REPIC
Renewable Energy & Energy Efficiency Promotion in International Cooperation

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Swiss State Secretariat for Economic Affairs SECO
Swiss Agency for Development and Cooperation SDC
Swiss Federal Office of Energy SFOE

Final Report:

Solar Electric Vehicle Demonstration

Public Transportation in Clean Air Island, Mumbai, India

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Date of the Report: 30th June 2015 / 2nd August 2015	Contract Number:2009.07
Institution: Engineering Office Muntwyler, Clean Air Island CAI	Country: India

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Swiss State Secretariat for Economic Affairs SECO
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1. Summary / Abstract

The project was implemented due to the current high dependence on energy sources which are fossil based in India, especially for transportation which is a heavy user of energy.

Oil is a scarce resource, worldwide. Besides, nearly 78 % of oil needs to be imported in India. Transportation with oil causes over 70% of the pollution. Delhi is the most polluted city in the world, followed by Mumbai at no.3. 10 major cities are highly polluted for human safety, as per WHO's assessment. Due to the high density of traffic in a highly populated country, reducing vehicle speeds to an average of 15 to 25 km an hour was necessary to concentrate on public transport. The models of Electric Vehicles chosen were a Bus and a Taxi, which could also be a maxi-cab when rules permitted. Progressively, these noiseless vehicles, in noise levels which can go up to 90 decibels in Mumbai, would be ideal for transport around metro stations and other stations used for longer distance movement, making both types of transport electric and less polluting. Energy saving is a major factor needed for sustainable transport as electricity is insufficient and 60% of it is coal or hydrocarbon based. Electric Vehicles being 85 to 90% energy efficient, compared to 35% efficiency of internal combustion (IC) engines, another kind of saving will also result, due to the use of these pure Electric Vehicles, which are not converted from an IC vehicle.

The project implemented a Solar Electric Bus and demonstrated a Solar Electric Taxi. Solar cells from Mitsubishi have been made into an array of 11 kWp, covering the project's requirement of 8 kWp. This covers 30% of the charge required for an E Bus battery or 50% of charge for an E Taxi. The terrace of the Electrical Maintenance Lab. of the Indian Institute of Technology- Bombay (IIT-B) has been contributed by them for this purpose. A GSM has been installed, to give readings of the outputs of Monocrystalline 9.3 kWp and Poly-crystalline, 1 kWp. Output will be monitored and results will be assessed by the Berne University of Applied Sciences (BUAS) with Mr. Urs Muntwyler as Professor of SPV and Dr. P. C. Ghosh, Asst. Professor of Energy at IIT-B. Mr. Dwipen Boruah, MD of Global Sustainable Energy Solutions, who has planned the energy needs, will also be involved. A battery change arrangement has been installed in both vehicles. The vehicles will be demonstrated as a service at IIT-B in its 100 acre campus. Public transport organizations are invited to view these demonstrations with a view to adopting them in their areas.

The objective of the project *to promote solar energy for demonstration as public transport* has been primarily achieved through a Solar E Bus and a Demo of a Solar E Taxi. Technology inputs for increasing functionality, such as a battery change arrangement and footswitch development, have been made. Fast charging through consultancy from Clean Carb needs to be installed, with additional funding. The solar installation carried out is a prelude to installing a balance of 33 kWp, to complete the 100% requirement for a Solar E Bus and Solar E Taxi, if funded. IIT-B has very kindly given permission for the entire 41kWp to be installed on the same terrace.

Multiplication of Solar Electric Vehicles has been explored and initiated with the following agencies.

1. Dept. of Heavy Industries, Govt. of India, spearheading the National Electric Mobility Mission
2. Millennium Alliance consisting of US Aid, DFID-UK, FICCI- India, ICICI Foundation and Wadhwani, covering a Solar Electric School Bus and a Mobile Medical Van
3. US Embassy's initiative for "Combating Air Pollution in North India", covering a Solar Electric Tow Tractor for vermiculture of waste and International and national conferences where the two Project vehicles are expected to be demonstrated at Delhi.

2. Starting Point

Mumbai being the economic and financial centre of India was chosen to have a clean air island, to demonstrate the feasibility of using solar energy which is non-polluting and which has 40% higher insolation in India than in Europe or the US, at 6 kWh per m2. It has a good technology base and has a good chance of succeeding in a new demonstration, the first of its kind in India.

Clean Air Island, an environmental Society, and Chatelec vehicles India Ltd., pioneers in the manufacture of Electric Vehicles in India, came together with Engg. Office Muntwyler at Zollikofen Switzerland to demonstrate Solar Electric Public Transport in Mumbai. The Indian Institute of Technology- Bombay, a highly regarded technical institute, is located here and has associated itself with the project closely, though not envisaged at the beginning.

Mr. Urs Muntwyler, then Chairman of Engineering Office Muntwyler and Solar Center Muntwyler, was approached by manufacturers of the EVs, Chatelec Vehicles India Ltd. in 1998, for an over view and improvements of EV technologies as available. In 1999, Clean Air Island, an environmental Society, was formed and its Convener, connected with Chatelec, kept up contact with Mr. Muntwyler due to his dual expertise in Solar Energy and Electric Vehicles as Chairman of the IEA Implementing Agreement on Fuel Cells, Hybrid and Electric Vehicles, also through the European and World Electric vehicle associations where Clean Air Island made regular presentations, introduced by Mr. Muntwyler as a good potential for EVs in India.

In 2008, with the popularity of REPIC as an organization promoting solar energy, it was logical that both Engg. Office Muntwyler and Clean Air Island saw the opportunity of being able to make a beginning in India, with its market and technological potential, backed by geography and the availability of renewable energy. The search was fruitful in that REPIC, after detailed interactions on feasibility and suitability, decided to support the project of a demonstration with a part of the funding.

3. Results

A Bus has been made with hip rests for standing passengers, with 4 seats making a total of 21 persons. Trials were last taken again on 15-6-2015. Arrangements have been made for the E Bus to operate at the IIT-Bombay's campus of over 100 acres, which has over 3'000 students. A Bus service of about 25 Buses exists there, with this Bus being the only Solar Electric Vehicle.

An electronic foot switch was developed, to complete the speed controller being used. 5 Nos. were made and tested at IIT-B's Wadhwani Electronic Lab. and is now operating on the E Bus.

E-Taxi

E-Bus

Battery swapping unit

A battery change arrangement has been installed in the E Bus and E Taxi, though originally envisaged for the E Bus only, to cater to a battery change during the day, so as a solar battery can take the place of the discharged battery. This has specially been arranged for transport companies who are used to rough and ready working. Three types of battery change arrangement platforms have been designed as an off shoot of the project, one for single vehicle changes by a pallet truck, one on a battery platform on both sides, with shifting trays in which batteries could be charged and kept ready for one or two vehicles, to be multiplied as required, and the third is for fleet uses by a transport company.

A Solar array (11 kWp), completing the commitment of 8.3 kWp cover 30% of the requirements for the E Bus, as proposed in the project of solar energy, has been installed on the Electrical Maintenance Lab terrace, a two storied building known as the Power House, as it has the Executive Engineer located there.

A complete study was made of the bus routes in the 10sq. km Clean Air Island area, which would be suitable for Electric Vehicle use. This resulted in identifying 15 routes, adding up to the projected 55 uses. Mileages between 6 and 15km on fixed routes can be covered by either one or two battery changes.

Per passenger costs were worked out and shared with its GM and Chief engineer and other technical staff of the Transport undertaking, BEST. Familiarization sessions were carried out with them, where Mr. Muntwyler also participated.

The Municipal Commissioner was sensitized.

A low step chassis has been designed by an M Tech student at IIT-B under the Professors of Mechanical Engineering's supervision and funding options are to be looked at.

Different materials for frames, Aluminum, mild Steel, hot dip Galvanized iron, epoxy coated mild steel have also been used to assess the effect of saline air near the sea.

4. Project Review

4.1. Project Implementation

The project was able to act as a catalyst to the Dept. of Science and Technology, Govt. of India (DST) supporting a Demonstration project, which has helped greatly in working in tandem and fulfilling objectives. While funding delays have sometimes slowed down both projects, the fast charging objective of the current REPIC project will get a boost in implementation in the next few months, with the availability of LI batteries not covered in the REPIC funded project, which are essential to give the required C5 current for fast charging. The LI batteries are available as envisaged from a concomitant project under the Dept. of Science and Technology, Govt. of India. This may take three more months. Overruns of costs need to be met.

Additions have been largely possible through funding support from the Dept. of Science and Technology, Govt. of India.

4.2. Achievement of Objectives and Results

The Project was designed to give a ready, manageable tool to transport agencies, to move away from fossil fuels to a sustainable form of renewable energy - solar, to marry the abundance of this energy in India with the escalating needs of public transport, thereby also replacing individual transport, wherever possible.

This purpose has been largely achieved:

1. Through the involvement of an international agency like REPIC and connections with the International Energy Agency, thereby building confidence in potential transport companies, of the viability of Solar Electric Transport, in a country where it is largely unknown.
2. Through indigenization of the Electric Bus, its servicing ease and lesser number of parts.

The main objective of demonstrating pollution-free transport from a sustainable source of energy - the Sun, has been achieved, with an estimated saving of 523 MT of CO_2 per Solar E Bus and 183 MT savings for the Solar E Taxi, when charged 100% by solar energy.

Two modifications took place:

1. The Govt. transport undertaking could not make available their roof space for a solar installation due to a new building blocking in the way and other connected matters. This turned out to be fortuitous as the Indian Institute of Technology-Bombay, a premier technical institute, which had agreed to carry out energy modeling for this innovative project, offered one of their roofs, as also invited Clean Air Island to run the E Bus in their premises. Over 3'000 top students will, therefore, be exposed to this technology and hopefully, think of improvements and optimal use as decision makers of the future.
2. D. G. Sanghvi College of Engineering, not accredited, was replaced by Saboo Siddiq College of Engineering, which specializes in Automobile Engineering. Interns from this college, ranging from 6 to 10, participated in the project in various sections and one of them is now a designer with CAI, designing further innovations.

Apart from this, all other objectives of the project have been fulfilled, as projected.

4.3. Multiplication / Replication Preparation

Apart from DST being enthused to fund two projects of an E Bus and an E Taxi demo by Clean Air Island, the Dept. of Heavy Industries (DHI), which has been charged with the task of taking a National Electric Mobility Mission forward, has shown interest in funding innovations and introducing further EVs at IIT-B, ranging from 5 to 40. Three IIT-B Professors, Head of Electrical Engineering Dept. a Professor of Energy and a professor of Mechanical Engineering have been giving continuous advice on the current projects and have agreed in writing, to participate in the DHI project.

IIT-B is considering moving towards making their fleet of Mini buses Electric. DHI are interested in working out an arrangement where they cover the incremental costs of such an introduction. IIT-B are willing to be involved increasingly, in assessing and monitoring as well as assisting in technological innovations. Putting on a student to work on a variation is a hopeful sign for other students to be progressively detailed to get involved under the Professors' supervision.

4.4. Impact / Sustainability

Demonstrations at IIT-B are likely to have a salutary effect on transport companies and industrial users to take the plunge into a technology which is still new to them.

The smooth transfer of solar energy to a vehicle battery and its methods of monitoring will build confidence towards the use of solar energy for transportation and hopefully, influence the incentives to this use, more than only for solar energy, which also needs to be streamlined and fine-tuned with market trends.

Renewable materials being designed for the forthcoming vehicles are being tested at IIT-B, apart from test reports from NIIST, Trivandrum and AMPRI Advanced Materials Institute, Bhopal and NECTAR, for Bamboo panels received all scientific institutions under Affiliated to the Council of Scientific and Industrial Research, Govt. of India.

5. Outlook / Further Actions

6.1. Multiplication / Replication

Future actions will revolve around extending the numbers of EVs in the public utility sector by way of:

1. An E Bus with renewable materials for the body and with natural cooling.
2. A Solar School Bus with a low step and a Mobile Medical Van expected to be funded under other projects generated as a result of REPIC's very generous and patient support.
3. Demonstrations of these vehicles at Delhi under a program for raising awareness in the most polluted North India, covering 7 States, where participation of REPIC will be much appreciated at an international conference under consideration by the US Embassy.
4. Making a low step public transport vehicle, with innovations of microprocessor controllers and switch reluctance motor, connected with the Dept.of Heavy Industries, Govt. of India, for a clean air island at IIT-B Powai North Mumbai. Technical tie ups have been discussed with IIT-B and agreed to by them, including for fuel cell demos. Extending the number of Solar E Buses in the original Clean Air Island initiated in South Mumbai, to 55 numbers. This will be followed by ring route services around railway stations in Mumbai, estimated at 1680 E Buses and E Taxis.

Ultracapacitors from Switzerland would be of interest as per earlier discussions with a Swiss University of applied Sciences (HSLU). Induction charging has also been discussed in the past, with the University of Lausanne and another Swiss University.

If funded, the following types of solar cells can be added to evaluate comparative outputs and effect of pollution as compared to Swiss figures. CIGS, CdTe, amorphous Silicon single junction which need to be imported to India.

6.2 Impact / Sustainability

Environmental sustainability is beyond question for the technology of Solar Electric Transport.

With 100% solar, CO_2 savings can be generated to equal 523 MT for a Solar E Bus and 183 MT for a Solar E Taxi. With covering about 39% of the E Bus requirement or 73% of the E Taxi requirement, the present project is estimated save 203 MT of CO_2.

Socio economic: Space availability for solar arrays has been a constraint in Mumbai due to its narrow geography and built up area. However, about a month ago, a notification by the State Govt. has enjoined all govt. buildings to put up solar arrays. This is a good sign.

In the State of Maharashtra where the project under review is located, rules do not allow putting solar power into the grid. We are therefore, installing an inverter for 1 kWp only to demonstrate the feasibility, with an arrangement where this solar power through the grid will only be used for captive purposes, when grid power is also on, which will repel solar power going into the grid. Other States in India freely allow solar power into the grid. The change of rules to put over 100 KWp into the grid is in the offing in Maharashtra.

6. Lessons Learned / Conclusions

The main finding is that the project has kick started interest in solar transportation, for the first time in India.

It could have been faster, with timely availability of funds. These delays at long distance need to be taken into account in such new projects.

A good deal of trust and goodwill between the partners, all moving towards one goal has helped overcome any impediments. The unstinted co-operation and technical advice of Dr. Jorgen Horstmann, Professor in the University of Denmark and planning EVs for Copenhagen based on renewable Energy, of Dwipen Boruah though his assignments with IT Power India and Global Sustainable Energy Solutions and of SirajIzhar from xyzlondon and of Dr. Eva Schupbach, Prof. of Sustainability from Berne University of Applied Sciences has truly added international co-operation to the project

Personal memories are those of breaking new frontiers joyfully, taking the rough with the smooth. There are substantial amounts of good will and respect generated by this project for the Swiss, from all the Govt. departments and agencies involved , as also IIT-Bombay which could well turn out to be a lasting connection for both REPIC, the Berne University of Applied Sciences and IIT-B.

The absence of too much commercial interest, until the project is done, has helped any bugs to be ironed out smoothly and there may be more to come as EVs proceed in India. If that is understood and the vagaries of a developing country taken into account, with changing govts. and equations, further partnerships will be good and something to look forward to. The Swiss technical expertise, quietly delivered as is their practice, could be a big asset.

7. References

Reports sent on Solar EV Demonstration Project in Mumbai, REPIC:
10-1-09, ,24-5-09, 23-9-09, 15-6-11, 10-8-11, 29-8-11, 3-11-11, 16-4-12, 21-5-12, 22-5-12, 7-3-13, 16-7-13, 24-12-13, 25-3-14, 8-5-14, 9-7-14, 23-5-14, 27-5-14, 29-11-14, 23-6-14, 28-11-14, 17-1-15, 28-5-15, 13-6-15, 30-6-15. Copies can be sent, if required.

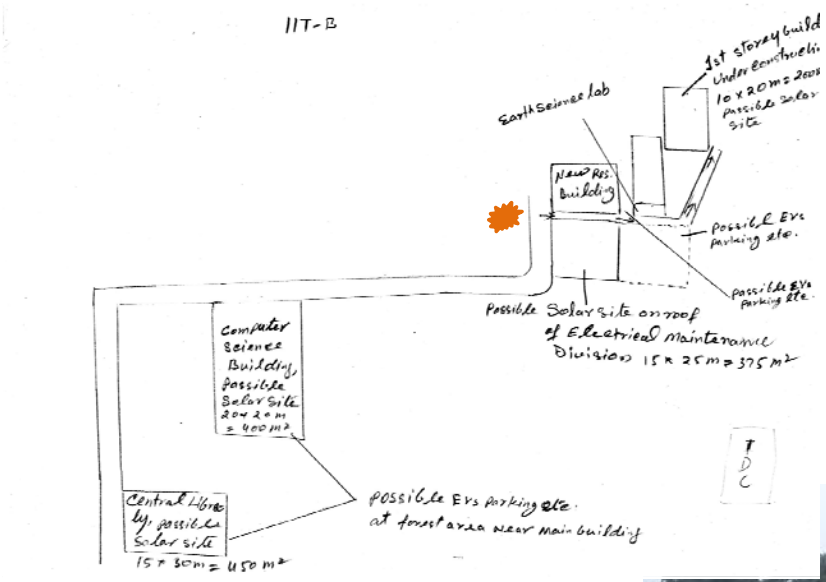
Reference may be made to the following persons, in respect of the project.

- Dr. Neeraj Sharma, Head Technology Development and dissemination Programme. Dept. of Science and Technology, Govt. of India , New Delhi. Dr. Sanjay Mishra, Addl . Head,
- Dr. Juzer Vasi, Head, Dept. of Nano Technology, IIT-B Powai Mumbai,
- Dr. P. K. Ghosh, Asst. Professor for Energy, IIT-B.

8. Annex

- Photos in a Powerpoint presentation.
- Specs E-Taxi, E-Bus
- Pictures of E-Taxi, E-Bus

REPIC leads with Solar Electric Vehicles in India



Dwipen Boruah,
MD, Global Sustainable Energy Solutions

Dr. P. K. Ghosh, Prof. of Energy, IIT-B
Planning at the solar site

Electrical Maintenance Lab ITT-B-

PV inverter installed for
1 kWp polycrystaline cells

IIT-B road leading to

Electrical Maintenance Lab terrace
with solar installation of 11 kWp

Solar cells from Mitsubishi have been made into an array of 11 kWp, covering the project's requirement of 8 kWp. This covers 38% of the charge required for an E Bus battery or 73% of charge for an E Taxi.

Monocrystaline: 9.36 kWp
Polycrystaline: 1.125 kWp

Mitsubishi Monochromatic cells
260 Wp
36 modules 9.36 kWp

Mitsubishi Polychromatic Cells
225 Wp
5 Modules 1.125 kWp

Solar Electric Bus

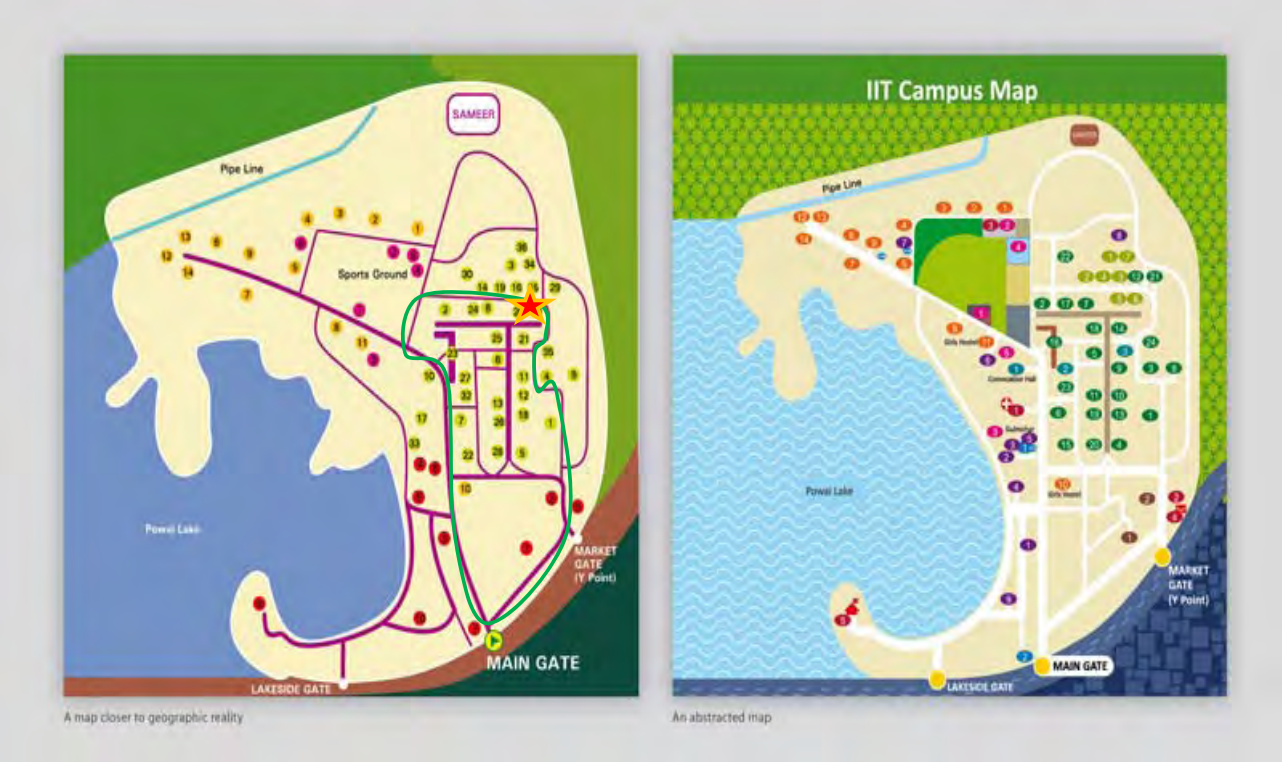
E-Bus with hip rests
for standees

5+1 E Taxi

Potential for maxi-cab

The Solar EV lane at IIT-B

Route of Solar Electric Vehicle



Indian Institute of Technology-Bombay

Hostel H at IIT-B

Overlooking the Solar array at EMD Lab

Cheek by jowl

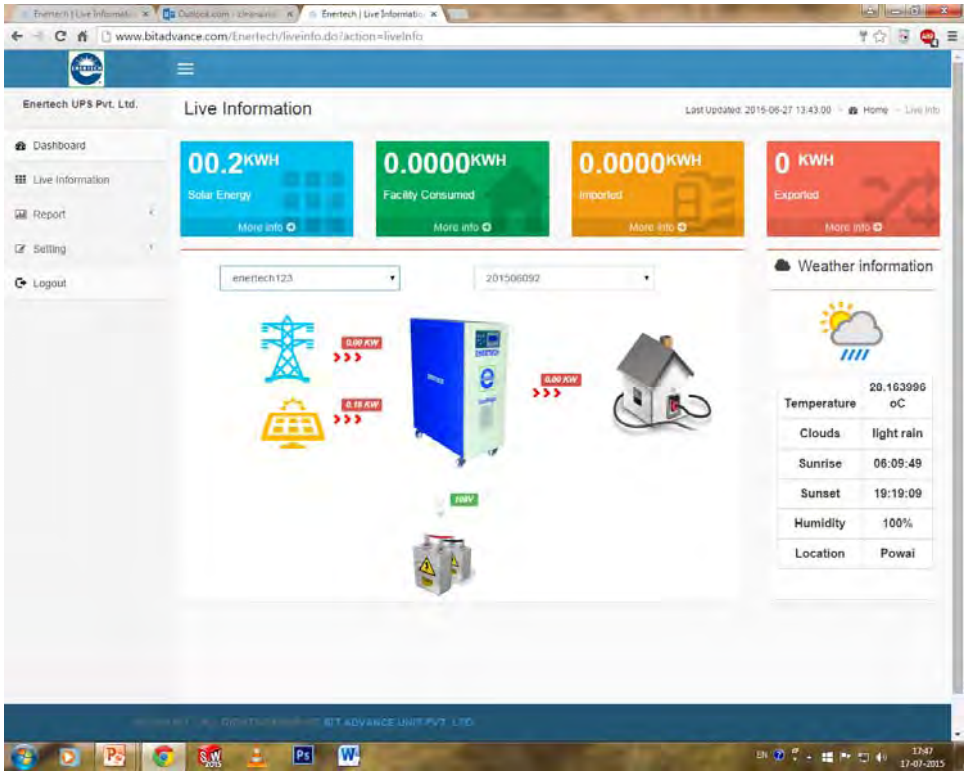
But away from trees

E Taxi to demonstrate
73% of solar energy use

MPPT – DC to DC
Charge controller
50V to 140V

On -board solar charging service

Website Display of Solar Signals



Manually Checking Solar Array Voltage Output

Cable Length : **85 m**.

For 9.3kWatt MONO
Max Current : Ioc : **72A**
Max Current : Imp : 56A
Voltage at the Start : **160v**
Voltage drop : **3.**85v
Voltage drop percentage: **2.41%**
Voltage at the end: **156.**15

For 1.1kWatt Poly
Max Current : Ioc : **9A**
Max Current : Imp : 8A
Voltage at the Start : **150v**
Voltage drop : **1.**97v
Voltage drop percentage: **1.31%**
Voltage at the end: **148.03**

Battery Change Arrangement

Battery Change on rollers

Solar charging and Study

Contiguous Project planned by Urs Muntwyler

- 14 kWp /5 types of cells, frame materials / coatings with research results of output

- Setting up of field testing facility and test protocol by Dwipen Boruah, Co-Investigator in hand.

Dwipen Boruah

- IIT- Bombay and Bern University of Applied Sciences have interacted, as Guides for joint study.

Dr. PC Ghosh

- IIT-B on stream for monitoring data

- Comparison with Swiss data

Urs Muntwyler, Chair, IEA-H/EV, Solar and EV-Electronics

Indian Institute of Technology- Bombay assistance

Juzer M. Vasi

Research Interests: Silicon photovoltaic devices, Nanocrystal based solar cells, Reliability of solar modules, CMOS insulators, transport in MOS insulators, characterization of bulk and interface traps in these insulators, Flash memory devices, CMOS device degradation and reliability: Study of hot-carrier effects, radiation effects, high-field stressing and breakdown in MOS devices, Nanoelectronics.

Baylon G. Fernandes (Currently, Head of the Department)

Research Interests: Inverter topologies for VAr compensation., Power electronic interface for non-conventional energy sources, Permanent magnet machines for wind power generation, Switched reluctance machines for electric vehicle application.

Himanshu J. Bahirat

Research Interests: Renewable Energy Sources, Grid Integration of Renewable Energy, Offshore Wind Energy, Transients in Power Systems, DC Power Systems, DC Wind Farms, Multi-terminal DC Networks, Circuit Breakers, Power Electronics.

25kw motor
120V 423Ah Battery
25 persons- standees and sitting

Project Partners

Sanjeev Mukherjee-Chatelec, Shanta Chatterji-Clean Air Island, Siraj Izhar-xyzlondon
Prof. Urs Muntwyler,
Dr. Eva Schupbach, Bern University of Applied Sciences

The Environmental Family

REPIC

CHATELEC — **Engg. Office Muntwyler** — Dr. J P Horstmann

Dept. of Science & Technology- India — **xyzlondon** — Saboo Siddik Engg. College

IIT Bombay — Bern University of Applied Sciences

clean air island

Specs of Solar E Bus and E Taxi Mumbai

Electric Bus

- 136 km/one battery change
- 120V 420Ah Battery
- 25 kw DC series Motor
- Electricity 62 kwh/Charge

Gradient Capacity	- 1:10
Turning Radius	- 6m
Speed	- Up to 60 kph
Persons	- 25 - Standees with 3
seats	

Electric Taxi

- 120V 300Ah Battery
- 13 kw DC series Motor
- Electricity 36 kwh/Charge

Seats	-	6 -11
Gradient capacity	-	1.5
Speed	-	50 to 55 kph
Range	-	200 km with one battery change

Electric Bus

Louvers

Vermiculture spittoon

Battery box door

Batteries set

Luggage space

Hip rests for standing

Spare wheel

Seats

E-Bus

Battery change arrangement with rollers

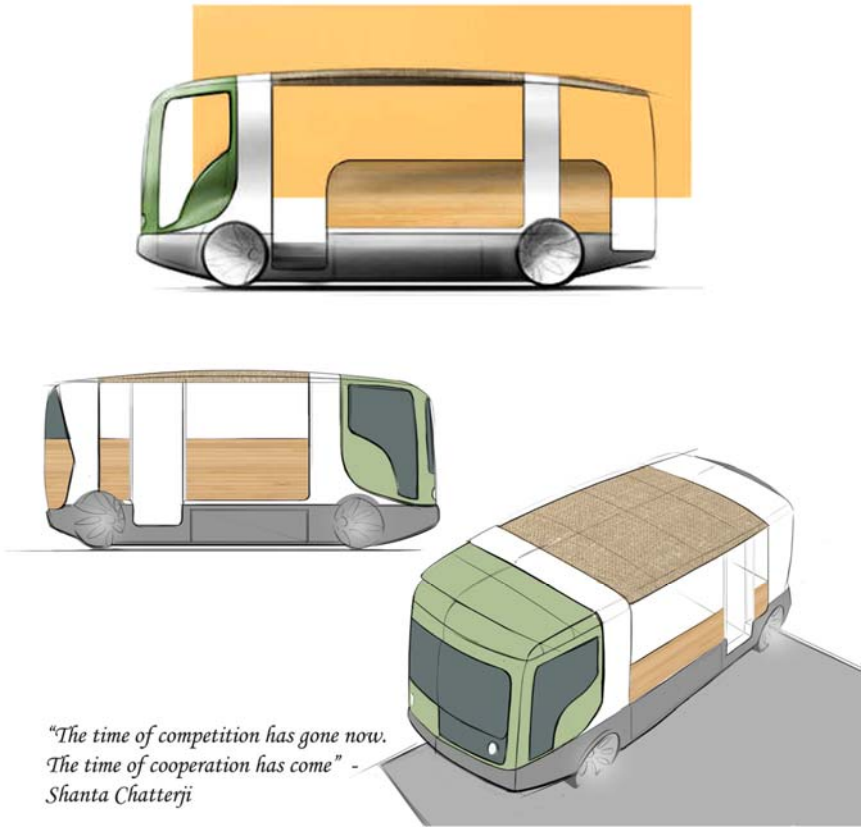
E-Taxi

Locking arrangement bottom

Locking arrangement top

Open floor board

E-bus design with Renewable Materials for further use



Electric Taxi

E-Taxi design with Renewable Materials

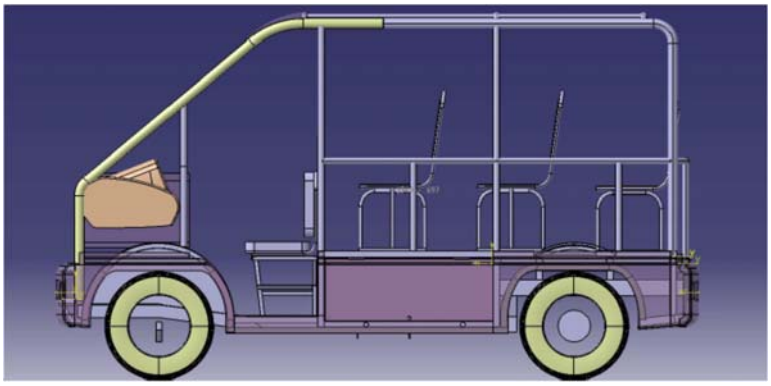
comparison

1

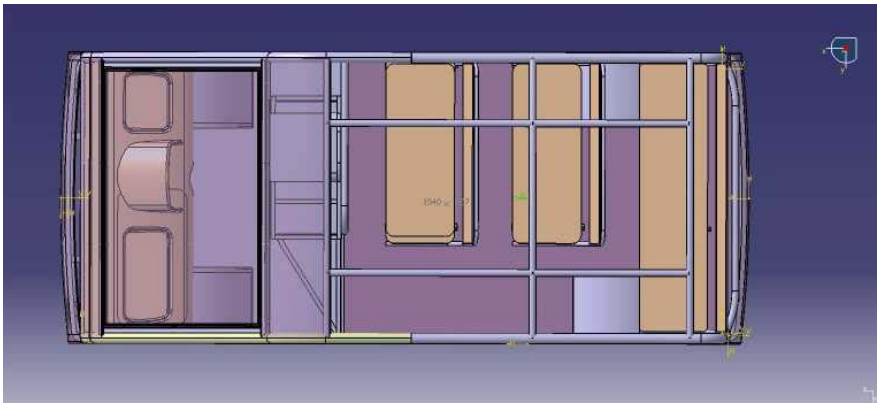
2

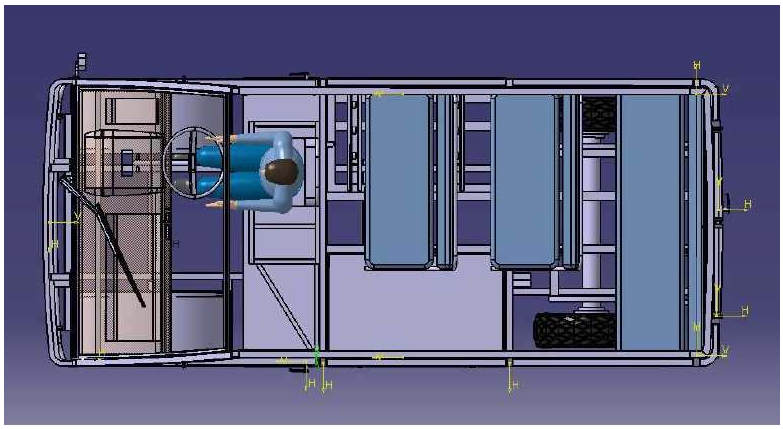
3

1.Metal and glass version.
2. Bamboo board version.
3. Open vehicle concept.



10 + 1 plywood seats





Front entry

10 + 1 seats

Front & rear entry