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Final Report:

Market Launch of Lithium Batteries for Electric Vehicles in Nepal

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1. Executive Summary

In Nepal, about 700 electric vehicles (called Safa Tempos) are in use. They essentially depended on one supplier of lead-acid batteries, which leaves much to be desired in terms of economy, performance and quality. This is why the owners of vehicles and charging stations in particular have been looking for alternatives to lead-acid batteries for many years. Most of the vehicles are privately owned. Many of them belong to women who also drive the vehicles. The vehicles are usually financed by leasing from local financing institutions.

The Nepalese electric vehicle industry wished to equip vehicles with better batteries. This demand was exacerbated by the scarcity of fossil fuels that existed in the country for a long time. Towards end of 2015 several Nepalese stakeholder approached Markus Eisenring to assist in introducing Lithium batteries in Nepal.

An early analysis showed that the lifetime costs of Lithium batteries are far better than those of lead-acid batteries. Although the procurement costs for Lithium batteries are higher than for lead batteries, the operating costs for Lithium batteries are much lower than for lead-acid batteries. A project with the aim of launching Lithium batteries in Nepal was initiated.

The objective of this project is to demonstrate that energy efficiency is increased and that service life costs are reduced by the installation of Lithium batteries. This should also help to ensure that existing electric vehicles can survive, that they are not replaced by conventional vehicles and that other electric vehicles are placed on the market in the near future. This was to be demonstrated on 10 Safa Tempos with early adaptors in a pilot project.

REPIC was approached to finance part of the cost. In spring 2016, REPIC decided to support and thus facilitate the "Project Market launch of Lithium batteries for electric vehicles in Nepal".

We have intensively clarified which kind of Lithium battery system could best achieve our goals and have decided to use LiFeP04 Lithium batteries with the best battery management system. This system is scalable and can be adapted to other needs and applications. It was planned to demonstrate this Lithium battery system on 10 Safa Tempos.

All targets were achieved, such as:
- All 10 vehicles are successfully in operation, three since December 2016 and seven more since January 2018. The conversion of these 10 vehicles was supported by a contribution from REPIC to the hardware cost.
- Energy efficiency was increased, the participants get more income, replication and implementation in other vehicles happens, a clean means of transportation is ensured to the public.

In some cases the targets were even exceeded, for instance:
- We expected that with the Lithium batteries, approx. 25% of energy could be saved. However, energy consumption was reduced by more than 50 %, from 6.6 kWh/loop to 2.8 kWh/loop!
- 15 more vehicles were converted. This means that since end of January 2019 a total of 25 vehicles are running with the same system. The conversion of these vehicles was done by using the same Lithium system technology, but without financial support of REPIC to the hardware cost.
- Other Lithium battery systems were also introduced, 13 vehicles were running with these batteries.

People are very enthusiastic now and believe in the Lithium battery technology. As a consequence, and a side benefit of this project modern AC drive systems were introduced, replacing the old DC drive systems. By this, energy consumption is even less.

Many other owners of Safa Tempos now also want to switch to Lithium batteries. The installation of Lithium batteries in other vehicles is in progress and is planned for many more vehicles.

2. Zusammenfassung

In Nepal sind etwa 700 Elektrofahrzeuge (genannt Safa Tempos) im Einsatz. Sie waren im Wesentlichen von einem Lieferanten von Blei Akkus abhängig, was in Bezug auf Wirtschaftlichkeit, Leistung und Qualität zu wünschen übrig ließ. Deshalb suchten insbesondere die Besitzer von Fahrzeugen und Ladestationen seit vielen Jahren nach Alternativen zu den Bleibatterien. Die meisten Fahrzeuge sind in Privatbesitz. Viele von ihnen gehören Frauen, die auch die Fahrzeuge fahren. Die Finanzierung der Fahrzeuge erfolgt in der Regel durch Leasing von lokalen Finanzinstituten.

Die nepalesische Elektrofahrzeugindustrie wollte die Safa Tempos mit besseren Batterien ausstatten. Diese Nachfrage wurde durch die lange Zeit bestehende Knappheit an fossilen Brennstoffen noch verstärkt. Gegen Ende 2015 wandten sich mehrere nepalesische Interessenvertreter an Markus Eisenring, um bei der Einführung von Lithium-Batterien in Nepal zu helfen.

Eine erste Analyse ergab, dass die Lebenszykluskosten von Lithium-Batterien weitaus besser sind als die von Blei-Säure-Batterien. Obwohl die Anschaffungskosten für Lithium-Batterien höher sind als für Bleibatterien, sind die Betriebskosten für Lithium-Batterien deutlich niedriger als für Bleibatterien. Es wurde ein Projekt zur Einführung von Lithium-Batterien in Nepal gestartet.

Ziel dieses Projekts ist es, zu zeigen, dass die Energieeffizienz gesteigert und die Lebenszykluskosten durch den Einbau von Lithium-Batterien gesenkt werden. Dies sollte auch dazu beitragen, dass bestehende Elektrofahrzeuge überleben können, dass sie nicht durch konventionelle Fahrzeuge ersetzt werden und dass andere Elektrofahrzeuge zu einem späteren Zeitpunkt in Verkehr gebracht werden. Dies sollte an 10 Safa Tempos mit Early Adaptors in einem Pilotprojekt demonstriert werden.

REPIC wurde angefragt um einen Teil der Kosten zu finanzieren. Im Frühjahr 2016 beschloss REPIC, das "Projekt Markteinführung von Lithium-Batterien für Elektrofahrzeuge in Nepal" zu unterstützen und damit zu erleichtern.

Wir haben intensiv abgeklärt, mit welcher Art von Lithium-Batteriesystemen wir unsere Ziele am besten erreichen könnten und haben uns für den Einsatz von LiFePO4-Lithium-Akkus mit dem besten Batteriemanagement System entschieden. Dieses System ist skalierbar und kann an andere Bedürfnisse und Anwendungen angepasst werden. Es war geplant, dieses Lithium-Batteriesystem bei 10 Safa Tempos zu demonstrieren.

Alle Ziele wurden erreicht, beispielsweise:
- Alle 10 Fahrzeuge sind erfolgreich im Einsatz, drei seit Dezember 2016 und sieben weitere seit Januar 2018. Die Umrüstung dieser 10 Fahrzeuge wurde durch einen Beitrag von REPIC an die Hardwarekosten unterstützt.
- Die Energieeffizienz wurde gesteigert, die Teilnehmer erhalten mehr Einnahmen, Replikation und Implementierung in andere Fahrzeuge geschieht, ein sauberes Verkehrsmittel steht der Öffentlichkeit zur Verfügung.

In einigen Fällen wurden die Ziele sogar übertroffen, zum Beispiel:
- Wir erwarteten, dass mit den Lithium-Batterien ca. 25% Energie eingespart werden könne. Der Energieverbrauch konnte jedoch um mehr als 50 %, von 6.6 kWh/Fahrt auf 2.8 kWh/Fahrt reduziert werden!
- 15 weitere Fahrzeuge wurden umgebaut. Für die Umrüstung dieser Fahrzeuge wurde die gleiche Lithium-System-Technologie verwendet, jedoch gab es keine finanzielle Unterstützung von REPIC. Damit fahren seit Ende Januar 2019 insgesamt 25 Fahrzeuge mit diesem System.
- Zusätzlich wurden andere Lithium-Batteriesysteme eingeführt. Bis Januar 2019 wurden 13 Fahrzeuge mit diesen Lithium Batterien in Betrieb genommen.

Die beteiligten Menschen sind jetzt sehr begeistert und glauben an die Lithium-Technologie. Als Konsequenz und Nebeneffekt dieses Projekts wurden moderne AC-Antriebssysteme eingeführt, welche die alten DC-Antriebssysteme ersetzen. Dadurch ist der Energieverbrauch noch geringer.

Viele andere Besitzer von Safa Tempos wollen nun auch auf Lithium-Batterien umsteigen. Der Einbau von Lithium-Batterien in andere Fahrzeuge ist im Gange und ist für viele weitere Fahrzeuge geplant.

3. Initial Situation

In Nepal, the electric vehicle industry is well organized. The Electric Vehicle Association of Nepal (EVAN) is the umbrella organization that brings together all organizations dealing with electric vehicles in Nepal. The main members are Clean Locomotive Entrepreneurs Association of Nepal (CLEAN), Nepal Electric Vehicle Charging Association (NEVCA) and Electric Vehicle Manufacturing and Importer Association of Nepal (EVMIAN). EVAN is active in the promotion and expansion of the use of electric vehicles, as well as in raising awareness among the population. It deals with legal aspects and is also active in the technical development of the electric vehicle industry in Nepal.

About 700 3-wheeled electric vehicles (EV), called Safa Tempos, are used in public transport in Nepal. Most vehicles are privately owned. Women, who also drive the vehicles, own many of them. The vehicles are mostly financed by leasing from financial institutions.

Each of the 700 Safa Tempos has two sets of lead batteries of 12 batteries each. At noon, the batteries are changed because one battery set is not enough to drive a whole day. On average, they drive about 50 km per set, so a vehicle drives 100 km per day with both sets together. Driving takes place on 270 to 300 days a year.

The quality of the conventional lead batteries used as the driving force for all Safa Tempos in Nepal became worse and their price increased. They now last barely 12 months (formerly 18 months). This put a question to the profitability of the Safa Tempo in operation. Every year, 10’000 batteries, worth US$ 1.4 million were imported.

So far, lead batteries from Trojan (type T-125) have been used in the Safa Tempo in Nepal. Many attempts to use other lead-acid batteries did not lead to better results. Other types and sizes were tested, but without success. Until now, there were no alternatives to these batteries, mainly for financial reasons. The whole electric vehicle industry is dependent on Trojan and the general importer for Nepal.

An early analysis showed that the lifetime costs of Lithium batteries today are better than those of lead batteries, although the costs of procuring the batteries are higher in the beginning.

The operating costs are much lower for Lithium batteries than for lead batteries. Since Lithium batteries are lighter, have a longer range and because there are no empty runs for recharging, electrical energy can be saved. Lithium batteries also have a significantly higher efficiency at charging and discharging than lead batteries. Since the Lithium batteries do not have to be exchanged at noon, less personnel is required. The maintenance costs are lower because of the lower weight and because Lithium batteries do not need to be refilled with water. The 4 to 5 times longer battery life saves a lot of grey energy.

This is why the owners of vehicles and charging stations in particular have been looking for alternatives to lead batteries for many years. The Nepalese electric vehicle industry also wishes to equip vehicles with Lithium batteries.

The use of Lithium batteries saves costs and energy. The energy saving is particularly important in Nepal, because electrical energy was not always sufficiently available. The project helps the electric vehicle industry to survive, expand and not be replaced by vehicles with combustion engines.

4. Targets

The aim of the project, with help of the 10 converted vehicles, was to demonstrate that Safa Tempos with Lithium batteries have the following advantages:

- Improvement of the Nepalese market for electric vehicles: The Nepalese electric car industry has an alternative to lead batteries
- The chances of survival for the Safa Tempos are better
- Improvement of the workplace situation of people involved with Safa Tempos
- Creating more income to the participants
- Achieving optimum operating efficiency
- Safa Tempos with Lithium batteries save energy compared to Safa Tempos with lead-acid batteries and are more economical
- Prevent existing electric vehicles (700) from being replaced by vehicles with internal combustion engines
- Replication and implementation in other vehicles
- Provide a clean means of transportation to the public

The project will be successful if the calculated advantages prove to be correct in practice and further vehicles are converted to Lithium batteries.

Towards the end of the project, a workshop was to be held to disseminate the experience gained in this project and to further stimulate replication so that all 700 vehicles will be converted from lead to Lithium batteries and additional electric vehicles will be put on the market in Nepal.

5. Project Review

5.1 Implementation of the Project

In Switzerland, Ingenieurbüro Eisenring and Ingenieurbüro Kuster were involved in the implementation of the project.

Engineering office Eisenring
Markus Eisenring worked from 2000 to 2006 for various organisations, e.g. Winrock International, SDC and others for the Nepalese electric vehicle industry and knew the scene very well. Through his efforts, the expertise of the EV industry was built up and various improvements could be made.
Markus Eisenring was project manager and did calculations, detailed clarifications, design proposals, evaluation of batteries and BMS and was responsible for the charging and measuring technology.

Partner Office: Engineering Office Thomas Kuster
Thomas Kuster is an electronic engineer. He was responsible for the electrical and electronic activities, developed various hardware for the project in Nepal and made calculations, assisted in the evaluation and execution of the charging technology and the BMS, the charging process, the measuring technology and on the installation.

Other people and companies from Switzerland were called in as needed.

In Nepal CEN, EVAN and Clean Cooperative were involved in the implementation of the project.

At the start of the project, Clean Energy Nepal (CEN) was appointed as project coordinator in Nepal. CEN worked closely with the Swiss project partners and ensured the proper implementation of the project on the Nepalese side.

EVAN is the umbrella organisation which includes all Nepalese electric vehicle organisations and was the main project partner in Nepal. Contact person is Umesh Shrestha. He is a doer and very active in

the EV field. He's the president of EVAN and also Managing Director and owner of Shree Ecovisionary and has experience in the procurement and import of materials. He also organised the execution of the work for planning and installation of the batteries, testing, measurements and putting into operation etc. EVAN is active in the promotion and expansion of the use of electric vehicles, as well as in raising awareness among the population. She deals with legal aspects and is also involved in the technical development of Nepal's electric vehicle industry

Another important partner is Clean Multipurpose Cooperative Society Ltd. (better known as Clean Cooperative). It is one of the organisations that supplies the vehicles with batteries, either for cash or through leasing. They also give credits for the procurement of the vehicles to the owners who drive them themselves and also procure spare parts. The contact person is the director Hridaya Manandhar. He is very active in the scene, owns two charging stations and vehicles and is a former president of EVAN.

Details of the Nepalese partners involved Appendix 1: Organigram

In the pilot phase, the Lithium batteries were imported directly by the Nepalese project participants. For other vehicles, the batteries were also imported by other importers.

In addition to EVAN and Clean Cooperative, other actors such as private individuals, organisations or companies also participated.

Replacement of the lead batteries by another type then Lead acid batteries was intensively assessed and analysed. It turned out that the best remedy is to implement Lithium batteries. The cost-benefit ratio of Lithium batteries is considerably better than of lead-acid batteries.

Under Swiss guidance, lead batteries were replaced by Lithium batteries in 10 vehicles. These vehicles belong to owners who have decided to install Lithium batteries. For these vehicles, they finance 81% of the costs for the battery system and the local costs for the conversion themselves. The conversion to Lithium batteries took place in a charging station, where the batteries of the vehicles with lead batteries are changed at noon and the empty battery sets are charged.

The conversion of 10 vehicles was carried out in close cooperation with the owners of Safa Tempos, who had agreed to participate in the project. They also participate financially in the project by paying the Nepalese part with their own funds.

After the first 10 Safa Tempos were equipped with a Lithium Battery System, the local players independently converted other vehicles to Lithium batteries, bought, and installed other Lithium battery systems. The conversion of the further vehicles was executed without financial support of Repic. Normally the owner of the vehicle has to finance 50 % of the cost for the installation of the Lithium battery system by his own money and 50% is being financed by a leasing company, for instance by Clean Energy.

We have actively promoted the use of the Lithium battery system, among others by making public all details of the Lithium battery system including part lists, brands and suppliers. Nobody has the right to use the Lithium battery system we have introduced or part of it exclusively for himself. Everybody who wants can use the system we have introduced and it is freely available. After the conversion of the first vehicles, another group of people made use of this provision and converted the vehicles 21 to 25. Thus, a continuation of the project is guaranteed, and no further Swiss intervention is necessary to install Lithium batteries in additional Safa Tempos.

The project had two phases:

Phase 1

This phase included the engineering, the purchase of the batteries, the battery management systems (BMS) and the chargers, benchmark tests and the installation of the batteries in 10 Safa tempos.
In particular, the following work was carried out in phase one:

Engineering and preparation works

- Verification of project parameters and final determination of layout concept and design parameters
- Examination of existing charging stations and chargers
- Evaluation of battery supplier, of appropriate Battery Management System (BMS) and battery chargers
- Determination of the type and brand of BMS and of the battery control and regulation parameters
- Calculations and supervision and detailed design of battery pack
- Quotations and purchase of batteries, chargers and BMS

Testing of the batteries outside the vehicle and mounting of the batteries

- Bench test of the batteries, BMS and charger outside and inside the vehicles
- Assembly of the battery packs and mounting of the batteries, charger and the BMS in the Safa Tempos
- Commissioning and supervision

Phase 2

The second phase included the testing, operation and monitoring of the batteries in the vehicles, training of persons involved, maintenance, the activities for replicating the use of Lithium batteries and the final works.
In particular, the following work was carried out in phase two:

- Testing of the batteries, the BMS and the chargers in still stand and when driving with the Safa Tempos
- Verification of the specified properties and of the performance
- Comparison of Safa Tempos with Lithium batteries and with lead acid batteries (kWh consumption, range performance)
- Projection of energy savings
- Compilation of testing results, workshop providing information for replication for use of Lithium batteries and final report

The achievements during project implementation are described in the chapter 5.3 and 7.

5.2 Technical Solution

Instead of the two sets of 12 lead batteries each (72 V, 200 Ah) of Trojan T-125, 24 Lithium iron phosphate (LiFePO4) batteries with a capacity of 300 Ah are used. Thus, one set of Lithium batteries replaces two sets of lead batteries. The Ah capacity of the Lithium batteries was chosen so that it can be used for a whole day. With one set of Lithium batteries 120 km can be done. Despite the larger capacity and the greater range, 1 set of Lithium batteries is lighter than 1 set of lead batteries.

Since Lithium cells with a capacity of 300 Ah are not easily available and at good prices, three cells of 100 Ah each are connected in parallel. This results in a battery pack of 300 Ah, 76.8 V and 23 kWh.
100 Ah LiFePO3 cells from Sinopoly are used.

A battery management system (BMS), which communicates with the chargers, is used. In our opinion the BMS of the company Elithion used by us is the best at the moment. This BMS guarantees the safe and long operation of the batteries. It ensures that the batteries cannot be discharged too deeply. An analogue output signal from the BMS is used to reduce the driving performance when the batteries are at a low limit and to switch driving off completely at a minimal limit. The BMS also prevents the Lithium batteries from being incorrectly charged or overcharged in the charging station. The BMS is connected to the charger via CAN bus. All parameters such as capacity, upper and lower limits for voltage and temperature and many more are easily programmable. The details were optimized to the operating conditions in the course of the project.

Each battery has a cell board that sends values to the BMS controller. In addition, each cell board has a balance booster. The passive balancing system can balance with a maximum of 2.2 A. Our own balance boosters have also been built, which can balance up to 6 A. These proved themselves well in one vehicle where they were installed on a trial basis.

With the BMS data can be acquired during charging and driving. Thus, the condition of the whole battery pack or of single batteries can be analysed and visualized.

4 different chargers were tested and installed. Almost all vehicles now run with a Chinese 3.3KW on board battery charger from TcCharger which can charge the batteries with 40 A (3.3KW HK-J Series Charger). This is by far the cheapest charger and has proven itself well in operation.

In each Safa Tempo a Battery Monitoring Instrument (BMV) is installed. It shows battery pack voltage, current, power, consumed Amp-hours, state-of-charge, time-to-go, makes a history of the charging cycles, protects the battery from deep discharge and it is programmable for different battery types.

Thus, the lifetime of the batteries is expected to extend from 12 months for lead batteries to an estimated 7 years for Lithium batteries.

5.3 Achievement of Objectives and Results

All goals were achieved, in particular:

State of the art:
- All 10 Safa Tempos are in operation now, equipped with Lithium batteries, the battery management system (BMS), the chargers and further devices
- Three of them since January 2017
- These vehicles meet expectations well
- Apart from the larger capacity and extended range, a set of Lithium batteries is much lighter than a set of lead batteries
- The service life is extended from 15 months for lead batteries to an estimated 6 -7 years for Lithium batteries

- In some cases, we can follow the daily journeys on the Internet, as some vehicles are equipped with a GPS. They travel 2,600 km to 3,200 km per month
- Since mid-January 2018, seven more Safa Tempos are in operation

- In the meantime, 15 more vehicles have already been converted to Lithium batteries. These were converted completely without further support of the REPIC project
- 10 of them are running since April/May 2018 and 5 of them since August 2018
- The last five were converted by another group of business people

Multiplication:
- The project has left a very good, positive impression on all those involved and on people from outside
- Word has got around that the vehicles prove themselves very well in operation
- In addition, many other owners want to use the new batteries
- Now several groups of investors and interested people want to convert more vehicles to Lithium batteries and have already started to do so
- Till now a total of 25 vehicles are running with this system
- Many additional owners of Safa Tempos now also want to switch to Lithium batteries
- This project has promoted the use of Lithium batteries
- Another interested group has introduced a Lithium battery system for Safa Tempos from Korea by LG. Currently there are three vehicles in operation and more are planned.
  They are working on equipping 100 to 300 Safa Tempos with this system.
- The equipment for installing another Lithium Battery Systems for 10 more vehicles was already ordered in 2018 and these vehicles are in operation since January 2019
- And many more Safa Tempos are going to be converted with different systems
- Close contacts were established with the press, a press conference was held and press releases were sent out. This made the project known to the public.

Future plans:
- There are plans to import Lithium battery systems from other manufacturers:
  . With other capacities for the Safa Tempos
  . For other cars (for instance buses)
  . For electric scooters
  . For E-rickshaws

For further details, see Report / Final Workshop: Development of the project and results Rev1

A battery life of 7 years is expected. The energy consumption of vehicles with Lithium batteries was compared on different routes with the energy consumption of vehicles with lead batteries.

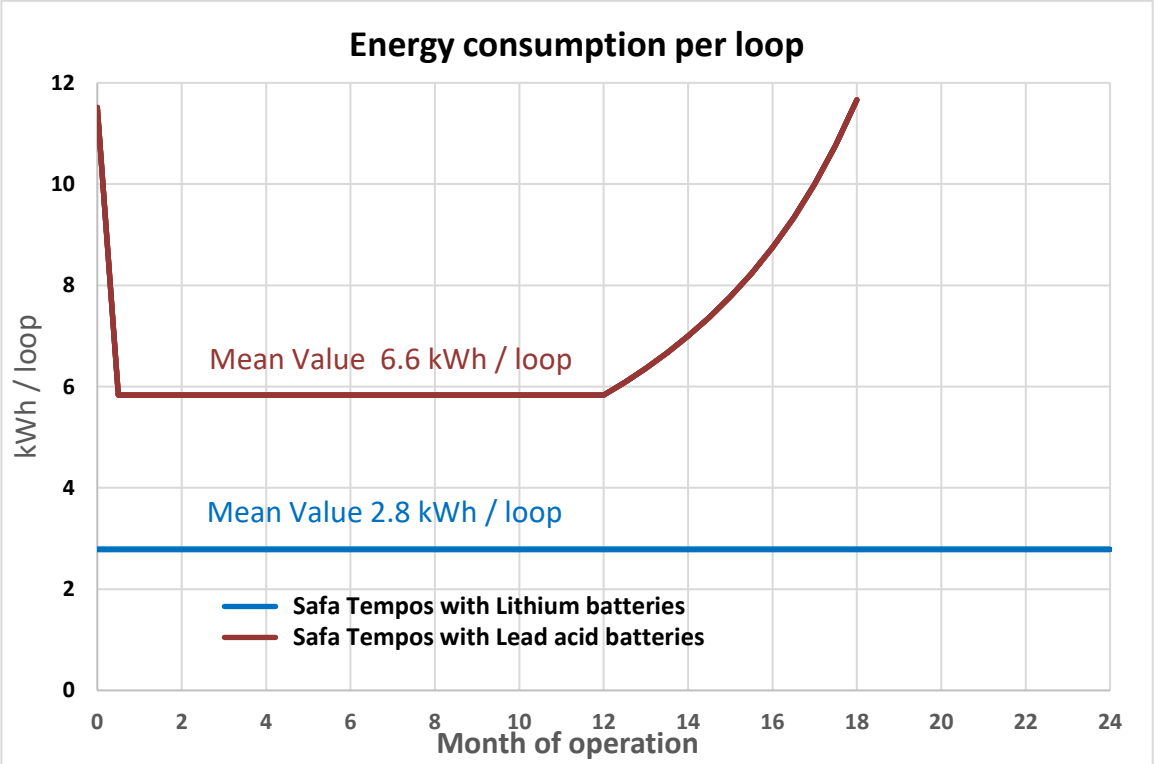
The motivation for retrofitting further vehicles lays in the successful everyday operation of the first 10 converted vehicles. Since the data on the performance and service life of the Lithium batteries were confirmed, financing organisations were prepared to finance the conversion of further vehicles. With increasing awareness, leasing companies are showing great interest in battery leasing.

Towards the end of the project, survey was made among drivers and owners of Safa Tempos with regard to satisfaction, energy savings, number of trips and personnel, mechanical maintenance, number of trips, etc. It is expected that in the lifetime of the batteries the profit from these additional benefits will be higher than the cost of the batteries!

For further details, see Report / Questionnaire Survey: Safa Tempo Data Analysis Report

As an example of the targets reached, energy saving is illustrated in the following. A lot of energy is saved with the Lithium batteries: We were expecting that with the Lithium vehicles, approx. 25% of energy can be saved. A survey conducted by CEN showed that our expectations were exceeded:

- The energy saving is more than 50%
- The average energy consumption was reduced from 6.6 kWh/loop to 2.8 kWh/loop



5.4 Tough Issues

There were also some tough issues in the course of project execution.
It turned out during the project work that substantial additional effort was required to get the whole project going effectively and sustainably. The time spent on the project and the number of trips to Nepal have been much more intensive than originally planned. This could not be foreseen during the preparation of the project.

The main reasons for the additional effort were the following:

- Already at the start, there were considerable delays in the import of the LiFePo4 batteries.
- The decree of the Nepalese authorities that all vehicles (including electric vehicles) older than 20 years of age lose their operating license led to a complete blockage of the project: Nobody was willing any more to convert his vehicle under these conditions. Lobbying was necessary to obtain an exemption for electric vehicles. Now the Safa Tempos can operate for 30 years.
- There was also an additional amount of lobbying effort required to ensure that Lithium batteries and other parts for electric vehicles receive the same customs tariff reductions as lead acid batteries. Meanwhile everything had to be started all over again due to a new government.
- There were also unforeseen technical problems because of electromagnetic disturbances caused by the existing drive system, affecting the operation of the vehicles. As a result, many actions had to be taken to reduce these, which required corresponding data acquisition and evaluation of the data.

5.5 Preparation of Multiplication / Replication

The use of Lithium batteries enables significant energy savings. With EVAN, Shree Ecovisionary and Clean Cooperative as main partners, stakeholders are involved to ensure sustainable project continuity. The EV industry will be strengthened by the low lifetime costs and the large profits from the ancillary benefits.

There was a training of the involved persons for the scaling of the used Lithium system. In addition, a documentation was handed in, in which the most important aspects in handling the new system are recorded. During the project, other companies willing to import the same Li system were also supported (knowledge transfer, also with the introduction of other Li batteries and BMS).
The Eisenring Engineering Office will continue to provide advice on the project from Switzerland within the limits of financial and time constraints.

5.6 Impact / Sustainability

The use of Lithium batteries enables significant energy savings.
Energy saving is 468’000 kWh/year with the 38 Safa Tempos equipped with Lithium batteries until end of January 2019.

With EVAN, Shree Ecovisionary and Clean Cooperative as main partners, the main stakeholders are involved to ensure sustainable project continuity. Thereby and by the low lifetime costs and the large profits from the ancillary benefits, the EV industry will be strengthened.

The electric vehicle industry has been active in Nepal since 1996. By using Lithium batteries as alternatives to lead batteries, an important boost is given to the continued operation and expansion of electric vehicles.

The implementation of the converted vehicles enabled 38 drivers to work, of which 20 new jobs were created. The actual conversion generated eight man-years.

Every day 900 passengers use a converted vehicle. This results in a transport of 324,000 persons per year for each converted vehicle. This results in a possible number of 227 million passengers per year.
In addition, 38 drivers and owners of vehicles are beneficiaries of this conversion.

As part of the conversion, 10 people were trained as workers for the conversion. 50 persons were instructed as drivers and six responsible persons of charging stations.

Each driver and owner of a Safa Tempos has an income of 360'000 NC per year.
The leasing companies earn on average 48'000 NC / vehicle and year. The leasing contract lasts three years.
Through the conversion of the vehicles, 8 people had an average income of 12'500 NC / month.

In one year the owner of a Safa Tempos converted to Lithium batteries has to pay 1’685CHF for the amortization of the lithium system, while in the same period an owner of a vehicle with lead batteries needs 2’765 CHF for amortisation.

As a side effect also new drive systems were introduced. It triggered the use of more efficient AC drives systems:

- BLDC motors and controllers, which are synchronous AC drive systems, were imported
- Asynchronous AC drive systems were introduced, which are running successfully since Dec 2018
- There are plans to import other drive systems

Thomas Kuster could optimise the settings of AC drive systems. One which was not running, operates well now and in others parameter settings were improved. In another drive system, he could advise a repair workshop which parts have to be added in the motor controller, to avoid early failures.

Some ready-made new vehicles with Lithium batteries were introduced in Nepal.
For instance:

- New Reva car by Agni Group
- BYD

the settings of AC drive systems, one which was not running, operates

There are plans to introduce new vehicles:

- EV's
- Electric buses
- E-rickshaws

In the course of the project it was clarified what happens to the Lithium batteries after the end of their service life. LiFePO4 batteries are much easier to recycle than lead batteries because they contain no toxic components. Recycling of Lithium batteries in Nepal has not yet been established. Also world-wide, this is only in its infancy.

A return to the manufacturers companies of the batteries is unlikely for financial and ecological reasons. But for Lithium batteries there is the possibility of a second and third life by using them, after they are no longer suitable for operation in electric vehicles, as stationary energy storage, for example for photovoltaic systems or for uninterruptible power supplies (UPS).

Another positive side effect is that many lead batteries are no longer disposed of in an uncontrolled manner, because they are being replaced by Lithium batteries.

In addition, the much longer battery life saves a lot of grey energy.

The project will help the electric vehicle industry to survive and expand, electric vehicles will not be replaced by vehicles with internal combustion engines, and Lithium batteries will also be used in other vehicles. In addition, the 4 to 5 times longer battery life saves a lot of grey energy.

6. Outlook / Further Procedure

6.1 Multiplication / Replication

After a Lithium battery system had been installed in the first 10 vehicles with the support of REPIC, the Nepalese partners independently equipped another 15 vehicles with the same Lithium battery system by the end of 2018. Due to the lower lifetime costs and the savings due to the side effects, the incentive to install Lithium batteries in other vehicles is great.

As already foreseen in the project submission and as was the case with other successful technologies, the use of Lithium batteries in Nepal was copied immediately because the use of Lithium batteries has proven itself. Some Nepalese people also searched for and found other Lithium systems on their own initiative.

Three more vehicles were equipped with a Korean Lithium battery system from LG and in January 2019 ten more Safa Tempos were equipped with another Lithium battery system from China by our main partner. We supported the main partner in doing so. The conversion of many more Safa Tempos to Lithium batteries is planned and partly already underway.

The project is integrated into the Nepalese context. In the application of this technology we worked directly with the local partners. The use of Safa Tempos has a long tradition in Nepal and is made much more attractive by the use of Lithium batteries.

By involving the important and right partners EVAN, Shree Ecovisionary and Clean Cooperative in this pilot project and by checking all relevant parameters, replication and implementation in other vehicles is guaranteed.

The project also initiated many other activities. Because it is a good business for the people involved, they are fully motivated to undertake not only the actual conversion of the Safa Tempos to Lithium batteries, but also other activities to improve the vehicles, such as the replacement of the old DC drives with modern AC drives. At the same time, the entire rear axle is replaced.

The use of Lithium batteries has given the whole scene a boost. Individual vehicle owners have already complained that they would not receive Lithium batteries fast enough and want to switch to a new drive system as quickly as possible.

There is a potential to save 8'600'000 kWh/year when all Safa Tempos are equipped with Lithium Batteries.

On January 3rd a workshop was held. The main purpose of this workshop was to summarize the results of the project, to inform once more the users what is important for a long life of the batteries and to advocate for replication of the using Li batteries.
The proceedings and the presentations can be downloaded from:
http://www.repic.ch/repic-en/projects/completed-projects/energyefficiency/eisenring-nepal/

According to the Nepalese partners, it is obvious that this project will open new business models. Not only will the 700 existing Safa Tempos benefit from this, but this technology will also be adopted for newly planned four-wheeled vehicles with AC drives.

Some sets of Lithium batteries were imported and have been successfully installed on E-rickshaws. This is especially important because there are about 18'000 E-rickshaws, running with lead acid batteries, in the Terrai region, which had replaced a large part of the 100'000 pedal operated rickshaws. The lead acid batteries, installed in the e-rickshaws, do not meet the expectation and were not economic, partly due to lack of knowhow. Therefore, an unwanted development started to take place that the e- rickshaws are being replaced by rickshaws with combustion engines. Lithium batteries contribute to stop this development.

6.2 Expected Impact / Sustainability

Due to the greater energy efficiency of vehicles with Lithium batteries compared to vehicles with lead batteries, more people can be transported with the same electrical energy available.

Lower operating costs make it more attractive to put a larger number of electric vehicles on the road. This reduces the need for fossil energy and improves air quality. All existing and additional electric vehicles replace vehicles with internal combustion engines and thus contribute to improving air quality in Kathmandu, as about 95% of the electrical energy in Nepal's public grid is generated by hydropower.

The use of Lithium batteries in the Safa Tempos is strengthening the entire electric vehicle industry in Nepal. New possibilities for the use of electric propulsion are pointed out, for example by installation in small 4-wheeled vehicles or in busses.

The use of Lithium batteries allows significant energy savings. The involvement of EVAN, Shree Ecovisionary and Clean Cooperative as main partners ensures a sustainable project continuity. The low life cycle costs and the high profits from the ancillary benefits strengthen the EV industry.

Women, who also own the vehicles, often drive the Safa Tempos. This opens up new opportunities for Nepalese women to earn a living.

7. Lessons Learned

In the run-up to the project, the conditions for such a project in Nepal were clarified as realistically as possible. No insurmountable obstacles were found.

The prospect that all the electric vehicle industry in Nepal will collapse no longer exists, because it received a new impetus from the successful use of Lithium batteries.

The biggest concerns for this project from the Nepalese side are the large initial investments. Successful implementation of the project dispelled these concerns.

Guarantees from battery manufacturers are not available worldwide. However, a successful operation with the first 10 vehicles created confidence in this technology. A good interaction of the selected components, battery set, BMS and charger, is required for a successful operation. A good BMS was an important prerequisite for achieving battery life.

There was a risk that the Lithium batteries will not reach the planned lifetime under Nepalese everyday conditions. These risks are minimised by appropriate installation of the batteries, optimal programming of the parameters in the BMS, careful electrical insulation of all live parts and training of the technicians involved.

It was also conceivable that the charging stations could try to charge the Lithium batteries with unsuitable devices and thereby destroy the batteries. To prevent this, the chargers are permanently installed in the vehicles (on board) and wired in such a way that maximum safety is guaranteed.

The project has proved the following for Lithium battery systems in the Safa Tempos:

Technical achievements

- Lithium batteries are an alternative battery solution to lead acid batteries
- Lithium ferrous phosphate (LiFePO4) technology used is safe and cheap among the Lithium technologies
- Technology is well proven
- 1 set of Lithium batteries replaces 2 sets of lead acid batteries
- With 300 Ah batteries the vehicles can run whole day @ 80% DOD
- No battery changes at noon --> no trip to charging station necessary --> safes energy
- Batteries can be fast charged (< 1 hour) (fast charger required)

Economic achievements

- Less workers required for battery management in charging stations
- No watering in battery → no cost for water and less labour cost
- Less total weight of vehicle, equivalent 2 to 3 persons
- Less wear of tires
- Less maintenance cost, stress and tear on chassis, suspension and rims
- Less energy cost, because of driving and charging
- Charger on board --> can be charged anywhere where electricity and plugs are available
- Average number of loops increased

- Battery Management System (BMS) ensures safe and proper charging and discharging of batteries and guarantees a long cycle life
- Longer battery lifetime then lead acid batteries (6 to 7 years expected)
- Smaller lifetime cost
- Battery cost will decrease in future
- Thus, the cost are lower and the income is higher
- Although the initial investment is higher than with lead batteries, the lifetime costs are much lower with Lithium batteries

Advantages of lead acid batteries

- Technology well know and established in Nepal
- Lifetime of batteries known
- Less initial cost
- No Battery Management System (BMS) is needed

From our point of view, the project was very successful

- Replication happens
- The Nepalese partners and other people understand now more from the Lithium battery technology
- They continue to install it in Safa Tempos and in other electric vehicles

After this we shall of course continue to support you also in future for any issues concerning EV's, be it Lithium batteries, AC drive systems, EV's, layout systems for EV's, calculations and others, as per our possibilities. For specific tasks, further assistance may be needed to.

Appendixes

Appendix 1: Photo Documentation

Examination of Existing Charging Stations and Chargers

1. Charging station at the former bus depot

2. Charging station of Umesh Shrestha

3. Battery charging station of Ram Hari Neupane

4. Checking the electrical net in a charging station

Project Coordination CEN

5. Rajan Thapa Project Coordinator, CEN

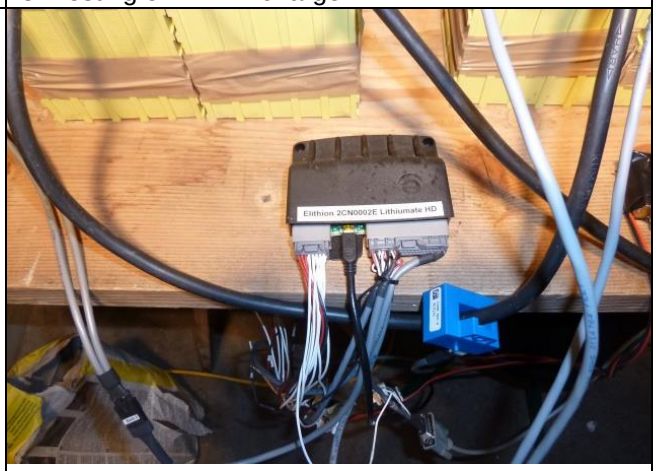
6. Damodar Dital of CEN explains driver Pralad how to fill in the battery charging/discharging chart

Testing of the Equipment outside the Vehicle

7. Testing batteries, cell boards, BMS controller

8. Testing of ZIVAN charger

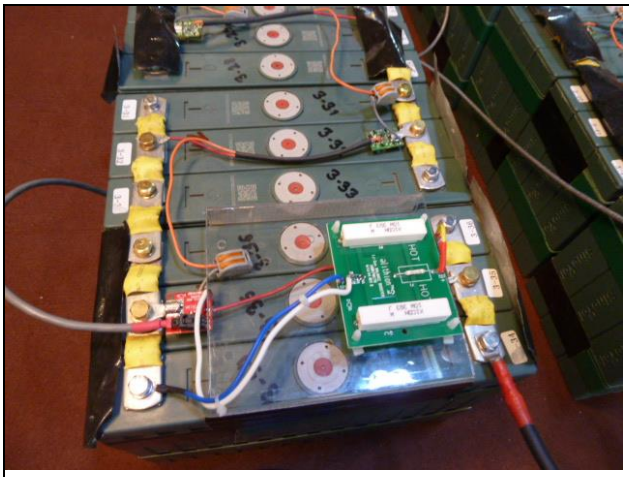
9. Testing of TcCharger chargers



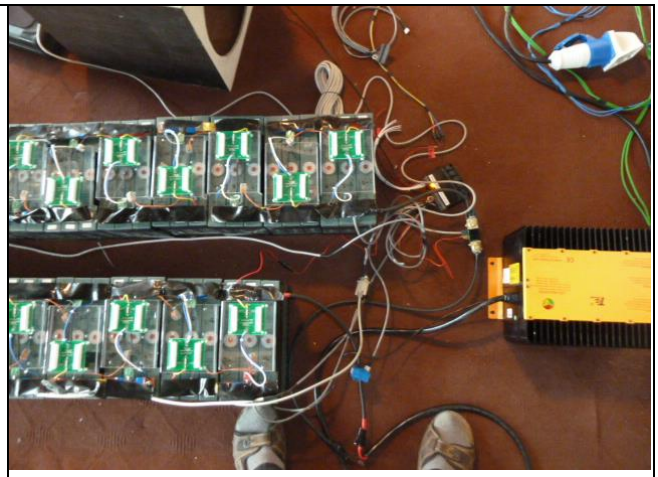
10. Testing BMS controller

11. Brainstorming session

12. Assembly of Lithium Battery sets outside the vehicle



13. Lithium battery set partly assembled



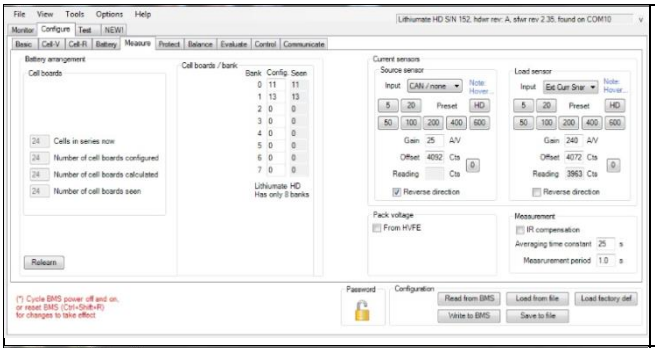
14. Charging 3rd battery set

Battery Management System (BMS)

15. Battery management system (BMS)

- Collects data from cell boards
- Controls charger over CAN
- Balances the battery pack
- Calculates state of charge (SOC)
- Generates battery protection (DCL)
- Enables data monitoring via USB

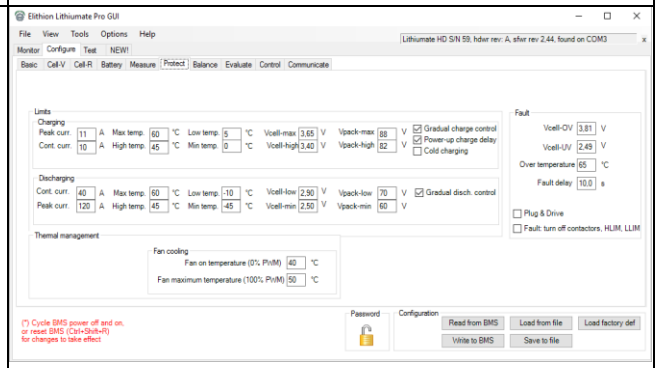
Graphical User Interface (GUI)



16. GUI: Graphical User Interface

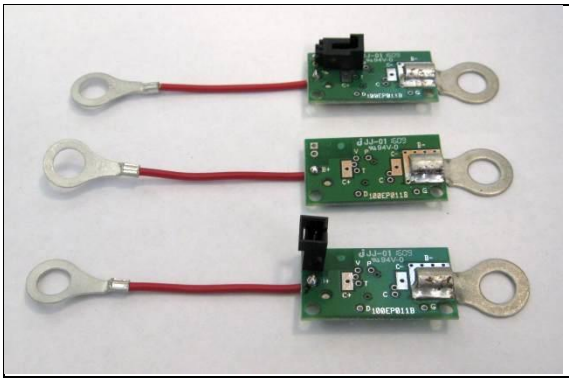
- The GUI (on any laptop or pc) can collect data from BMS via USB
- In Configure mode, all parameters can be set
- In Test mode, outputs can be set manually for calibration process
- The GUI enables analysis of the health of the battery pack

17. GUI Menu: Monitor / Status



18. GUI Menu: Configure / Protect

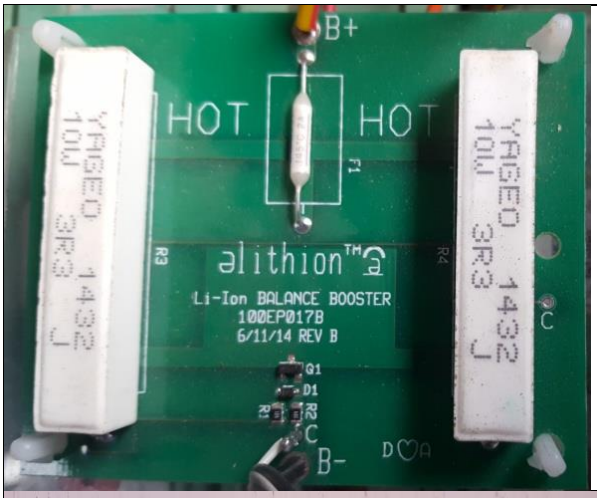
BMS Cell Boards



19. Cell boards

- are measuring temperature and voltage of a cell.
- have a small microcontroller, with a isolated 1-wire communication line and a small capacity for balancing (200mA)
- Each of them has a control output line for one or more balance boosters

Balance Boosters

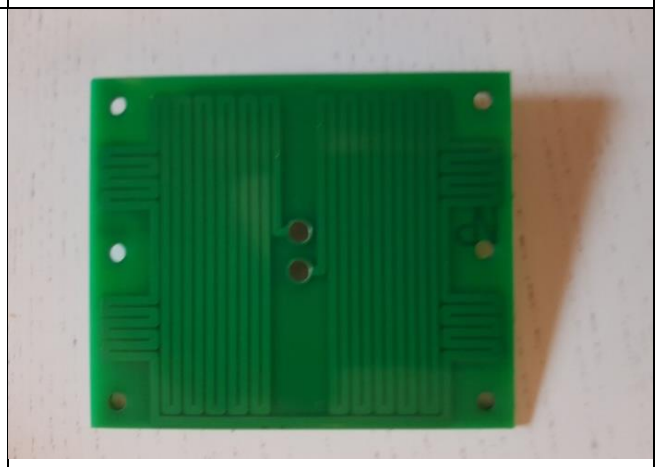


20. balance booster

Balance the cells with an additonal current of 2 A

21. Prototype of **6A** Balance booster, *developed at ZBW (St.Gallen)*

With security function :



22. Backside of Balance Booster

Booster begins auto balancing at **3.7V** and ends at **3.5V**

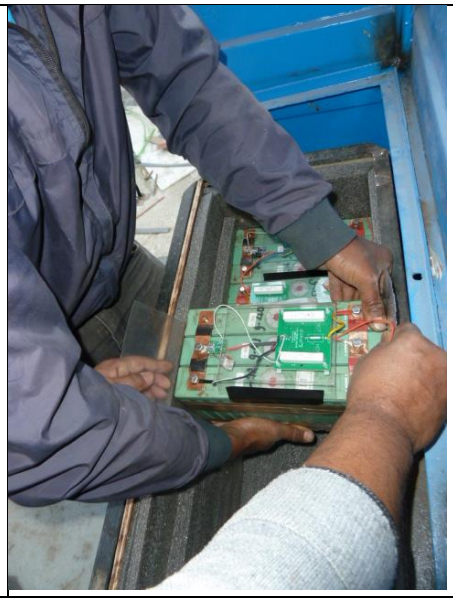
Battery Monitoring from Victron (BMV)

23. Display in Safa-Tempo : BMV

- Shows voltage, current, capacity of battery pack
- Makes a history of the charging cycles
- Protects the battery from deep discharge
- Is programmable for different battery types
- Has a model of LiFePo4 battery inside

Installation of the batteries, charger and the BMS in the Safa Tempo

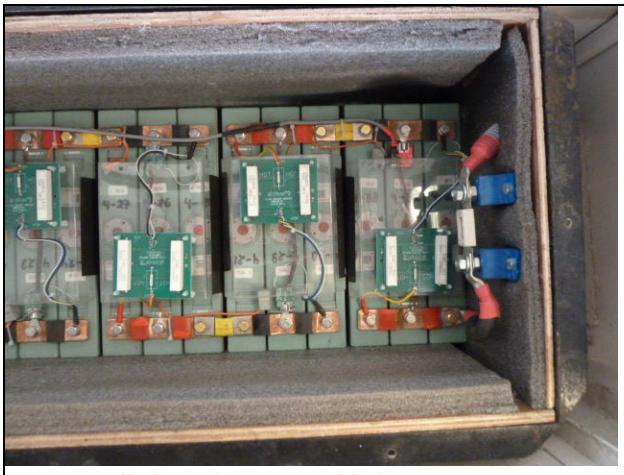
24. Mounting of batteries



25. Mounting of batteries

26. Nepali Technician Anil makes last tests

27. Wiring of Safa Tempo



28. Installation of Battery with fuse

29. Battery box fuse

30. Wired BMS controller box

31. Built in battery charger

Testing of Lithium Battery System on Test Runs

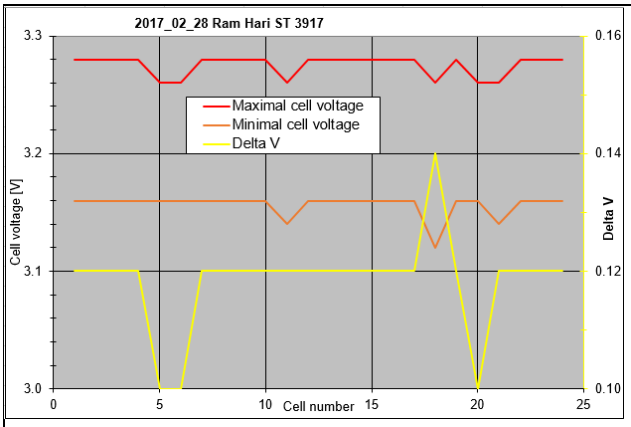
32. 1st Safa Tempo ready for test run

33. Converting team before first test run

34. Passengers in Safa Tempo

35. View from the passenger cabin on test drive

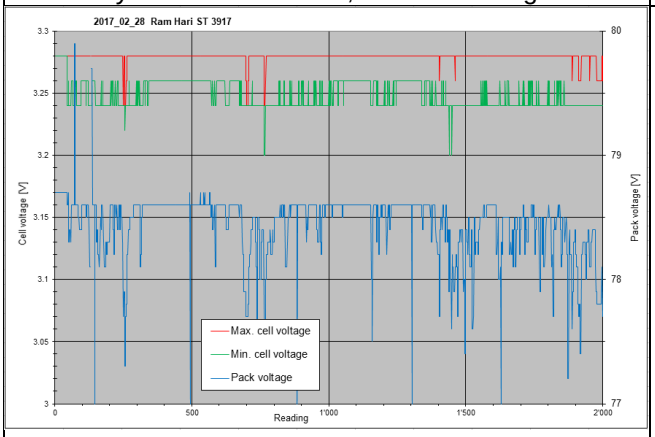
Data Acquisition with GUI when Driving



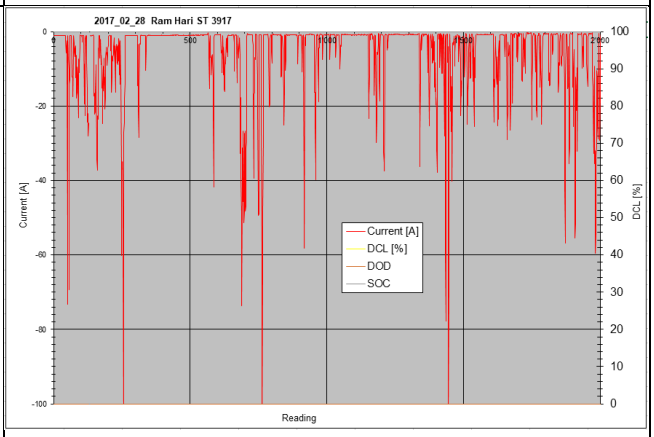
36. Analysation of data: min, max cell voltages

- With the GUI data can be captured during driving and during charging.
- Analysis of the data gives valuable infromation about the battery pack and the individual cells.

Pictures 36., 37. and 38 show part of a driving cycle.



37. Analysation of data: voltages



38. Analysation of data: current

Public relation Work / Meetings

40. Second project visit of Diepak Elmer, director SDC Kathmandu and Madan Sah, Swiss Embassy KTM, August 2018

41. Meeting with owners of charging stations

44. Meeting with Safa Tempo owners

46. Meeting with press representatives

More and more Safa Tempos are being equipped with Lithium batteries

47. More and more Safa Tempos are quipped with Lithium batteries

48. Technician Anil does maintenance work: checking of battery condition

49. Safa Tempos with Lithium batteries

50. ….are visible more and more

As a side benefit AC drive Systems were introduced

51. AC drive systems

52. ….safe even more energy

Other Lithium battery systems are introduced

53. Korean Lithium battery from LG

54.
Illuma Lithium battery set: 10 vehicles were equipped with these batteries in January 2019

Final Workshop

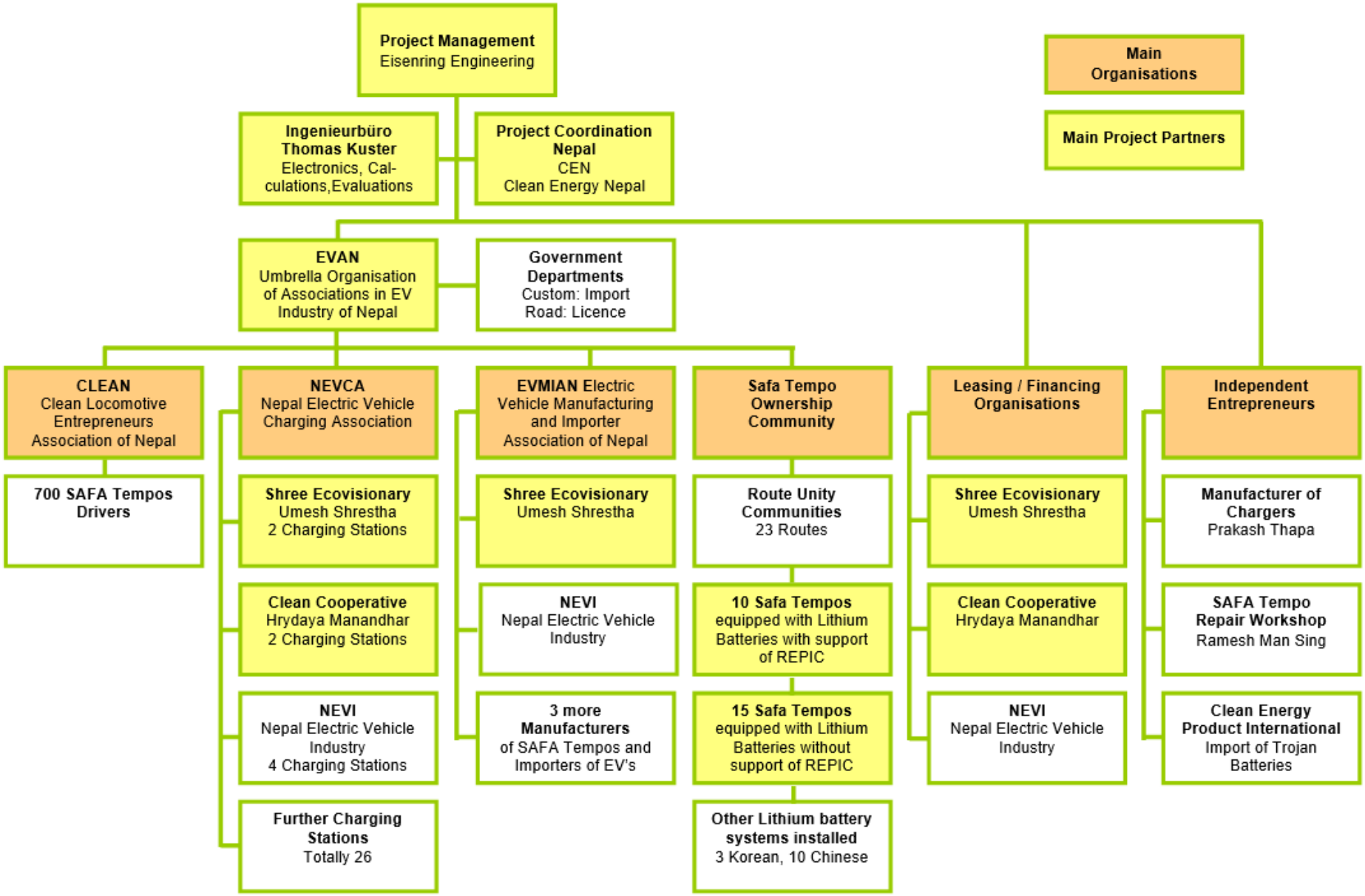
55. Various presentations were held

56. ….and an interactive discussion took place

58. Many participants

59. …from various groops were attending

Appendix 2: Organigram



Reports

Questionnaire Survey

Clean Energy Nepal, under the supervision of the Swiss partners, started documenting and recording several parameters of the vehicles replaced with the Lithium batteries since the initiation of the project. In summer 2018 they made of a questionnaire survey with the aim to collect data and compare the performance of the Safa Tempos with Lithium batteries with those with lead acid batteries.

The specific objectives of the questionnaire survey were

- To make comparative study of Lithium and lead acid batteries and test the feasibility of Lithium batteries in Safa Tempos.
- To examine the perception of users and performance of Lithium and lead acid batteries

The results of the Questionnaire survey are published here:
http://www.repic.ch/repic-en/projects/completed-projects/energyefficiency/eisenring-nepal/
Safa Tempo Data Analysis Report

Final Workshop

On January 3rd 2019, there was a final workshop of the project.

The proceedings and the presentations can be downloaded from here:
http://www.repic.ch/repic-en/projects/completed-projects/energyefficiency/eisenring-nepal/

- Proceedings
- Reliability of Li Battery to make Electrical Vehicle more Energy Efficient
- Development of the Project and Results
- Technical Aspects of LiFePO4 Batteries and BMS
- Technical matters that must be observed