Electric Power-Assisted Bicycles Reduce Oil Dependence and Enhance the Mobility of the Elderly

Alan A. Parker
Alan Parker Design, Melbourne.

1 Introduction

[PAB is an abbreviation for Power Assisted Bicycle]

In 2005 11 million electric power assisted bicycles (PABs) were produced, mostly in Asia: 10 million in China and 210,000 in Japan. 150,000 were sold in Europe and 100,000 in the US. This is the fastest growing powered vehicle industry in the world. It is arguably the most innovative, ecologically sustainable transport development in the world today. Today the use of PABs is reducing air pollution, enhancing the mobility of the elderly and lame and, when used by the able bodied, are proving a practical substitute for many car trips of less than 10 km. This paper describes new innovations in the design of electrically powered PABs and their future potential as frugal users of DC electricity generated by roof mounted solar cells.

The post World War 2 petrol fueled PABs with their polluting two-stroke internal combustion engines were very economical for consumers., as are today's electrically powered PABs. In most countries they were and still are legally classed as bicycles, there are no compulsory registration and insurance fees and they have very low running costs. The difference in quality between the 1950s petrol fueled PABs and “state of the art“ Yamaha and Panasonic electric PABs is like the difference between a post war Holden car and a fuel saving petrol/electric hybrid car or a Mercedes' Benz A class diesel. Today many electric PABs are precision engineered consumer products that are far safer to ride and do not produce polluting emissions.

There were millions of petrol fueled PABs in post war Europe and until very recently millions in China. However most of them were a simple add on fitted to a heavy duty bicycle: motors that were bolted on to the frame or handlebars with small wheels driving on a tyre, or a replacement back wheel with a motorised hub. Today the mass use of these PABs in large cities is no longer desirable due to the exhaust fumes from the two-stroke engine and is only referred to here in a historical context to highlight new innovations. This is why the countries of the European Union, the U.S. Canada and New Zealand have recently upgraded their transport legislation to encourage the use of electric bicycles and to allow the manufacture and import of the safest PABs. (Brusch 2003)

Australian legislation discourages PAB use and the 35-year-old power output limit of 200 watts denies Australian consumers the right to buy the most innovative and safest Japanese electric bicycles. This paper advocates the need to change that legislation - which is a restriction on free trade - and describes the innovative trends in electric bicycle technology that have evolved in Japan and China. (Rose and Cock 2003)

1.1 Introducing Japanese electric PABs

These PABs weigh only a few kilograms more than bicycles providing between 200 and 250 watts of power assistance from an electric motor with a lightweight rechargeable battery. (See Figure 1 which shows a state-of-the-art version which has electronically controlled power assistance with no throttle once an ignition key is inserted.) They are designed to maintain a safe cruising speed and to halve the effort required to get from A to B on an average trip. It is powered on the flat by pedals but power assist cuts in when starting off, climbing hills, overcoming strong wind resistance or when carrying a heavy load.

The crucial safety feature is automatic speed limitation which fades out from 20 to 25 km per hour. Their silent operation and lack of emissions makes them very suitable for use on both shared footways and local residential streets, especially as residential streets have 30 kph limits in Japan. Since 1997 there has been a growing range of electric PABs on the world market with sophisticated electronic controls and there are around 130 companies producing them world wide. Some of these companies use Japanese made drive units and electronic control systems.

Figure 1 Sanyo electric PAB: 250 watt rated output Ni MH battery price today around a $1000. Note the small battery behind riders left foot.

The batteries are designed to provide around 30 km of travel before a recharge. Most Japanese PABs use Lithium Ion or Ni -Mho rechargeable batteries. Since 1994 around two million people have bought Japanese PABs, mostly elderly Japanese. In 2005 technical improvements such as lightweight alloy construction and Ion Lithium batteries have reduced

their weight. They are becoming even more popular and more convenient to use by the over 50's. (Cycle Press 2006B)

In Japan some companies are producing PABs with solar PV battery rechargers for public and domestic use. The ecological footprint of tomorrow's solar powered PAB is so small it could enhance mobility without irreparable environmental damage and resource depletion.

There are 12 companies manufacturing PABs and annual production has been around 210,000 for the last few years. The Japanese use bicycles as a means of transport and to access public transport and Bicycles sales are also steady at around 10 million a year. (See Figure 3) Thus providing a future market for the sale of electric bicycles as their population ages.

1.2 Introducing Chinese electric PABs

Chinese PABs have power outputs between 180 watts and 350 watts and are throttle controlled. From 1997 to Dec 2005 the Chinese produced 21 million electric bicycles and the quality of their product improved every year. In China in 2004 17 of the 49 Chinese PAB companies each produced more than 66,000 that year. Indeed electric PAB production in 2005 exceeded 10 million. Today many, but certainly not all, Chinese designed PABs are much cheaper, simpler and heavier and less reliable than Japanese PABs. However, more and more PABs are being produced in China that are designed in the European Union, the US, Canada and Japan. High quality throttle controlled and Japanese style PABs will be exported all over the world. In this respect electric bike manufacture is like Chinese car manufacture. (Cycle Press 2006A)

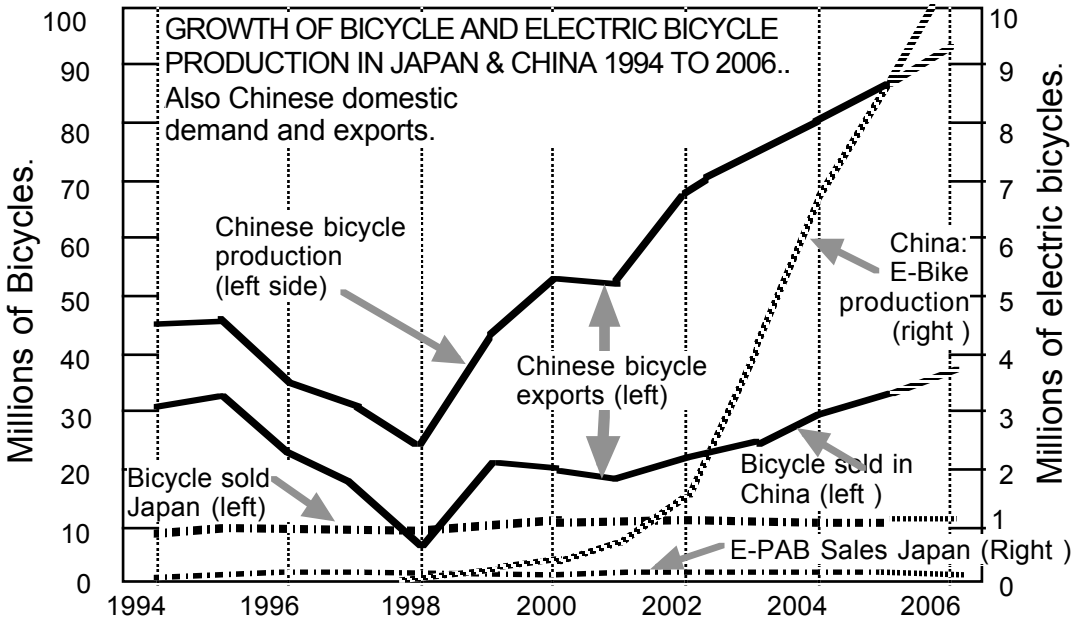


Figure 2

China has ten of the world's most polluted mega-cities in some of which the use of mopeds and petrol powered PABs has already been banned. By July 2000 37 cities had stopped issuing motorcycle licenses and from 2003 all new motorcycles made in China have been legally required to have much cleaner engines. The Chinese National Environment Protection Agency has issued regulations that encourage Chinese industry to produce electric PABs to

satisfy the growth in demand and to replace existing petrol powered PABs and mopeds.

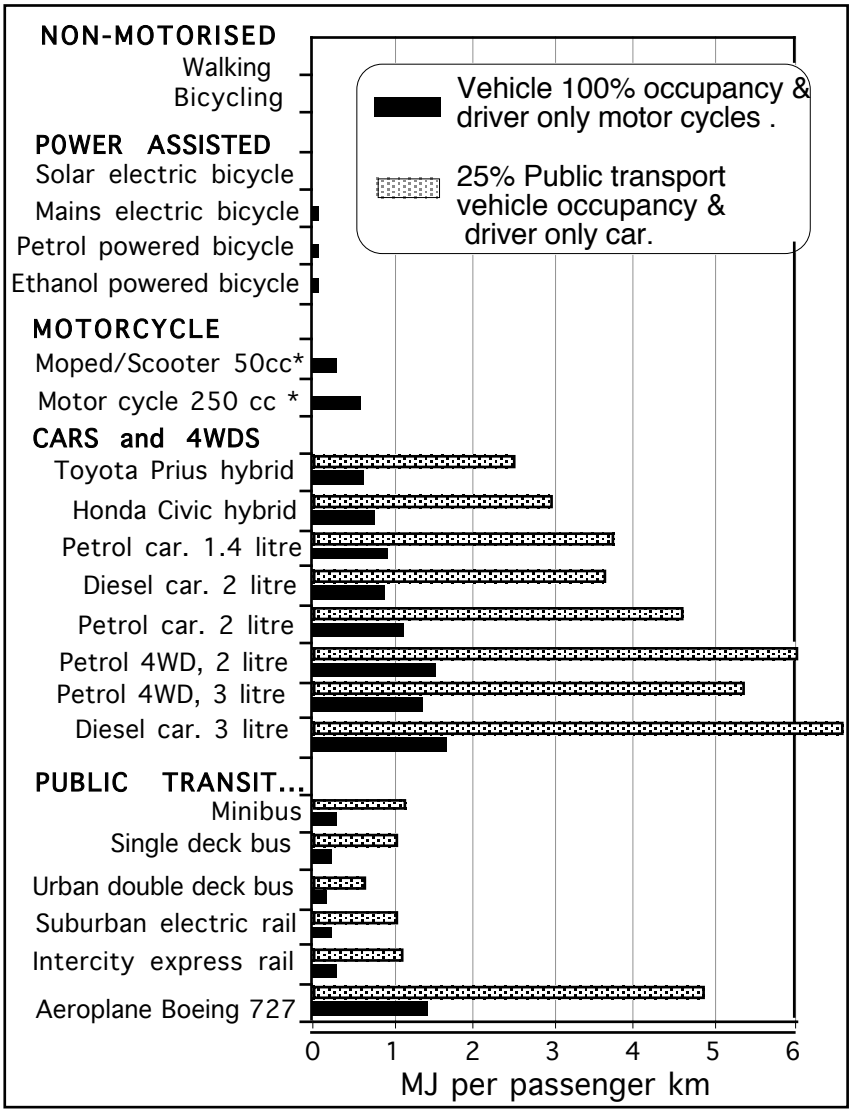
Within the next five years it is likely that predicted increases in world crude oil prices and decline in Chinese indigenous oil production will handicap China's economic growth. This will result in the national government taking strong measures to maintain high levels of bicycle and electric PAB use while restrictions on the use and parking of petrol and diesel powered vehicles in urban areas will be forthcoming. Chinese electricity production from coal is the major cause of air pollution and one of the worlds major producers of solar cells has many new factories planned so it seems logical that the mass use of solar powered PABs in cities will be the next sustainable transport innovation.

Figure 3

Showing energy use per passenger km travelled by various forms of transport including the bicycle, the electric bicycle, public transport, hybrid cars, SUVs and a Boeing 727

Showing that the 2006 electric bicycle is the most energy efficient form of motorised transport on the planet that can help the human race cope with the end of the age of cheap oil.

Showing that the next generation of solar electric bicycles will be more important because they can replace most car trips of less than 10 km saving petrol ,



2 Future markets for PABs in Australia

The Australian transport sector is grossly oil dependent and responsible for 76% of national oil consumption. This has to be reduced before world oil production peaks as it poses a very serious threat to Australia's future economy and as a consequence the well being of all Australians. (Parker 2005) The mass use of bicycles and electric bicycles can be used to substitute for short car trips of less than 10 km and to access public transport so as to substitute for longer intercity and urban car trips. See Figure 3 which shows the energy

efficiency of electric PABs compared to other forms of transport in Australia.

Tomorrows PABs, coupled with roof mounted solar PV panels for recharging, will be mass-produced in China. The opportunity to sell imported or assembled PABs using batteries recharged by Australian made roof mounted solar cells could reduce oil consumption. Unfortunately, the Australian government and its agencies have ignored the need to prudently risk manage the growth of oil dependence. The encouragement of the mass use of bicycles and electric bicycles with the provision of bicycle infrastructure in the form of continuous network of bike lanes, shared footways and back street bike routes has very low priority. (Parker 2006)

A 200-watt PAB would be underpowered for Australians over 55, who are much heavier than the elderly females who make up the majority of Japanese users. A 200-watt PAB could not cope with many (60%) of the overweight and obese males on the steeper slopes of Australian cities. It is concluded that PABs with up to 300 watts output need to be classified as bicycles in Australia, as they are in New Zealand. (Parker 1995, 2004)

In addition there are around, 2.5 million Australians afflicted with some form of arthritis and a similar number with unspecified back trouble for whom using an electric bicycle could be helpful. Many people are limited in where they can go because walking is painful. Electric PABs are ideally suited to the needs of the larger number of partially disabled people or the elderly who may not have access to motor vehicles or those with ailments that stop them from driving cars. To enhance the mobility of the lame and elderly fully powered bikes with up 600-watt output should be allowed, as they are in NZ.

4. Petrol powered PAB product development since 1900

The Petrol fuelled PAB evolved from the development of the earliest European and British motorcycles, which had pedal start engines and were very slow. The oldest relatives to the modern were the 1900 Singer motorised back wheels that were fitted into heavy-duty bicycles which were popular for touring before 1906 but their use declined after World War 1.

In 1912 BSA in the UK marketed the Auto wheel a twin cylinder motorised back wheel that was fitted to a bicycle. It was much cheaper than a motor cycle and use 3 litres of petrol per 100 km so it was very economical and became very popular. It had a power output of 743 watts and would still be classified as a bicycle in the USA which has a 750 watt limit. (Deane and Crichton 1982)

After the First World War there was great demand for cheap transport and that was mostly satisfied by motor cycles, motor scooters and specially designed mopeds. The least promising form of power assistance for bicycles came in 1929 at a time when Germany had great interest in rocket propelled vehicles. Three cyclists had a race with rocket propelled bicycles on the Berlin Olympic cycling race track. Two later a Herr Richter almost blew himself up when he and the 12 solid fuel rockets mounted over the back wheel performed so well that at 88 km per hour his bicycle became unstable and he landed in a ditch.

By 1932 motor cycles were fast and powerfull and the world speed record reached 244 km per hour. And motorcycling became a passion for well off young male. However this was the time of the great depression and the demand for cheap transport was mostly satisfied by light motor cycles, mopeds and bicycles. After World War 2 the economic necessities of post war reconstruction in Europe encouraged the production of lighter weight PABs and mopeds as an economical means of mass transport.

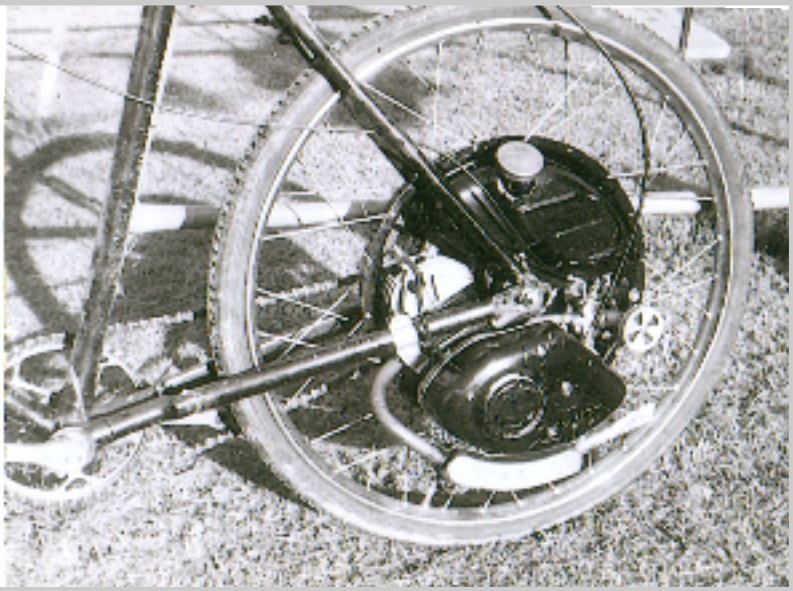
In war ravaged Japan in 1948 Soichiro Honda, working out of a wooden shed, bought 500 war surplus engines and fitted them to bicycle together with army surplus water bottles as

fuel tanks. They sold well as fuel was rationed. By the time army surplus parts ran out Honda was producing a 750 watt two stroke powered assisted bicycle which was expected to run on a variety of liquid fuels and was in much need of pedalling assistance. However by 1953 Honda Company had produced 30,000 light weight motorcycles.(Deane and Crichton 1982)

Figure 4

The BSA "Cyclemaster" motorised back wheel had a 32 cc cast iron engine built into a 27 x 1.5 inch rear bicycle wheel. It had a fuel consumption of 1.1 litres per 100 km on long runs, delivering its maximum power output at low speeds going uphill.

It was safer than many PABs of its time because it powered the back wheel and not the tire or the front wheel as on many European machines.



The British PAB, the 1952 BSA, was exported to Australia and N.Z. (See Figure 4). The 1952 BSA was typical of the models available which were designed to be bolted onto or into an existing bicycle frame. They were PABs in the sense that it was necessary to pedal to go uphill, to get the engine started or to overcome strong head and crosswinds. Front wheel drive PABs (Vel-Vap 48cc 2 stroke) were also popular in France but were dangerous on England's and northeast Europe's icy roads in the winter. (Deane and Crichton 1982) In Italy in 1953 the Garelli factory produced a 38.5 cc two-stroke engine to drive a bicycle back wheel via a pulley with a power output of around 200 watts. Speed assistance was required on start of, on hills and against strong head and crosswinds. (Deane and Crichton 1982)

Usage of petrol fuelled PABs and mopeds in Europe grew steadily in the post war years and by 1965 there were thought to be a total of 15 million in use. The number of these that were PABs is not known, as they were all legally classified and counted as mopeds. After 1965 their use declined as the sales of motorcars increased. In 1979 some countries had classified PABs as bicycles provided that the power output was less than 200 or 250 watts but most countries classified them as mopeds with a great variation in the definition of a moped. (Wigan 1979)

In Germany in the 1970s the Solar Electra, an electric powered moped, was introduced with a very similar speed (25 kph) and battery range (40km) as today's electric bicycles. However it was much heavier and there were no automatic electronic controls and speed limiters, making it less safe to use. It did not catch on for use on the roads but it produced no exhaust pollution and was used indoors in large factories and warehouses.

In 1984 Honda introduced the 'People,' a petrol fuelled PAB with a 24 cc petrol engine weighing 26 kg. In the 1980s several Taiwanese companies were making petrol powered PABs, mainly for the domestic and Chinese markets. The technology did not change much and was mostly based on a motorised back wheel, or on a 30 to 40 cc two-stroke engine driving a small wheel on the top of the tyre. There were many millions of PABs in use in China and Europe in the mid 1990s.

Today there are some better quality petrol fuelled PABs available on the world market; the German Sachs IC-PAB with a 30 cc engine and power limiter is available in Australia. Even so, the latest petrol fuelled PABS produce fumes that are not pleasant for pedestrians and cyclists using shared footways off the road. That is until new and cleaner engines are developed powered by biofuels such as ethanol. For example the Orbital Engine Corporation (OEC) in WA has expertise in the design of small clean engines (Shawcross et al 2000). A bio-fueled PAB would be a very efficient user of ethanol, which could be produced from waste in many countries. In the long term, when the cost of fuel cells is greatly reduced, hydrogen power assisted bicycles maybe a practical option (Shell International 2001).

4 Japanese electric PAB product development since 1989

The development of electric PABs in Japan was in response to the high level of bicycle use amongst the elderly and grew out of the large domestic market of around 10 million bicycle sales a year. It was an industry initiative in the late 1980s to make pedaling easier for elderly cyclists and to comply with government concerns about the need to enhance the mobility of the elderly.

Consumer surveys by Yamaha in the 1980s showed that most PAB users were women or elderly males. From an ergonomic viewpoint the lower power to weight ratio of these groups was taken into account in formulating the 50% power assist concept for the second generation PAB which was released in 1989: the 'PAS Prototype' with a maximum power output of 235 watts. The Yamaha 'PAS Prototype' was a major design breakthrough with torque sensors in the cranks which are linked to the motor controls for automatic power assistance. The basic design concept was that only half the normal pedaling effort would be necessary for most trips. See Figure 5.

The 1989 PAS prototype shown of Figure 5 evolved into several later models including the PAS Littlemore shown on Figure 6 The PAS prototype was developed because the Japanese government was concerned about pedestrian safety because only 2% of cycling is done on separate bike paths; 98% is done in areas shared with pedestrians. The appearance of the PAS Prototype (see Figure 5.) which has the image of many today's Chinese E-Bikes with big ugly battery on the frame and the drive unit sticking out from the rear wheel is not elegant.

Figure 5 PAS proto type.

Figure 6.

*The **PAS Little More has***
(1) a stable child seat,
(
2) ease of control and operation with a new keyless switch design and battery remaining indicator,

(3) dynamo lighting control from handle bar mounted lever,

(4) battery charging time of only 2.8 hours; on a single charge will travel 38 Km's over flat roads.

(5) It has a 3 speed integrated gear.

6) the 2006 model has a Ion lithium battery.
(
7) it weighs only 29 Kg complete with child seat lights and kick stand.
(
8) The 2006 model is complete with battery charger high chid seat and auxiliary battery costs A$1,280 in Japan.

According to the Yamaha engineers the most difficult problem in addressing these safety concerns was designing the control system so as to integrate human pedal power and the power available from the motor in the safest way possible (Cycle Press 1997). The smart computer chip developed by Yamaha prevents aggressive riders winding their PAB up to more than 25 kph and terrorising pedestrians on the shared footways and narrow side streets. Above 25 kph the extra weight of the power unit and batteries also makes it more difficult to go faster than on a bicycle. Another advantage is that the precision power unit is connected to the chain and does not get clogged up with mud in wet weather, as did early models of some petrol fuelled PABs

In 1995, after six years of development, the Yamaha PAB was sold nation wide. From then on many companies in both Europe and Japan became involved in E-PAB design and production; many built their own bicycle frames around Yamaha's 'PAS power unit'. By 1997 Japanese PABs, which were designed for different purposes, were coming onto the market in various wheel sizes and frame configurations. By 2001 the focus was on improving the quality of their products and reducing their weight, made major gains. The 47 models of PABS available for sale in Japan in 2006 from 12 companies are shown on Table 1.

Table 1 Japan 2006 models of power assisted bicycles available.

Company	Model No	Female frame No	fold up No	Tyre size 27	26	24	22	20	18	16	14	Weight Range kg	Gear No	Battery type Lithium	NI Mh	Power output watts
National	11	9	1	2	5	5	-	2	1	-	-	18- 27	3 to 7	7	4	240
Yahama	6	6	-	1	5	3	-	-	-	-	-	21- 22	3	5	1	240
Bridgestone	8	8 #	-	1	5	5	1	-	1	1	-	21- 28	3	5	3	240
Mijata Indus	3	3	-	-	3	-3	-	-	-	-	-	22- 23	3	2	1	240
Sunstar	2	1	1	-	-	-	-	1	-	-	1	14- 20	1	2	-	235
Gic	3	-	3	-	-	-	-	1	-	2	-	18- 22	6	1	2	235
Giant	1	1	-	-	-	-	-	1	-	-	-	31	-	1	-	240
Tobu	4	1	-	-	2	-	-	2	-	-	-	16- 24	1 to 7	-	4	240
Takara	1	-	-	-	-	-	-	1	1	-	-	21	3	-	1	240
GSS	-1	-	1	-	-	-	-	-	1	-	-	23	-	-	1	180
Sanjo	3	3	-	1	2	1	-	-	-	-	-	21- 22	3	-	3	250
Shiga	3	3	-	1	1	1	-	-	-	-	-	22	3	2	1	240

Notes: # indicates that one of the eight female frames is a shopping tricycle.

4.1. Today's niche markets for the electric PABs in Japan

The electric PABs that hit the market from 1993 to 1996 were very successful. 70,000 Japanese women over 50 years of age purchased them and it is likely that most of them found that pedalling the electric PABs was as easy as riding bicycles had been when they were young. Table 1 shows that the 2005 models are lighter and 23 models have Ion Lithium batteries which are lighter and perform better in most Japanese cities.

In 1990s the main problem for most electric PABs users was that they were too heavy for lifting up stairs into a typical Japanese home or into other vehicles. Even the small-wheeled models weighed 24 to 27 kg and the large wheeled models weigh between 24 and 31 kg. The three-wheeled shopping electric PABs were much heavier at 36 kg to 39 kg (See figure 7) The weight problem was particularly troublesome for the elderly so a lot of design effort is going into reducing the weight without increasing the price.

Of the 2 million Japanese who bought electric PABs in the five years from 1997 to December 2004 70% were sold to women. Table 1 shows that of the 47 models of electric PABs 35 models had female frames and the 5 models of fold up bikes were all suitable for female riders. Figure 2 shows the growth of bicycle sales and electric PABs sale in Japan.
The three large niche markets were: -

• People over 50 years of age who bought 66% of all electric PABs, mostly women over 50 and men over 60.

• Women under 40 who bought 9.4% of all electric PABs; growing numbers are now using electric PABs fitted with specially designed child passenger seats (see Figure 2) or shopping baskets that are very stable.

Figure 7 *This Yamaha electric shopping tricycle has excellent stability and load carrying power. Battery charging takes 2.8 hours and it will carry the rider 35 km on flat roads. Electronic indicators show battery levels and a dynamo light is fitted that stays bright at low speeds. It comes complete with a built in front wheel lock, comfortable sprung saddle and front basket. This model weighing 36 kg is no longer available but the Bridgestone shopping tricycle that weighs 8 kg less is now available.*

• Business men in their forties who bought 7.6% of electric PABs and value the time saved moving around congested central business districts; most of them do not want to "work up a sweat" on a bicycle and have found the electric PABs easier and more convenient to use and park than a car.

4.2 Tomorrow's niche markets for the electric PABs in Japan

Since the Japan government signed the Kyoto Protocol in 2001 they have become interested in schemes to use electric PABs instead of cars to reduce greenhouse emissions. Japan is completely dependent on imported fuels and the cost of electricity is very high. In 2003 Japan imported 5.5 million barrels of oil a day and has proven oil reserve that will not last more than a couple of years.

Japan has been implementing an energy security policy since the mid 1970s that focused on reducing oil consumption. This explains the large investment in the rail network and the 27% of trips made to work or education by public transportation. Five million people cycle to the rail system every workday; around 15% of the population cycle all the way to work and another 12 % walk to work. Japan's energy security policy has reduced oil dependence in the transport sector from 80% in 1973 to 50% in 2004, thus reversing a negative trend (Alford

2005).

A Japanese economist states economic benefits of the energy security policy in the following: -

This policy... was part of a broader policy to nurture it's domestic industries, constrain consumption and encourage savings and minimise the costs of inputs to industry...By minimising aggregate transportation costs, Japan has been able to minimise their production costs, making their goods more competitive in international markets. Further by discouraging the use of automobiles and encouraging savings a larger pool of potential investment capital was created...and encouraged investments in modern technology...
The bicycle far from being a symbol of economic backwardness is rather a symbol of a society able to meet its passenger transport needs in a most cost effective and least environmentally damaging way, allowing scarce economic resources to be invested elsewhere." (Hooke 1994)

This also explains why Japan has been exploiting renewable energy resources since the early 1990s and now generates half the world's solar power. This fits in with the further evolution of the electric PABs into a solar powered means of transport. Solar powered electric cars requiring 50,000 or more watts power output have no future, but electric PABs with a power output of only 250 watts are economically viable now and will be on the market within a few years. Indeed, the Japanese solar power industry is expected to grow fivefold by 2010 when over one million homes will generate their own electricity from solar electric panels. In the last three years there have been several experiments using solar electricity for the recharging of batteries of electric PABs and other domestic appliances. A long-term vision is emerging of electric PABs charged from roof mounted solar electric panels as an ecologically sustainable means of transport, which is used by people of all ages even in hilly cities.

One innovation is the use of electric PABs to solve environmental problems. In Shimonoseki City in the prefecture of Yamaguchi. Yamaha designed a project for the charging of batteries of 30 Yamaha "PAS" electric PABs using solar power. Yamaha plans to promote electric PABs solar energy charging parking lots in many other areas (Cycle Press 2003). Sanyo has also been providing facilities for the solar electric charging of its workers' electric PABs.

Honda has been at the forefront of these environmental innovations and provided 200 "Racoon 24 Lx" electric PABs in April 2000 to Koga City in Ibaraki Prefecture, which has built an extensive network of bike paths. The bikes are assigned to different groups of people every 3 months and user comments are gathered to assist in developing electric PABs use. The objective is to find out how to reduce car dependence, particularly for short trips. Since 2002 battery charging stands have been provided that use solar PV panels to provide the electricity.

Another of Honda's environmental initiatives is the concept of "Intelligent Community Vehicle Systems" (ICVS). This is based on moving individual vehicle ownership to "shared vehicle use". Honda's vision is of a transport system that is "kind to people, the city and the planet" The ICVS aims to provide a solution to environmental conservation, coexistence with nature, better use of public space, smoother traffic flow and insufficient parking space. The basic concept of this system is based on moving from the individual ownership of vehicles to the shared ownership of environmentally friendly vehicles. This includes energy efficient cars, microbuses and electric PABs for door-to-door trips and to access an efficient rail system.

For the future there are four niche markets that can reasonably be expected to grow and contribute to a more passenger sustainable transport system:

1. People of all ages using their own or company electric PABs at apartments, factories and

offices with mains electricity or solar battery charging and secure storage facilities.
2. Commuters and students using electric PABs to access rail stations and modal interchanges. Five million Japanese park bicycles at rail stations every workday. Electric PABs will progressively move into that niche market for multi-modal travel, as many users need a bicycle at both ends of their rail journey.
3. Young male and female bicycle riders using electric PABs to take the extra physical effort out of riding in hilly cities so that they are as mobile as cyclists in flat urban areas.
4. The elderly for all kinds of trips particularly for recreation and shopping: lightweight fold-up electric PABs are allowed on bullet trains and easily fit in the boot of a car.

5 Japanese and European PABs technology is readily adaptable to Australia

From 1998 there has been a resurgence of electric PABs research and development in Europe because the 1970s moped legislation classifying PABs as mopeds and subject to compulsory registration and insurance was being removed. On March 18 2002 the European Union (EU) reclassified electric bicycles with a maximum power output of up to 250 watts as bicycles making it possible to import Japanese PABs and Japanese drive units to be built into European frames. (Jamerson and Benjamin 2005)

The EU requires that all PABs be fitted with electronic controls that progressively reduce the power output with increasing speed and cut off the electric power assist when a speed of 25 km per hour is reached. PABs meeting these EU requirements are now being produced in quantity in Japan, Taiwan and Europe. This will result in stable free market conditions for all producers of electric PABs both inside and outside of Europe. One review stated that PABs are sold under 53 brand names (Neurpert 2002). There are 17 different electric motor systems but most systems are sold in 2001 by Yamaha, La Prima, Merida, Sanyo, and Shanghai Elite.

Japan has made a lot of progress but there are still some battery recycling issues to address. The non-profit European company Extra Energy tested 17 electric PABs and eight E-Bikes, most of which where made in Europe. Hannes Neupert of Extra Energy seeks to promote the benefits of electric/human power hybrid vehicles through product testing and by raising concerns about battery use and disposal. He states that:

“PABs technology is still far from perfect. The issues of battery recycling, solar recharging and the need for 'smart or smarter chargers', and considerable information on these subjects, including the full test results, are on our web site; www.extraenergy.org.” (Neurpert, 2002)

In 2006 Neurpert's company was testing the performance of electric PABs and their batteries available in Europe in a systematic way. The data on the website www.extraenergy.org reveal that there would a serious problem with the use of Lithium Ion batteries in Australia. Their operational temperature limits for charging are between 0˚ C and 40 ˚C and recommended ended temperatures for battery storage are between -10˚C and 40˚C. On many days the temperature in the cities and regional centres in the north and central Australia exceeds 40 ˚C and is exceeded on a few days in Sydney, Perth, Adelaide and Melbourne. (Neurpert 2006)

However, 21 models of Japanese PABS use Nickel Mh batteries (See table 1) so there are plenty to choose from. Seven German companies make PABs and four of these companies use Nickel Mh batteries which would perform well in Australia. Note that there are also high quality PABs manufactured in Austria, Belgium, Finland and the Netherlands that use Nickel Mh batteries.

There are new innovations in battery technology under development which are beyond the scope of this paper and suggest that coping with high temperatures is not a major constraint

to the development of PAB's. Battery recycling should not present a problem in Australia as battery-recycling plants are being set up.

6 Chinese production of PABs for export and domestic use

In China high levels of bicycle ownership, are combined with manufacturing policy and environmental regulations which are designed to reduce air pollution, and provide a secure market for PABs manufacturers. In 1979 China became the world's leading maker of bicycles; in 2005 it manufacturing 88 million bicycles; a year with 53 million being exported. (See Figure 2) China has encouraged Japanese companies like Shimano; Taiwanese companies like "Giant " and many others to mass-produce their products in China for its 450 million adult bicycle users and for export. This has almost eliminated bicycle manufacture in the US which made 7.5 million bicycles in 1991 but less than a million in 2004 while Chinese bicycle imports increased from 1.3 million to 18 million. This is happening in many countries in Australia Chinese imports have wiped out bicycle manufacture.

China wants to build up an industry base that in the next few years can produce electric PABs replacements for the millions of polluting petrol powered PABs in Chinese cities. The major export markets of the future will be the US and Canada the European Union and Japan. The production of PABs in China increased to 1,590,000 by 2002 and reached 10.5 million in 2005. This greatly exceeds Japanese PABs production, which is expected to stabilise at around 300,000 (See figure 4). By 2015 China is predicted to be producing 44 million electric PABs and around 20 million will be exported.

The scale of the Chinese urban air pollution problem and the future market for E-Bikes within China is indicated by a GDP growth rate of 9.1% in 2004. Car production is growing rapidly and to reach 5 million in 2004; around 13 million scooters and lightweight motorcycles will be produced. Given the high and growing health costs of urban air pollution and 200,000 road deaths a year in China (according to the WHO), it is likely that more environmental legislation will be introduced to constrain car use in cities and increase the demand for PABs and E-Bikes.

A specific example is Shanghai which has a population of 20 million people. In Shanghai there were nearly a million licensed petrol powered PABs with dirty engine emissions so the city government decided not to issue new licenses for them but only to issue them for electric PABs, as was done in Beijing. 37 Chinese electric PABs brands are now being produced in Shanghai.

According to the Chairman of the China Bicycle Association there is likely to be a large increase in the domestic demand for E-Bikes:

"the majority of demand is for fully battery powered machines capable of self propulsion. These will provide the bulk of sales for the domestic market. As far as the development of Japanese style "intelligent" PABs is concerned the development of such models will be geared mostly to export sales" (Cycle Press 1998).

The domestic E-Bike market will be dominated by the better-paid workers in the new industrial parks and office complexes, most of whom will be male. In 2004 there were around 250 million adult bicycle users living in cities. This will happen first in the 10 cities of more than 10 million population and then in the provincial cities servicing rural areas as the standard of living increases. However some cities have restricted the mobility of bicyclists and PABs users despite the environmental concerns of the national government.

Many urban workers are upwardly mobile and wanting to enhance their mobility, but will not be able to afford a car. Housewives and the retired have only a small part of the PABs

market however that is changing rapidly according to the latest Census predictions.

China's population was 1.31 billion in 2005, according to census report released by China's National Bureau of Statistics in 2006. Since the last nationwide census in 2000, China has added an additional 40.5 million people to its population, registering an average annual growth of 0.63 percent. The age structure has also changed somewhat, as China continues to see a gradual aging of its population. Nearly 21 percent of the population is between the ages of 0 and 14, while 11 percent is over 60. Compared with the 2000 census, the former category decreased 2.6 percent, while the latter increased 0.76 percent. Chinese demographers estimate that China will see zero population growth by 2035, when the country's population reaches 1.5 billion. By mid-century, China is projected to have more than 400 million seniors, accounting for 20 percent of the total population. A huge future market for PABs

While oil use in the United States expanded by only 15 percent from 1994 to 2004, in China it more than doubled. Having recently eclipsed Japan as an oil consumer, China is now second only to the United States. (Pang, Quingyand, Guoping, Nator, and Jun (2005) What the Chinese passenger transport system will be like in 2050 is most uncertain because oil will be so scarce that it will be conserved critically essential purposes. It is most unlikely that car use will be a part of the Chinese life style. No matter what Chinese government states today about its rapidly growing car industry more fuel efficient forms of transport will be in use well before then. If not the chaos feared by the current government will have taken over.

Assuming that China survives t he peak in world oil production It seems reasonable to argue that if China's current investments in solar energy will have com e to fruition Their Solar electric powered PABs industry will by then be the largest in the world. In the short term the ambition of the Chinese PV industry is to grow with about 400%in the coming 5 years. Although the domestic PV market is still in its infancy, the production and export of solar grade silicon, cells and modules have grown by 50-100% in 2005. The total available production capacity for cell and module production (of the current 30 major companies involved) is already more than 20% of the world's total, coming from less than 1% only 5 years ago.

Currently, China is the world's third country in terms of solar cell production capacity. The overall goal of the Chinese government is to have 450 Mega Watts cumulative PV power installed in China by 2010: an average sales growth of 40% per year until 2010 is needed. The ambition has even been set to 8,000 MW by 2020 for the next decade where PV could already be cost competitive.

The mass production of high quality and very efficient solar electric PABs seems inevitable because the Chinese government is more likely to confront the urban air pollution problem and future oil shortages than the US, or the UK. There is concern in China about future oil supplies (Pang et all 2005). Already PABs manufacture is the fastest growing powered vehicle industry in the world. It is arguably the most innovative, ecologically sustainable transport development in the world today. China's one child policy has demonstrated that it is the only world power that still has the political capacity to make such tough decisions prior to a crisis emerging. It will turn back the middle class tide of car buying once its elite is convinced of the damaging consequences of peak oil.

7 New markets for electric PABs in North America and New Zealand

The USA and Canada are major potential markets for electric bikes. The high level of bicycle ownership indicates the size of the market. In the US in 1999 120 million bicycles were owned when the population was 272 million, and in 2002 there were 22 million bicycles sold. In 1999 31 million Canadians owned around 13 million bicycles. Canada and the USA recently amended their regulations to facilitate greater use of E-bikes or electric bikes. These countries now have far higher power output limits than in Australia. (Jamieson 2005)

7.1 United States legislation

In the USA legislation was introduced in May 2003 which allowed for a 750W power limit, a 20 mph (32 kph) assisted speed limit and functioning pedals on E-bikes and electric PABs. The passage of a new Federal Act (HR 727/SR 1156) recognises an electric bike as a “bicycle” in Federal law thereby allowing them on the street without a license and registration and onto bicycle paths. This allows youth below driving age and adults who have lost their driving licenses to ride them. (Benjamin 2003)

The Consumer Products Safety Commission (CPSC) is now the Federal agency responsible for E-Bikes, which will have to conform to CPSC safety requirements. Electric PABs and E-bikes are not regarded as a means of transport in the USA and most are used for recreation. Due to the lack of effective marketing most consumers are not familiar with the features of electric PABs and E-bikes (Benjamin 2003).

Today the major source of information about electric PABs and E-bikes is the Internet; there is very little television advertising.

There is no monitoring of electric PABs and E-bike sales in the USA but it appears that most that are sold are made in Taiwan. The Taiwan government reported that 37,000 electric PABs were sold in the USA in 2001/2. Light electric scooters are the most important electric two wheelers sold in the USA with estimates of 270,000 sold in 2001/2.

Distribution channels for electric PABs, E-bikes and electric scooters remain disorganised but the future appears promising for the new E-Bikes (Benjamin 2003).

7.2. Canadian Legislation

Canadian legislation was passed in late 2002 which allows a maximum power output of 500W, maximum assisted speed of 32 kph, and a stipulation that the motor not be engaged until a speed of 3 kph is attained on E-bikes and electric PABs. This is not sound legislation because starting the motor after 3 kph is reached. It disallows most Japanese electric PABs, which are switched on like a car with an ignition key, and is a major handicap for many of the elderly, lame or disabled wanting to use them because of the physical effort involved (Rose and Cock 2003).

However, the Canadian approach to regulating these vehicles is based on Performance Based Standards (PBS), which have been used for other vehicle types. The legislation includes requirements that:

1. Active pedal power is present for the vehicle to be classified as a bicycle.
2. The maximum speed at which the power assistance should cut out be 32 km per hour
3. Vehicles meeting these limits continue to be classified as 'bicycles' and require no registration
4. Vehicles which do not have pedals and/or exceed the above performance standards should not be classified as 'bicycles' and therefore be subject to specific regulations

7.3 New Zealand Legislation.

The use of electric PABs and E-bikes in New Zealand was constrained until 2004 by poor legislation which classified them as mopeds. NZ consumers were effectively denied access to the safest Japanese electric bicycles on the international market. The 200-watt maximum limit in the former Land Transport Bill definition of a bicycle was a serious restriction to free trade.

Energy Wise News an Energy Efficiency and Conservation Authority journal stated: -

“New Zealanders are missing out on one of the most energy efficient forms of transport - the electric bicycle - because the Land Transport Act defines it as a moped motor vehicle, needing registration and number plates with a light to illuminate them at night, a motorcycle helmet and a driver license.” (EECA 2003 A).

Table 2 New Zealand electric bicycle legislation

Table 2 New Zealand electric bicycle legislation

MINISTRY of TRANSPORT TE MANATU WAKA Changes to the New Zealand land transport Act regarding electric came into effect 24 June 2005 and upgrade NZ legislation in accordance with world best practice.	
New Provisions	**Agency responsible**
Any motorised vehicle with a power output of less than 300 watts will not be defined as a 'motor vehicle' under law. The Director of Land Transport NZ also has discretionary provision to exclude vehicles with motors up to 600 watts from being "motor vehicles'.	Land Transport NZ NZ Police
Mobility devices designed for people who requireand have mobility assistance and have motors of less than 1500 watts will not be defined as a motor vehicle under law.	Land Transport NZ NZ Police

The revised 2004 New Zealand Land Transport Act is set out in Table 2 and is a good model for Australia to follow because it addresses the needs of the elderly, the lame and partially disabled. (NZTS 2002)

8 Bikeway networks for the use of PABs in hilly Australian cities

The “state of the art” electric PABs and E-Bike have the potential for making urban transport systems far more energy efficient, reducing greenhouse gas emissions and reducing air pollution. The next generation of these vehicles will be powered from renewable energy resources and will be the most energy efficient form of motorised transport ever invented. For all practical purposes tomorrow's electric two wheelers are destined to join the bicycle and walking as the only forms of transport that emit no greenhouse gases.

Most cities have sprawled beyond the plains and valleys and are spread across hilly terrain. If bikeway networks existed electric PABs could overcome these constraints and could be used to enhance personal mobility in much the same way as bicycles do in flat cities. Modern multi geared bicycles are a help in climbing hills but, as recent experience in Japan shows, housewives and elderly cyclists start to give up cycling when it becomes too strenuous but if high quality and safe electric PABs are available they will use them.

If safe back routes to rail stations, secure bicycle parking at stations and modal interchanges were available electric PABs and E-Bikes could make it much more convenient to use public transport and effectively enlarge rail catchment areas. From a strategic transport planning perspective investing in urban bikeway networks would be more cost effective in Australian cities if they also enabled electric PABs and E-Bikes to be safely used of instead of cars (Parker 2002).

In the hilly parts of Australia's cities the more powerful 300 watts machines would enable able-bodied people to cycle much more than they do now. It would enable them to be more active as part of their daily life, increase their mobility, reduce isolation and improve health. An important safety consideration is having enough power assistance to ride up hills without weaving and to reduce the speed differential with motor vehicles when riding in the kerb lane or a bike lane.

8.1 PABs to meet the mobility needs of Australia's elderly

Those concerned with urban design seem totally unaware of the long-term potential of electric bikes in satisfying the mobility needs of the elderly. For example riding an electric bicycle can be less painful than walking for people with osteo-arthritis in the hips, knees or ankles. This is so because the saddle and not the legs carry the body weight and if one leg has problems it is easy to pedal harder with the other leg to travel locally (Parker 1992) They do not understand that fully powered PABs for the elderly and disabled will need to have a maximum power output of 600 watts to cope with longer distances, with the hills and the steep driveways in Australian suburbia.

The most interesting feature of electric PABs is that they are faster and more convenient than powered 3 and 4 wheeled scooters used by the disabled at low speed on footpaths. PABs are the in-between machine that bridges the gap between speeding cars and the very slow speed footpath scooters. They fill a vacant niche market. Electric PABs can safely use the network of on-road bike lanes and off road bike paths being constructed in all Australian cities. European experience shows that safety can be increased by a larger critical mass of bikeway network users. (Parker 2006)

8.2 PABs to reduce Australia's growing addiction to oil

Over the last forty years Australia has become addicted to cheap oil, especially for transport which uses almost 80% of Australia's petroleum; 55% of road transport fuel is petrol, 39% diesel and 6% is LPG. The oil dependent transport sector is responsible for 76% of oil consumption and that has to be reduced as it poses a very serious threat to Australia's future economy and as a consequence the well being of all Australians, particularly the elderly.

The disparity between the growth in Australian oil consumption and oil imports and the decline in indigenous oil production predicts a serious loss of self-sufficiency between 2006 and 2020. This coincides with the peaking and then decline of oil supplies however, the Commonwealth's policy on energy ignored oil for transport (Parer 2004 A).

Since 1980 the gap between world oil demand and oil supply, once considerable, has steadily narrowed and today is almost negligible. When oil consumption begins to exceed production by even a small amount, the price of oil could soar to well over US$100 a barrel, greatly increasing the cost of transport fuels, the petrochemicals used to make thousand of plastics products, fertilisers and pesticides for food production. (Heinberg 2005)

Of most concern is research published in 2005 showing that reducing oil dependence on both the supply and demand sides must be initiated more 20 years in advance of oil peaking, but it is likely that peaking may occur much earlier. Several future outcomes are possible (Hirsch 2005)(Aleklett 2005).

1. Oil production peaks then declines around 2010 inducing a worldwide depression, wrecking the Australian economy and producing mass unemployment.

2. Oil peaks between 2015 and 2025 making a less painful adaptation possible; provided that most developed nations agree to reduce oil dependence with strong government market intervention, the introduction of fuel rationing and fuel efficiency standards etc.

3. Oil peaking after 2025 allows a timely adaptation with mutually agreed supply and demand side oil conservation measures recommended by the International Energy Agency (IEA).

If as seems likely oil peaks around 2010 the impact on the well being of Australians with outer suburban lifestyles, hinged on two or three car families and constant car trips to work, school and supermarkets, would be disastrous (Parker 2005 Robinson and Powrie 2004). It would also be disastrous for the elderly who have retired in outer urban areas and rural areas where there is little if any public transportation. The use of electric bicycles would be a great help in enhancing the mobility of those most vulnerable in outer suburbia.

Many practical measures are needed to reduce oil consumption. The Commonwealth and state governments need to develop a risk management strategy and a national energy security plan to cope with that. The necessary change processes will have to emphasise oil conservation as the key risk management strategy as there appear to be no technical panaceas to enable the current oil consumption patterns to persist These changes will need to involve lifestyle changes; oil and transport demand management measures; congestion pricing; new "energy-lean" technologies; integrated land use and transport planning (Parker 2005).

The use of bicycles and electrically powered bicycles are a small but significant element of the change process. Building urban bikeway networks and providing secure parking for two wheelers at all modal interchanges and railway stations is easily done (Parker 2002).

9 Australia's obsolete legislation

The Australian Transport Council (ATC) which is responsible for introducing amendments to the Australian Road Rules (1999) established an Austroads Committee to conduct a review of the legislation and road rules for power assisted bicycles Scooters and Other Wheeled Recreational Devices in 2000. Sadly the brief failed to spell out the need to create sensible legislation for electric PABs in line with world best practice in the U.S. Canada the Japan and the European Union.

Due to negative state influences this Austroads committee has been meeting for five years and there is still a 200 watt power assistance limit which excludes state of the art Japanese E-PABS which are a mere 10 to 45 watts above this limit. This has denied Australian consumers the right to buy the safest PABs on the world market and is a restriction of free trade. There are no such restrictions on consumers buying the latest petrol electric hybrid cars but this committee has made it impossible to import the safest PABs.

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This Austroads committee allowed dangerous scooters to be legally classified as bicycles even though they had 1000 watts in excess power output. Some scooters had dirty two stroke engines (1,200 watt) fitted with easily removable speed limiters which were supposed to reduce power output to 200 watts. However scooter salesmen instructed buyers how to remove them. Due to the very small wheels and the absence of saddles they are dangerous on roads (Paine, M 2001). Their smelly petrol engines pollute the shared footways used by cyclists and pedestrians. (Parker 2004)In 2005 they restricted use of scooters but the 200-watt limit on electric PABs remains in 2006

As a minimum requirement it would be prudent for the Commonwealth and the state to bring their regulations into line with the new NZ regulations so that consumers have the choice of

buying safe “state of the art” electric PABs.

Figure 7 2006 model of a Japanese electric PAB that cannot be purchased in Australia due obsolete legislation

Feedback from the Australian bicycle industry suggests that the Australian electric PABs

market is not like either the Japanese or Chinese domestic market. The Australian market is likely to be dominated by males aged over 50 years. It is likely that these older riders will represent a growing market particularly as mobility issues for older drivers are magnified with the ageing population. Initial research conducted at Monash University has confirmed that electric PABs can provide health benefits to them (Rose and Cock 2003).

10 CONCLUSIONS and RECOMMENDATIONS

There is a need to enable Australia to survive the predicted depletion of the world's conventional oil reserves (cheap oil) between 2010 and 2020. Using bicycles, electric PABs and E-bikes, instead of many 'drive alone car journeys' is one of many measures required to conserve oil in passenger transport.

Changing the Australian and states road rules to encourage green products like the electric PABs will reduce car and oil dependence and greenhouse gas emissions by small but significant amount. Legislation allowing a maximum power out put of 300 watts for the able bodied is required and to enhance the mobility of the elderly the lame and the disabled a maximum power output of 600 watts is required.

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It is recommended that:

1 As an optimum solution Australia should adopt the New Zealand approach to regulating electric PABs by having a Performance Based Standard for able-bodied people which allows a maximum power output of 300 watts. The speed control system should be either fully automatic (actuated with a starting key with no throttle), or semi automatic with a throttle but in both cases power assistance will fade out at 25 kph.

2 To enhance the mobility of the elderly, the lame and disabled; electric PABs specially designed for the US and Canadian markets which have a power output of up to 600 watts should be classified as 'bicycles' at the discretion of road or transport minister, as is done New Zealand.

3 That State and Commonwealth agencies provide marketing incentives for imported electric PABs to be sold as part of a package, complete with a PV 24 Volt or 36 Volt DC battery charging system coupled to solar panels. There is a need to Commissions a study to develop a prototype solar PV battery recharging installation for electric PABs, and E-Bikes, test the recharging installation over a period of one year and produce a feasibility study and detailed costing for factory production.

4 Solar PV battery recharging installations could be introduced in new housing schemes, new flats, factories and office complexes and for the general public to purchase. This should be part of the development of domestic solar power systems for other DC powered appliances as well as electric PABs. There is no necessity in the long-term recharge batteries from the mains electricity. This would reduce the demand for oil and electricity from or coal powered generators.

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NOTE
Cycle Press is a Japanese publisher serving the information needs of Asian manufacturers and distributors of around 80 million new bicycles and over 2 million electric PABs and E-Bikes per year. It produces their power assisted bicycle (Pedelec) International Year Book; monthly journal CyclePress and catalogues in English and Japanese. Publications available from the publisher. URL http:/www.cyclepress.co.jp