UYILO E-MOBILITY PROGRAMME
enabling electro-mobility innovation

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UYILO NEWS

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Albert Einstein once said: "Life is like riding a bicycle. To keep your balance, you must keep moving." What would he have to say about the eBike?

Besides the need for the bike to keep moving, the battery must also be kept charged and looked after, or else you will loose your easy ride and end up having to peddle yourself up the steep hills of life.

So utilize the opportunities given to you in life, just like a battery to help you climb the hill with an eBike. But with it, comes the energy needed and responsibility to keep the battery charged. Also, don't blame the hill, the battery or the bike if you get stuck half way up a steep incline of life. Ensure you were prepared and occasionally when there are the unexpected turns on an uphill journey, you might just have to "help my trap".

In This Issue

- Interesting facts on the use of eBikes
- eBike projects at NMMU
- Mechanical Doping
- NMMU researcher, Dr Vorster tells us about his eBike experience

Electric Bicycles (eBikes)

by Hiten Parmar

It was in 31 December 1895 that Ogden Bolton Jr. was granted a U.S. Patent for a battery-powered bicycle with a "direct current (DC) hub motor mounted in the rear wheel." With the increase in global urbanization in the 20th century, the use of eBikes usage has experienced rapid growth in both European countries and developing nations such as China and India. Currently today, China is the world's leading producer of eBikes and there are roughly 200 million in use in China, and sales are expanding rapidly in Brazil, India, the United States of America, and in European countries like the Netherlands and Switzerland.

eBikes consist of a bicycle frame with pedals that includes an electric motor, usually in the form of a hub motor, connected to the rear or front wheel, where a bike without pedals would be considered as scooters. The eBike allows a rider to either pedal the bike and leverage assisted power from the motor drive system, or the rider may use the twist grip accelerator placed on the handle bars to run on pure electric drive.

The benefits of eBikes are many and often go unrealized, some of which include:

- No drivers license or insurance required to ride. However some countries limit the maximum speed the bike is allowed to achieve. In South Africa the legal maximum speed is 25 km/h
- Less expensive to run than fuel powered vehicles with no exhaust emissions
- The eBike is quieter and safer to run when compared to conventional fuel powered motorbikes. However, some cities have put restrictions on their use due to them being used by courier services in cities such as New York to "zip" through traffic and cause problems at pedestrian intersections

eBike is a modern, efficient and affordable way of travelling used by various individuals (Source kalkhoff-bikes.com)

- eBikes can be used to avoid and skip through congested traffic areas and modern eBikes can achieve up to 140 km on one charge
- Efficiency with affordable parking options, where eBikes can fit on any normal bike rack or railing. However, charge points for eBikes would have to be considered in places were they are used regularly
- In many countries, the cities public transportation systems like trams, trains and subways have dedicated carriages that accommodate bikes or eBikes for long distance commuting. These can be also used to commute workers quietly without exhaust fumes within large warehouses or factories

eBike Battery Packs

by Dr Nico Rust

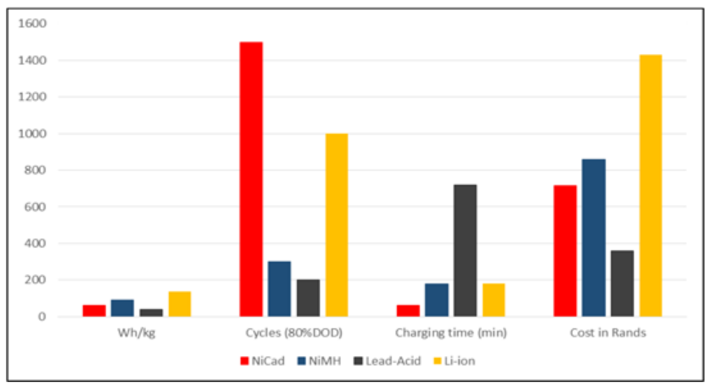
Within an eBike, the battery directly influences its weight, range and cost. There exists a multitude of chemical combinations which can be made into battery packs, but in practice only four rechargeable types are readily available and suitable for eBike type applications. These include Valve Regulated Lead–Acid (VRLA), Nickel Cadmium (NiCad), Nickel Metal Hydride (NiMH) and Lithium-ion batteries (Li-ion).

For many years, the lead-acid battery or in particular, the sealed valve regulated battery has been the de-facto standard for light electric mobility platforms such as eBikes and eScooters. The chemistry is well understood and the costs are relatively low in comparison to other types of batteries. The VRLA battery however should not be left in a discharged or partial state of charge and should always be fully charged after a period of use in order to improve the battery's life expectancy. The number of cycles (discharge and charge) a VRLA battery can undergo are related to the depth of discharge (DoD) when operated. For a good deep-cycle battery at 100% DoD use, the typical number of cycles are generally in the order of 200 to 400 cycles, which also depends if it was fully charged after each discharge.

The NiCad was the long-standing batteries for rechargeable consumer portable devices and are best known for their robustness, electrical safety, good cycle life and high discharge rate capabilities. Since early 2000, these types of batteries have been replaced due to the toxic nature of cadmium by the NiMH and Li-ion batteries. The NiMH battery is similar in its charge and discharge profile to NiCad with a slightly higher energy density and is safer in terms of the elimination of cadmium, but with less expected life cycles.

Nowadays, Li-ion batteries can be found in many portable consumer electronics and probably best known for their use as cell phone batteries. They can store almost 3 times more specific energy than NiMH batteries and almost 5 times more than VRLA. They can be formed into a variety of shapes and sizes to fit into a range of devices, from cell phones to laptop batteries as well as electric vehicles. For many years, the disadvantage of the Li-ion battery was its destructive safety concerns, limited high power usage and high costs. With recent improvements in cell manufacturing and the use of various electrolyte additives some of the former concerns have been addressed. In terms of comparative costing, their prices have also started to decrease, mainly due to the large number of global companies that are now manufacturing and selling their batteries for a large range of consumer goods, which further include large scale grid power systems for load levelling.

The Li-ion battery can be classified according to the various types of chemistries used as the cathode material. In general, these would be the phosphates ($LiFePO_4$) and the metal oxides ($LiCoO_2$, $LiMn_2O_4$). The development of the cathode material is probably one of the most researched areas in the field of batteries with many types of new chemistries being developed that include a large variety of dopants, coatings and additives. This results in batteries with improved benefits such as higher cell voltages, longer cycle life and high power capabilities. The anode in almost all Li-ion batteries currently on the market consists of graphitic carbon with the electrolyte being either an organic solvent or polymer. These are also referred to as Li-Polymer batteries, which are generally safer in terms of abuse situations where it is less likely to burn due to a short circuit or a puncture. Good modern Li-ion batteries can generally provide between 2000 and 3000 cycles at 100% DoD with extremely low self-discharge properties. They do not suffer from thermal runaway when combined with a good battery management system which renders them very safe for use in eMobility type applications. However, the main disadvantage with Li-ion batteries at present would be their comparatively initial high cost which makes them the less attractive for use in eBikes than VRLA batteries. The illustration below is a typical comparison between the various types of batteries.



Comparison between various battery technologies

When comparing battery types, a number of factors have to be considered. Even though the NiCad type batteries would provide excellent cycle life with minimal charging time, their costs and energy density by comparison would be lower with additional problems of a negative environmental impact due to its toxicity. Hence, comparisons of battery types for a particular use such as an eBike have to be done across a number of properties.

For example, one can see that the initial cost of the VRLA battery would far outweigh the cost of a typical Li-ion battery and is generally the reason why most people buy VRLA battery packs. However, what the consumer does not always consider is the cost over the life of the battery where the Li-ion battery will generally cost about R1.43/cycle whereas the VRLA battery will cost about R1.79/cycle. There are however additional considerations such as the cost of a good battery management system and the availability of reliable battery packs.

These economic dynamics will obviously start changing as more lower cost reliable Li-ion batteries become locally available with an uptake of more portable electronics and eMobility products. In addition, there will also be stricter environmental legislations around the use and the recycling of toxic materials such as lead that is used in VRLA batteries.

Some battery basics:

Voltage: NiCad/NIMH cell voltages are around 1.2V, VRLA around 2V and Li-ion cell voltages around 3.7V. Cells connected in parallel will increase capacity (Ah) whilst cells connected in series will increase the voltage. Battery voltages for eBikes range from 24 to 48V.

Capacity: (Amp hours) If a battery is rated at 12Ah you can draw a current of 1A for 12 hours.

Power: (Watt hours) When comparing how far a given battery pack will take you, you can consider the power needed by your motor and the Wh stored in a battery pack. This is derived by taking the Ah and multiplying by the battery pack's voltage. In general, a higher pack voltage will need fewer Ah to deliver the same range. A 48V/4Ah battery will deliver 192 Wh. The energy consumption for direct-drive setups are in the order of around 10Watt-hours/km.

Specific Energy: (Wh/kg) Relates to the weight of the battery pack. This usually excludes additional battery management systems and controllers.

Batteries on eBikes come in a variety of sizes and are positioned in various areas on the eBikes to compliment design and purpose

C-rating: A term used to normalize the performance characteristics of batteries of different capacities that can then be compared. 1C relates to the amount of current to be applied in order to discharge the battery in 1 hour. Also referred to as the 1 hour discharge rate. Automotive lead-acid batteries are generally rated at the 0.05C or C_{20} rate which corresponds to a current at which the battery will have to last for 20 hours.

eBikes in professional cycling: Mechanical doping

by Xander Theron

Professional cycling has been on the wrong side of doping scandals during recent years especially after the Armstrong 2012 Tour de France saga. The 2016 UCI Cyclocross World championship in Zolder Belgium marked an interesting first for cycling as the winner of the Under-23 women's race was accused of mechanical doping.

Electric motor and crank example (Source bikeradar.com)

What is mechanical doping? Well, it seems that electric mobility enthusiasts are not the only ones that have seen the potential in eBikes. Mechanical doping in cycling is when the bicycle is fitted with an electric motor to assist the rider in gaining an advantage over the rest of the riders.

The electric motor fits within the framework of the bicycle and is powered by a battery which is either fitted in the frame or even in the water bottle. The motor is activated by switch hidden on the handlebar.

Typical systems range from 40 to 200 watts that would add additional weight to the bicycle and can weigh about 1.8kg depending on the battery size. The margins between losing and wining in professional sport is getting more and more competitive each year where the aid by a 200 watt electric motor could certainly help your performance even with the extra bit of weight.

According to some sources, the mechanical doping scenario had been rumored as early as 2010, where it raised concerns about the frequent bike changes that the participants underwent during a typical race such as the tour de France.

It is clear that mechanical doping can pose a major threat to conventional sports such as cycling, where in the future, efforts to combat it and clear boundaries have to be set to what level does one allow technological advancements to give athletes the additional "edge". Guidelines have to be clear around improvements around mechanical assisted competitive sporting. Maybe in future, a new category of eBike racing will be established known as e-tour de France.

Electric Bike fleet sharing demonstrator project at NMMU
by Hiten Parmar

The uYilo e-Mobility Technology Innovation Programme (EMTIP) was established to support the developments of key technologies that will support the establishment of the Electric Vehicle (EV) industry as well as promote electric mobility within in South Africa.

As one of the initiatives, the programme is demonstrating various eMobility modes and concepts. A fleet sharing scheme using eBikes is deployed at the Nelson Mandela Metropolitan University (NMMU), North and South Campus. The scheme allows staff and students the opportunity to use eBikes for intercampus transport.

The initial project within the uYilo Programme was co-funded by merSETA, eNtsa and the NMMU to establish two “Green” eBike stations at the North and South Campus in Summerstrand. Port Elizabeth based solar components manufactures, Microcare, kindly donated the inverter being used within the project. The charge stations make use of solar panels to generate electricity for charging of the eBikes to essentially provide green energy towards a green transport solution.

Objectives of this project include:

- Collect usage data from the eBike’s logging devices
- Create a web interface dashboard for statistics and reporting
- Provide facilities for reservation and a real-time fleet usage map
- Collect and compile relevant data to develop and expand business cases for fleet sharing
- Creating awareness of electric mobility and its role in everyday life

Scope of the project

The first phase included the establishment of the two charge stations, located at North Campus and the second station located at South Campus. Both stations include custom made docking stations developed by the NMMU eNtsa engineering team which have solar generated energy for charging of the eBikes. Each docking station access is integrated into the NMMU student and staff access card system. Users are required to complete a once-off online registration process which also provides a guided tutorial on how to use the service as well as the eBikes itself. The second phase of the project will be to facilitate the development and implementation of the monitoring and reservation system from a web-based portal.

Facts about the eBikes used within this project:

- The bikes were developed by a local entrepreneur in the Eastern Cape that have a unique shape different from conventional bikes.
- Total average range distance is 40 km at a regulated top speed of 25 km/h.
- eBikes are geographically zoned to allow their use only within the north and south campus. Additional features that will be included in future is the ability to remotely deactivate the battery if it is used outside the demarcated zone, causing the rider to make use of manual peddle power for mobility.

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Picture on the left: Ms Unathi Mabi & Mr Hiten Parmar at eBike fleet sharing station at NMMU South campus at the Embezweni Building

Interesting facts

For every **800 km** an electric bike is used in place of a car an average of **94 litres** of fuel is saved.

eBikes can generally cover **32** to **80km** on a battery charge, well within the distance of many daily commutes.

Avoiding just **10km** of driving every week would eliminate **500 kg** of carbon dioxide emissions a year

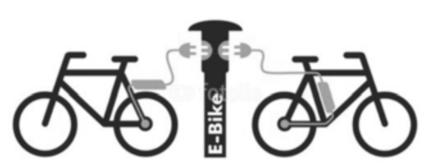
For every **800km** an eBike is used in place of a car, the pollution prevented is:

- **1.55** kg of hydrocarbons

- **0.77kg** of nitrogen oxides

- **11.46** kg of carbon monoxide

The cost per km (including energy usage, purchase cost and running cost) is less than **45c** for an eBike vs **R6.40** for a car

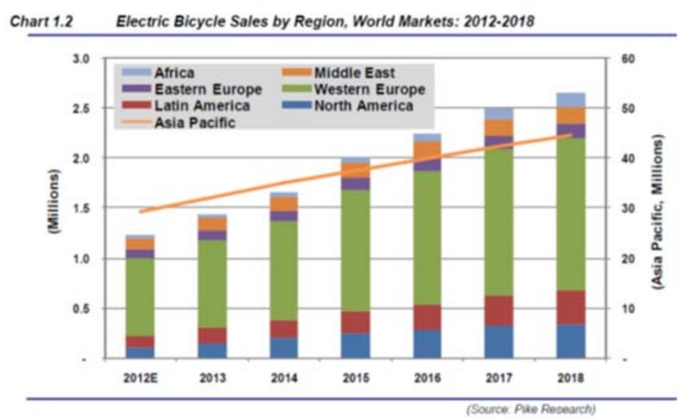


eBike phenomena in China
by Laurence Geyer

The growth of eBikes and the creative application usage in China is a fascinating subject compared to other countries. When one looks at eBikes in Europe, the main driver for their usage is to reduce traffic congestion and to encourage green mobility to reduce CO_2 emissions. In China, on the other hand, the eBike is more used as a tool in daily life for people who cannot afford a normal fuel powered vehicle. This has resulted in very creative and often dangerous use of eBikes, as people use whatever resources they have available to make a living. Here are some interesting points:

- In China, 90% of the eBikes sold use lead acid batteries, which provide a lower cost bike. In Europe and North America most of the eBikes use the lithium ion battery which attracts a higher cost, but has a longer cycle life.
- More than 90% of eBike sales globally are in the Asia pacific region (40 million sales in 2015).
- In China, eBikes usage is very creative, often being used as family transport (4 people on a bike), delivery vehicles (often precariously loaded), business transport (e.g. electricians or plumbers), as well as for normal individual usage.
- Traffic regulations in Chinese cities for eBikes vary. e.g. in Shanghai the eBikes ride against the flow of the traffic which seems quite dangerous.
- On-road charges for normal vehicles in Chinese large cities is extremely high due to the traffic congestion and population density. This is providing a stimulation for the eBike growth to continue at the present rate.

The above pictures of daily uses of eBikes in China



The above diagrams illustrate the eBike sales per region from 2012 — 2016 (Source: Pike Research)

eBike Legislation

Countries around the world allow the use of electric bicycles on their public roads with some regulations compared to a conventional pedal bicycle, these regulations can be reviewed here http://en.wikipedia.org/wiki/Electric_bicycle_laws

In South Africa, within the SANS specifications for Motor vehicles of Category L (October 2008), electric bicycles are not classified as motor vehicles as long as the auxiliary electric motor has a maximum continuous rated power of 0,25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h, or sooner.
However the National Road Traffic Act still requires clarification between electric bicycles as motor vehicles/ motorcycles for use on public roads.

My eBike - sharing my experience
by Dr FJ Vorster (Centre for Energy Research)

I have been using an eBike to since the beginning of 2007 for commute between the North and South Campuses of the university, and to and from home in Summerstrand. On average my travel distance is about 5 - 6km per day. The eBike is powered by a rechargeable battery which drives a 400W brushless electric motor positioned on the front wheel. The motor is virtually maintenance free.

About my eBike

I assembled my eBike starting with an existing standard 26'' mountain bike and a kit that was supplied via a local agent "Adequate Energy" in Cape Town. The kit included a complete hub motor and wheel rim, speed controller with non-contact throttle and 3 x 12V 12Ah sealed lead acid batteries (430Wh). Currently I use a much lighter, lower spec 37V li-Ion battery pack and the resulting reduced power the motor does not quite make up for the higher acceleration that can be achieved with the heavier 48V battery pack. Apart from replacing the batteries the only maintenance that I have done to the eBike since 2007 was to replace a motor hub bearing in 2014.

Practical considerations when assembling your eBike or considerations buying a new one

Weight is an important consideration. When using heavy lead acid batteries the battery pack needs to be as low as possible. The eBike was cumbersome; with a heavy battery at the back and a heavy motor on the front wheel it is comparable to a scooter or a small motorbike. Pushing the bike to a place of safety or repair (particularly up a hill) will thus require great effort. It is inevitable that a staircase or steps will be encountered at some point which will prove to be difficult, particularly for women and children. Pedalling it without any assistance from the motor when the battery runs flat or electronic problem is very difficult and tiring.

Although the maintenance is in line with a standard mountain bike, the weight of the bike and the increased stress from the forward pull of the hub motor on the steering headstock will increase wear and tear compared to a standard bike. This is particularly true for the braking system. The brake system has to work much harder to slow the bike down to a stop.
The brushless hub motor is very low to no maintenance as there are no moving parts in it. Batteries do deteriorate over time, no information is available on how many charging cycles the eBike's battery can go through before failing. A good ball park figure though would be around two years of regular use.
Depending on the battery pack and one's driving habits the eBike can be used for between 20 and 40km in total before it needs to be recharged. A full recharge will require anything from 3-6 hours.

When using the twist throttle, wrist fatigue is a factor a push button throttle is may be a better choice when purchasing an eBike.

In the context of rising fuel costs and increased awareness around more sustainable forms of transport, a battery driven mountain bike promises to be a viable alternative to the scooter/ small motorbike market. The eBike can be effectively used for errands and trips where not much storage space is required, and is ideal for daily trips to work. Since pedalling is not required on the flat or gentle uphill's (unless you wish to go faster) the degree of exercise required to ride the bike can be determined by the rider. It is possible to have anything from a totally relaxing trip to a really good exercise session, depending on the effort the rider puts in.

Dr Freddie Vorster (left) and Prof Ernest van Dyk (right) with their eBikes at NMMU

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