
Oil and Australia 1976.

8.2 Cosgrove, K.J. 1975
Safety of Electric Cars.
Electric Cars, Their Future Use in Urban Transport
B.T.E. and A.E.V.A. Conference, Canberra, February 1975.

8.3 Daly, N.J. and Steel, L.P., 1975
The Nature of the Environmental Problems
Electric Cars, Their Future Use in Urban Transport
B.T.E. and A.E.V.A. Conference, Canberra, February 1975.

8.4 Hamilton, W.F. (Ed.) 1974
Air Quality Impacts of Electric Cars in Los Angeles
Task Report 7
The Impact of Future Use of Electric Cars in the Los Angeles Region
General Research Corp., L.A.

8.5 Hamilton, W.F. (Ed.) 1974
Parametric Energy, Resource and Noise Impacts of Electric Cars in Los Angeles
Task Report 8
The Impact of Future Use of Electric Cars in the Los Angeles Region
General Research Corp., L.A.

8.6 Iverach, D. 1975
Planning for Oxidant Control in Sydney
Int. Clean Air Conf., Rotorua, New Zealand, February 1975.

8.7 Iverach, D., Mongan, T.R., Nielsen, N.J. and Formby, J.R., 1976
Vehicle Related Air Pollution In Sydney
JAPCA 26(1); 39-44.

8.8 SPCC N.S.W.
Air Pollution from Motor Vehicles.

8.9 Stenhouse, K.J., 1975
The Environmental Implications of Electric Vehicles
Electric Cars, Their Future Use in Urban Transport
B.T.E. and A.E.V.A. Conference, Canberra, February 1975.

8.10 Sydney Area Transportation Study
Volume 2, Travel Mode and Development Forecasts, February 1974.

ACKNOWLEDGEMENTS

Australian Bureau of Statistics.

Australian Institute of Petroleum Ltd.

Chloride Batteries Australia Ltd.

Chrysler Australia Ltd.

Department of Economic Development, South Australia.

Department of Overseas Trade, Canberra.

Electricity Commission of New South Wales.

Electricity Trust of South Australia.

Energy Authority of New South Wales.

Flinder's University, South Australia.

Japanese Association of Consulting Engineers.

MacKellar County Council.

National Roads and Motorists Association.

Prospect County Council.

St. George County Council.

State Electricity Commission of Queensland.

State Electricity Commission of Victoria.

State Electricity Commission of Western Australia.

Sydney Area Transportation Study.

Sydney City Council.

Sydney County Council.

Town and Country Planning Board, Melbourne.

Volvo Australia Pty. Ltd.

Western Australian Government Trade Representative.