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# SANERI 2010 Green Transport Demonstration Project

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## Abstract

To lead up to and coincide with FIFA World Cup to be hosted by South Africa in 2010, SANERI is implementing a Green Transport Demonstration Project. The purpose is to showcase clean energy and green transport technologies in order to confirm South Africa's seriousness in promoting environmentally friendly transport technologies and to some extent, offset the $CO_2$ that will be emitted through travel associated with the event. The intent is to star the Joule electric vehicle manufactured in South Africa by Optimal Energy. A Green Transport Centre has been established for the exhibition of green transport technologies and vehicles. Electric vehicles that have been part of Eskom's project will also be used in this demonstration. The invitation is out to parties who could contribute to the success of the project and want to take part in the exhibition and vehicle demonstrations.

*Keywords: Demonstration, education, promotion, vehicle performance.*

## 1 Introduction

The FIFA World Cup will be hosted by South Africa in 2010. It is expected that visitors will travel from all parts of the world to attend the soccer matches. Most soccer fans will come to Gauteng to watch the final. With the increasing awareness of the impact of climate change on the weather and the lives of people throughout the world, the South African Government, particularly the Department of Environmental Affairs and Tourism (DEAT), Department of Transport (DoT) and the Department of Science and Technology (DST), have plans to showcase clean energy and green transport technologies. The main aim is to demonstrate South Africa's seriousness in promoting environmentally friendly transport technologies and to some extent, offset the $CO_2$ that will be emitted through travel associated with the event.

SANERI, who are hosting the 2010 Green Transport Programme on behalf of the Government, is planning to create a central facility where these technologies can be exhibited and shown to the public. Among other functions, the Green Transport Centre would serve as the core (HQ) of the Green Transport 2010 and beyond demonstration project.

Emphasis on minimising its dependence on the importation of energy for transportation has always been a strong objective for South Africa. The creation of Sasol, a world leader in producing liquid fuels from coal serves as a good example of this.

As early as the first oil crises South Africa looked at alternative energy to power its vehicles and the first electric vehicle programme at the CSIR in the early seventies, led to the first electric vehicles to be driven on local roads. This was very much an experimental exercise that led to a number of scientific papers and theses at that time. But as history has shown, once the oil crisis was over so did the interest in alternatives fade.

The second wave of interest in electric vehicles was during the late eighties at the National Energy Council. This led to the Eskom demonstration programme and ended in 2002, coinciding with another low in the oil price (about $10 per barrel of Brent).

## 1.1 Past EV Projects in SA

### 1.1.1 Work at the CSIR

Perhaps the most significant development was the sodium nickel chloride battery technology or better known as the ZEBRA battery, developed at the CSIR. Currently this technology is being commercialised by MES-DEA in Switzerland.

## 1.2 Work at Eskom

Work on electric vehicles at Eskom was driven by the marketing department and therefore aimed mainly at demonstrating the feasibility and benefits of electric vehicles in order to create a market for these “alternative transport options”. Eskom would benefit from increased sales at off-peak times - when batteries are recharged - thus filling the valley between the two peak of evening and morning electricity demand. Due to the single time zone applying to South Africa, this is the only option in terms of levelling the demand load. Furthermore Eskom would be seen as promoting air quality and reducing the price of transportation.

The work done at Eskom included evaluation drive as well as energy storage systems and then converting various vehicles to electric propulsion. These vehicles were then operated under controlled conditions and closely monitored. Some were offered for use in the areas where it was believed to be better suited for electric vehicles.

To kick-off the Eskom programme the first prototype imported was the Solectria Force:

### 1.2.1 The Solectria Force Electric Car

This car was imported in May 1993 in order to introduce the concept of electric vehicles into Eskom and the general public. Data was gathered to determine the energy efficiency and environmental pollution benefits compared to a similar petrol car.

The Solectria was a retro-fitted General motors, Canadian manufactured Geo Metro. It was powered by a 21kW peak 3 phase induction motor and used nickel cadmium batteries.

An extensive national road show was undertaken and all potential stakeholders were invited to look and feel what it was all about.


Figure 1 The Solectria Force EV

Although the Solectria was not much more than a slow city car, it cost less than R4.00 (*$1.00US = R10.00*) to run a 100km and except for checking the battery fluid levels, required almost no maintenance.

### 1.2.2 The AC Propulsion Electric Car

This second prototype imported in May 1994 by Eskom, exceeded performance expectations. With acceleration from stand still to 100km/h in less than 9 seconds and with a top speed of 136 km/h the perception that electric vehicles were milk floats, was finally changed. The conversion was done by AC propulsion, and this was then the base from where more appropriate niche market demonstrator EVs could be developed. Ten similar systems were imported by Eskom and built into various vehicles with the assistance of vehicle manufacturers.


Figure 2 The Honda VX AC100 from AC Propulsion

The Honda VX, AC100 EV is powered by a 100kW AC motor which runs off a 336 volt battery system. The vehicle was tested at Gerotek high speed test track at a constant speed of 60km/h, 90km/h as well as a simulated city cycle. The vehicle achieved ranges of 135km, 97km and

135km respectively. Energy efficiency varied between 7.85kWh and 11.46kWh per 100km.

The AC Propulsion control system incorporates regenerative braking, a 60 amp battery charger and a 13.8 volt DC power supply for vehicle accessories. Thanks to the high efficiency, power and torque over a wide rpm, a fixed ratio gearing system is used in place of a conventional transmission. This eliminates losses, cost and weight associated with normal transmission systems. The converted Honda used a sealed lead acid battery pack supplied by Optima.

As with the Solectria, the AC 100 was exhibited and demonstrated no fewer than seventy times around the country in 1994 to a variety of interest groups and prospective stakeholders.

On average the energy costs to run the electric Honda came to about R4.50 for 100k.

As the operation of the imported vehicles added to our confidence and opened our imagination to application spaces in the market for electric propulsion we started to do our own conversions of niche market vehicles for evaluation and demonstration.

It was understood that due to the limitations of onboard energy storage niche markets would need to be targeted. A good example of such a niche markets were commercial and industrial sites and conservation areas like the Kruger National Park.

### 1.2.3 Small Truck Conversions (LDV)

The Nissan B140 was the first conversion attempt at Eskom and also the last using flooded lead acid batteries. These were too heavy and risky at recharging time. An Opel Corsa and a Ford Bantam LDV were also converted to electric using AC propulsion systems with Optima batteries. Both vehicles were in daily operation until Eskom terminated its programme in June 2002. Below are photos of the Ford Bantam conversion:


Figure 3 Under the bonnet of the Ford Bantam LDV.

Figure 4 The battery box in the load area.

### 1.2.4 Go-Kart

The electric go-kart was an old petrol chassis fitted with a 3 kW, AC system and ten 15amp hour batteries which allowed us to achieve a distance of twenty laps at an incredible one second deficit against the petrol units in a one day test window.

### 1.2.5 Lacoba Scooters - “eBike”

Working with Cockerill Consulting & Technical Services in Germany, battery operated scooters were imported mid 1995 and evaluated locally.

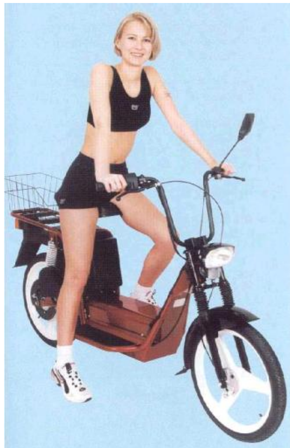

Figure 5 The electric Scooter – “eBike”

The “e-Bike” is a low cost, easy to use, and environmentally friendly battery powered cycle, suitable for use in town to go to school, work, or shopping.

The e-Bike is powered by two 45amp hour lead acid batteries providing 24 volts to an electric motor which is rated at 198 Watts at 2800 rpm.

An indicator panel, situated on the handle bars shows the battery status at all times. The drive is controlled by a twist grip with stepless increase and decrease in speed via the electronic control panel.

The Lacoba is an extremely cost effective form of transport and one can travel up to 50 km on a single charge, resulting in a cost of between 4 and 5 cents (South African) to the user in energy costs per charge.

### 1.2.6 Microbus Electric Shuttles

Working with the International Institute for Energy Conservation (USA), Midrand Town Council and Midtran (A body providing a public transport service to Midrand), Kyalami Business Park was identified as the ideal testing ground for these shuttles because it covers an area of 74ha with a radius of about 2km. On weekday mornings taxis drop off employees at the entrance to the Park, from where they have to walk considerable distances to reach their various places of employment.

Two microbus shuttles, from old Eskom fleet stock, were converted to electric by using 150kW AC Propulsion systems, with lead acid batteries Optima. The vehicles were capable of a top speed of 120km/h and a range of 60km. Each shuttle transported about 150 to 200 people per day from the main gate to their places of work.


Figure 6 The Eskom Microbus Shuttles

About 400km were travelled per week at a consumption rate of 26kWh per 100km. This translated into an energy cost of about 2c per person per day at the time. (1996)

This project provided us with useful information on what to expect from electric vehicles operating under similar conditions (such as city shuttles, delivery vehicles, game viewing vehicles, security patrol vehicles, etc.). All too often we have been quoted *"international operational data"* just to find it cannot be repeated locally. Therefore, there was a need to do our own evaluations.

In the six month operational period, eighteen thousand one hundred and seven passengers used the service, demonstrating the need for such a service. Running costs for the 7 990km travelled was R6.00 per 100km and sixteen cents (SA) per trip.

### 1.2.7 Nissan/Eskom Game Viewing EV

Nissan Automakers assisted Eskom to convert a Nissan truck into an electric night drive game viewing vehicle for the Kruger National Park. These vehicles take visitors on a very popular game viewing drive at night. These trips are usually within the capabilities of lead acid batteries and at speeds less than 30km/h. Electric operation is sought for because it is quiet and pollution free. An added advantage is that when the vehicle stops there is no vibration to interfere with the taking of photographs or noise interfering with the sounds of animals.

More detail about this vehicle will be provided in the next section. (3.3.2)

Figure 7 The Nissan /Eskom Game Viewing EV.

### 1.2.8 The Electric Utility Vehicle

Using the vehicles we converted in daily commuting, we soon understood their benefits and their limitations. At the time and until onboard energy storage becomes affordable and convenient in terms of use, then electric vehicles will be limited to niche markets.

Performance in terms of acceleration and speed was on par with what we become used to and expected from a car.

However, it was not difficult to live or adapt to the shorter trip distance and the convenience to recharge the batteries at any 15Amp outlet, went a long way to make up for this range limitation.

This gave birth to the idea of doing an investigation into what it would take to produce a low cost electric utility vehicle

The idea was to develop the concept into a range of low cost niche market vehicles - just basic mobility for farm, industrial and commercial use with all the added benefits of electric propulsion.

It started off with a frame and chassis (shown on the right of the picture below) designed to hold the EV components.

Global Composites, who were working with Eskom on the project however, turned the ugly duckling into a sexy "eUV". (seen on the left in the picture below)


Figure 8 The Electric Utility Vehicle

This happened just before the Eskom terminated the EV programme and this development initiative then also suffered.

However, we are at new beginnings and the South African National Energy Research Institute (SANERI) has taken the initiative to do research in this area in order to stimulate capacity building, education, promotion and development in alternative energy for transportation:

# 2 2010 Green Transport Demonstration Project

The FIFA World Cup will be hosted by South Africa in 2010. It is expected that visitors will travel from all parts of the world to attend the soccer matches. Most soccer fans will come to Gauteng to watch the final. With the increasing awareness of the impact of climate change on the weather and the lives of people throughout the world, the South African Government, particularly the Department of Environmental Affairs and Tourism (DEAT), Department of Transport (DoT) and the Department of Science and Technology (DST), have plans to showcase clean energy and green transport technologies. The main aim is to demonstrate South Africa's seriousness in promoting environmentally friendly transport technologies and to some extent, offset the $CO_2$ that will be emitted through travel associated with the event.
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## 2.1 Objectives & Scope of the Project

The objectives for the Green Transport Project are to:

- Showcase South Africa's clean energy research outputs, capabilities and achievements during 2010 Soccer World Cup.
  - Clean fuels supply and infrastructure (Refuelling Stations).
  - Electric vehicles (battery and FC powered).
  - Conversion of petrol/diesel engines to alternative fuels (LPG/CNG/H2/HCNG).
- Demonstrate how clean fuels and efficient transport technologies could benefit millions of people.
  - Health benefits, Economic benefits, Sustainability.
- Verify and demonstrate quality of fuels, reliability of supply, safety, operating costs, etc.
- Provide an opportunity for practical skills and human resource development in clean transport technologies.
- Provide a platform for the exploitation of SA developed intellectual property.
- Create awareness, visibility and acceptance amongst the public, entrepreneurs and key decision makers in South Africa about the operability, safety, high performance and low emissions of clean transportation technologies.
- Develop local capability and experience to operate and maintain clean transportation technologies, with its required fuel supply infrastructure.
- Develop collaborative partnerships both locally and internationally regarding clean transportation technologies for both skills and IP transfer.

## 2.2 The Green Transport Centre

In order to show and demonstrate the various technologies to the public and industry, it was decided to have a central and visible place. Such a place was found next to the highway in Midrand and it was decided to name it the "Green Transport Centre".
Beyond 2010, this facility will be used to carry out research, development and commercialisation of alternative vehicles, alternative fuels, refuelling and battery charging infrastructure, transportation systems and propulsion technologies. Ongoing training and education of the public and government officials could also take place at this centre.

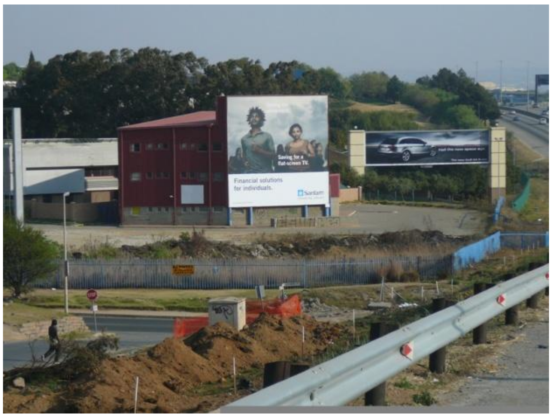

Figure 9 The building next to the N1 highway to be converted into the "Green Transport Centre"

At the centre:

- electric and hybrid vehicles can be *safely demonstrated* to the public under controlled conditions,
- electric vehicle (EV) related technologies can be *tested, evaluated* and *demonstrated* by experts,
- the public and others can be *educated and trained* on the new technologies and the benefits SA can reap through the introduction and use of alternative vehicles, alternative fuels, cycle ways and pedestrian routes feeding into bus networks,
- the public and others can be *educated, trained and capacitated* to plan, manage and implement sustainable transportation options,
- *future development, support and maintenance* services can be provided to developers of alternative vehicle technologies and the public,
- *conversion* of petrol or diesel engines of government and private vehicles to electric or gas can take place.

### 2.2.1 Next Steps

During April and May 2009 it is planned to setup office in the building and transfer the Eskom electric vehicles to the building. Partners will be sought to share the exhibition space and setup demo conversion and refuelling/recharging facilities at the building.

There is enough space around the building for two conversion workshops and three refuelling facilities.

Starting in June 2009, the various road demonstrations will be planned and implemented. Partners will be sought to assist with the development of the vehicles. This will build up to June 2010, with brochures, exhibitions and demonstrations at the various events. Vehicles will also be used to transport the soccer players and VIPs.

Concurrently a press programme will be maintained - building up to the World Cup.

### 2.2.2 Invite to Industry

SANERI invited the South African Automotive Industry to take part and become involved in this Green Transport Project via the National Association for Automobile Manufacturers in South Africa (NAAMSA). We have had and expect more talks to follow with the local industry. (It needs to be said that the experience this time was much warmer than about ten years ago).

At EVS24 the international community involved in electric vehicles will be invited to partner SANERI in their efforts. SANERI would like technology and component developers and suppliers to exhibit at the Green Transport Centre and also get involved in the various on-road demonstrations of electric vehicles.

## 2.3 EV Technology Exhibition and Road Demonstration Projects

### 2.3.1 Eskom Electric Vehicles

As a first step to ensure EVs for demonstration, SANERI approached Eskom to transfer their previously used electric vehicles to the Green Transport Centre for exhibition and demonstration. This Eskom agreed to and the process is underway. Some of the vehicles will be on static exhibition, while others will be used to provide the public with a real EV driving experience.

### 2.3.2 The Joule

The Department of Science and Technology was instrumental in the birth of the Joule and assisted Optimal Energy with their project. They are also funding the Green Transport Demonstration Programme through SANERI and therefore the intention is to make the Joule the "Star" of the show during our demonstration in 2010.

Figure 10 The Joule EV from Optimal Energy

Discussions with Optimal Energy on how we can synchronise their promotion activities with those of the Green Transport Demonstration Project have started.

### 2.3.3 Game Viewing Vehicle

One of the vehicles converted to electric propulsion at the time of the Eskom programme, and an EV we would like to give prominence to during our demonstration, is the Game Viewing EV developed jointly with Nissan SA:

Figure 11 The Electric Game Viewing Vehicle in the Kruger National Park

Conservation areas, such as the Kruger National Park, are created with the purpose to conserve and protect our natural heritage. The use of a game viewing vehicle that does not emit any exhaust gas, is quiet and could be powered by renewable energy therefore makes complete sense!

The vehicle is ideal for night time game viewing. For safety reasons one is not allowed to turn off the engine of a game viewing vehicle while in the bush close to potentially dangerous animals. With an electric vehicle, even though it is not turned off, the motor does not turn. So there is no noise when the vehicle stands still – sounds of the animals can be heard and when needed, the ranger can pull off immediately. There is also no idling vibration – so the body of the vehicle can be used as a support for recording a video.

To make it even more attractive an electric vehicle has a low cost of operation and maintenance. Ideal for remote areas.

While the volumes are low, the cost of the energy storage system and the propulsion system will cause the price of the total vehicle to be high. As an incentive for their introduction it is expected that government will introduce measures to relieve this situation until the introductory costs have come down.

Visitors to private game lodges and the national parks often do not have their own vehicles or are limited to certain roads and times for game viewing. Game viewing rides on open vehicles, adapted to seat people on the back, have become very popular. These vehicles varying from Land Rovers, 4x4 trucks and even bigger trucks, have been modified to seat between 6 to 20 people. The use of these vehicles has grown tremendously. It is estimated that more than 4000 such vehicles are operating in Southern Africa.

The electric night game viewing vehicle came about when Eskom and the Kruger National Park (KNP) agreed on an initiative to develop an electric game viewing vehicle. It was at this point that Nissan SA was approached and they agreed to develop and build an electric game-viewing vehicle in a joint project with Eskom. A standard Nissan Cabstar 4ton truck was specially prepared for game viewing with high rise seats to accommodate 20 people. Nissan did all the mechanical work by removing the diesel motor to create space for the electric motor and control system:

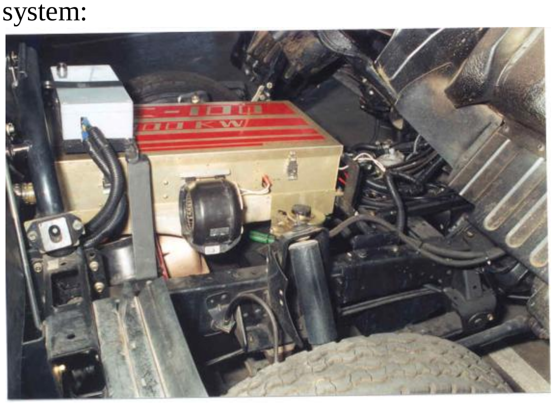

Figure 12 The engine compartment: The electric motor and controller box replaced the diesel engine.

Eskom installed an AC Propulsion 150kW electric drive and controller system and 56 Optima yellow top batteries to power the vehicle. The truck was also adapted to house the twin battery pack – on each side of the vehicle:

Figure 13 The Battery Compartment: Lead acid batteries were installed in the space between the front and rear wheels under the load bay.

Eskom also did all the fine tuning and final settings on the control system. The outlay of the instruments can be seen below:

Figure 14 Monitoring and Control System for the Energy Storage System (Battery Pack).

#### *2.3.3.1 Performance*

The vehicle has a top speed of 80km/h and an energy consumption rate of 36kWh per 100km at an average speed of about 20km/h (About 40kWh off the grid to recharge the batteries). This allows the vehicle a maximum driving range of 70km or a maximum operating time of 3 hours, depending on the acceleration, speed and number of stops made.

In order to make electric game viewing more attractive, more advanced energy storage systems need to be used. These would allow more in terms of trip distance and cycle life. In the long run this would reduce operating costs and increase utility of the vehicle.

### 2.3.4 Hybrid Bus

The City of Johannesburg is planning and implementing a high quality Bus Rapid Transit (BRT) system called “Rea Vaya”. The overall goal of the Rea Vaya initiative is to develop a system that places over 85% of Johannesburg’s population within 500 metres of a Rea Vaya trunk or feeder corridor. The picture below indicates the main routes of the project:

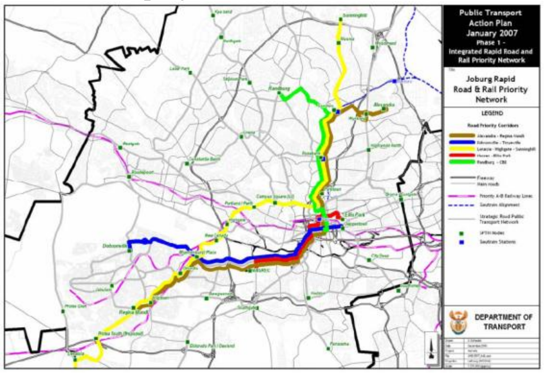


Figure 15 The Rea Vaya BRT Mass Transit Project.

The key to a high-speed service is the development of dedicated median busways. These busways will ensure priority movement for the vehicles and minimise conflicts with left-turning private vehicles. Along some portions of the corridors, the system will operate with a single busway lane and a single mixed traffic lane in each direction.

SANERI commissioned Fraunhofer Institut in Germany to research the various propulsion alternatives for BRT buses and then produce a concept design of the best practical alternative. This concept combines certain features of light rail vehicles with characteristics of conventional transit buses. The major objective is for the provision of user friendly and energy efficient public transport vehicles as well as most of the construction and assembly to be done in South Africa.

The focus was on energy efficiency of the propulsion system as fuel consumption and fuel costs are major challenges for sustainable public transport in South Africa in years to come.

The basic Fraunhofer AutoTram® concept was used to develop the E-Tram concept and has been adjusted to an application in a BRT-like system using the planned BRT system in Johannesburg as a suitable case study. The principle design of the E-Tram can also be used for other BRT-like systems, as long as elevated platforms are part of the structure.

The presented concept design will be used to promote the idea of an energy efficient road bound public transport vehicle with high capacity in the BRT operational cycles planned for six South African cities.

Figure 16 The Concept BRT Bus Design (E-Tram)

The E-Tram is to be equipped with a series hybrid propulsion system that in the first stage uses a diesel engine based generator as the primary energy source (PES). The principle design of the propulsion system is depicted in the following diagram:

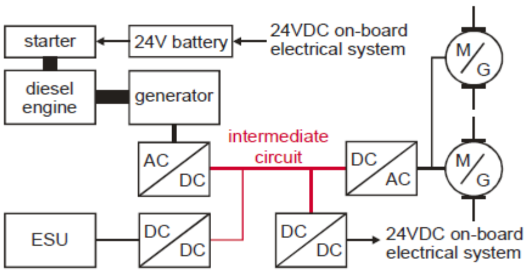


Figure 17 The diesel and ultra capacitor hybrid electric propulsion and energy storage system.

The nominal power of the propulsion system components has been chosen for hilly topography and normal requirements for acceleration.

- Diesel engine EURO IV: 240kW and 1 300Nm
- Generator (e.g. synchronous generator): 200kW
- Two three-phase asynchronous drive motors: 180 – 200kW
- ESU consisting of super-capacitors: approx. 1,5kWh

The configuration has been tested using MatLab-Simulink simulation equipment in standard operating conditions. To start with, two conventional drive motors with a shaft and differential on the second and fourth axle (alternatively second and third axle) were recommended in order to improve the driving capability. Electrical hub motors might be a future option but must still prove their long-term suitability under rough operational conditions.

To ensure high energy efficiency, a predictive and adaptive energy management system was designed for the propulsion system of the E-Tram.

Its major advantages are:

- optimal state of charge of the energy storage unit;
- real time power supply according to the real demand;
- downsizing in order to optimise the primary energy source (diesel engine and
- generator) for its best mode of operation; and
- operation of auxiliaries according to their real demand and required traction power.

# 3 Conclusion

## 3.1 Continuation from a sound platform.

The 2010 Green transport Demonstration Project is based on a solid foundation of past performance and strong intent to implement sustainable, energy efficient and environmentally friendly transport technologies and systems – from individual to mass transit options.

This time we believe chances for success is better, not only due to lessons learnt, but also due to a much more favourable environment that is ready to accept more efficient and environmentally sustainable alternatives.

Please join us in our efforts!

# Acknowledgments

This initiative would not have been possible without:

- SANERI for their vision and determination to implement this project. In particular Kevin Nassiep, CEO of SANERI and Zwanani Mathe, Programme Manager of the Green Transport Programme.
- Eskom for their support in terms of the vehicles and components transfer and also for making Peter Langley available to assist on the project.

# Author

Carel started his career in energy 20 years ago when he joined the National Energy Council and was responsible for research and policy on "Alternative Transport Energy". He initiated the EV project in the late eighties and later continued this work at Eskom. Today, he is involved in a number of projects with SANERI concerning energy and transport. Carel holds masters degrees in science and business leadership.