E-mobility & DRE Innovations in Emerging Economies

UNIDO

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UNIDO NETWORK OF INVESTMENT AND TECHNOLOGY PROMOTION OFFICES
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Alliance for Rural Electrification
Shining a Light for Progress

Imprints

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About UNIDO ITPO Germany

The UNIDO Investment and Technology Promotion Office Germany (UNIDO ITPO Germany) opened in 2017 at the UN Campus in Bonn. It was founded based on an agreement between the United Nations Industrial Development Organization (UNIDO) and the German Federal Ministry for Economic Cooperation and Development (BMZ). ITPO Germany supports German and European technology providers and investors to find potential partners in developing countries. The office additionally advises companies and representatives from developing countries on sustainable and innovative technologies.

About ARE

With more than 200 Members, ARE is the global association for the decentralised renewable energy (DRE) industry, catalysing private sector-driven markets for sustainable electricity services, creating jobs and powering equitable green economies.

About the UNIDO ITPO Germany & ARE cooperation

The UNIDO ITPO Germany - ARE cooperation was established in the wake of the MoU signed between UNIDO and ARE in January 2019. Autumn 2020 marked the commencement of this cooperation with the common objective to foster cross-sectoral coordination, technology exchange and business matchmaking. The cooperation aims to showcase technologies, expertise and experience of German/European companies from the DRE sector in emerging markets. The cooperation also strives to facilitate interaction between key DRE stakeholders by providing a strong platform enabling further investments to be mobilised towards global energy access efforts and the achievement of SDG-7 and other SDGs by 2030.

Sustainable mobility solutions driven by decentralised renewable energy (DRE) systems in rural and peri-urban areas of emerging economies **can be a game changer** for reaching **prosperity and economic development.**

Contents

1. Introduction

The global mobility sector is increasingly becoming electric as a result of climate action, changing regulatory landscapes, shifting consumer behaviours, as well as technological improvements and reducing costs through innovations in battery technologies and charging infrastructure. This increased focus on sustainable transportation is triggering market growth for electric mobility (e-mobility) solutions and especially electric vehicles (EVs).

With an increase of e-mobility solutions powered by decentralised renewable energy (DRE) in rural and peri-urban regions of emerging economies, the potential for these regions to become the frontrunners of the future low-carbon mobility sector is high. This hypothesis is best exemplified by the case studies featured in the publication.

UNIDO ITPO Germany and the Alliance for Rural Electrification (ARE) have joined hands to promote the role of integrated DRE and e-mobility solutions to accelerate the transition to sustainable and decarbonised mobility by showcasing innovative real-life examples from emerging economies. The 13 case studies and an expert interview in this publication highlight key challenges and benefits of this transition, while also proposing key recommendations and a way forward.

The sustainable mobility sector will ensure the smooth and efficient movement of people and goods and thereby contribute to the immediate and long-term socio-economic growth of society. The overarching benefits can be encircled using the Sustainable Development Goals (SDGs), in particular SDG 3[1], SDG 7[2], SDG 9[3], SDG 11[4], and SDG 13[5].

This publication is dedicated to all companies taking pioneering steps by incorporating DRE solutions to power e-mobility. This not only boosts labour and economic productivity but also, on a broader scale, increases overall energy efficiency, thereby contributing to the decarbonisation of the mobility sector. The target audience for the publication are private sector companies and investors looking to enter the e-mobility space, the public sector entities considering establishing favourable environments for DRE-powered e-mobility solutions in their respective countries and regions and lastly, the international organisations, civil society, and local communities who are crucial at all levels of the project cycle to ensure their long-term sustainability.

Transforming the global mobility sector is vital for the success of the clean energy transition

The mobility/transport sector is one of the key contributors to air pollution and greenhouse gas (GHG) emissions accounting for about 17% or 846 billion metric tonnes of carbon dioxide equivalent (CO_2e) globally (see figure 1)[6]. Furthermore, the ongoing dependency on internal combustion engine (ICE) vehicles for over a century and the fluctuating oil and gas prices have indicated that the current economic, social, and environmental structures within the mobility sector are unsustainable. With less

1 UN, Ensure healthy lives and promote well-being for all at all ages, (online)

2 UN, Ensure access to affordable, reliable, sustainable and modern energy for all, (online)

3 UN, Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, (online)

4 UN, Make cities and human settlements inclusive, safe, resilient and sustainable, (online)

5 UN, Take urgent action to combat climate change and its impacts, (online)

6 Statista, Distribution of greenhouse gas emissions worldwide by sector, 2019 (online)

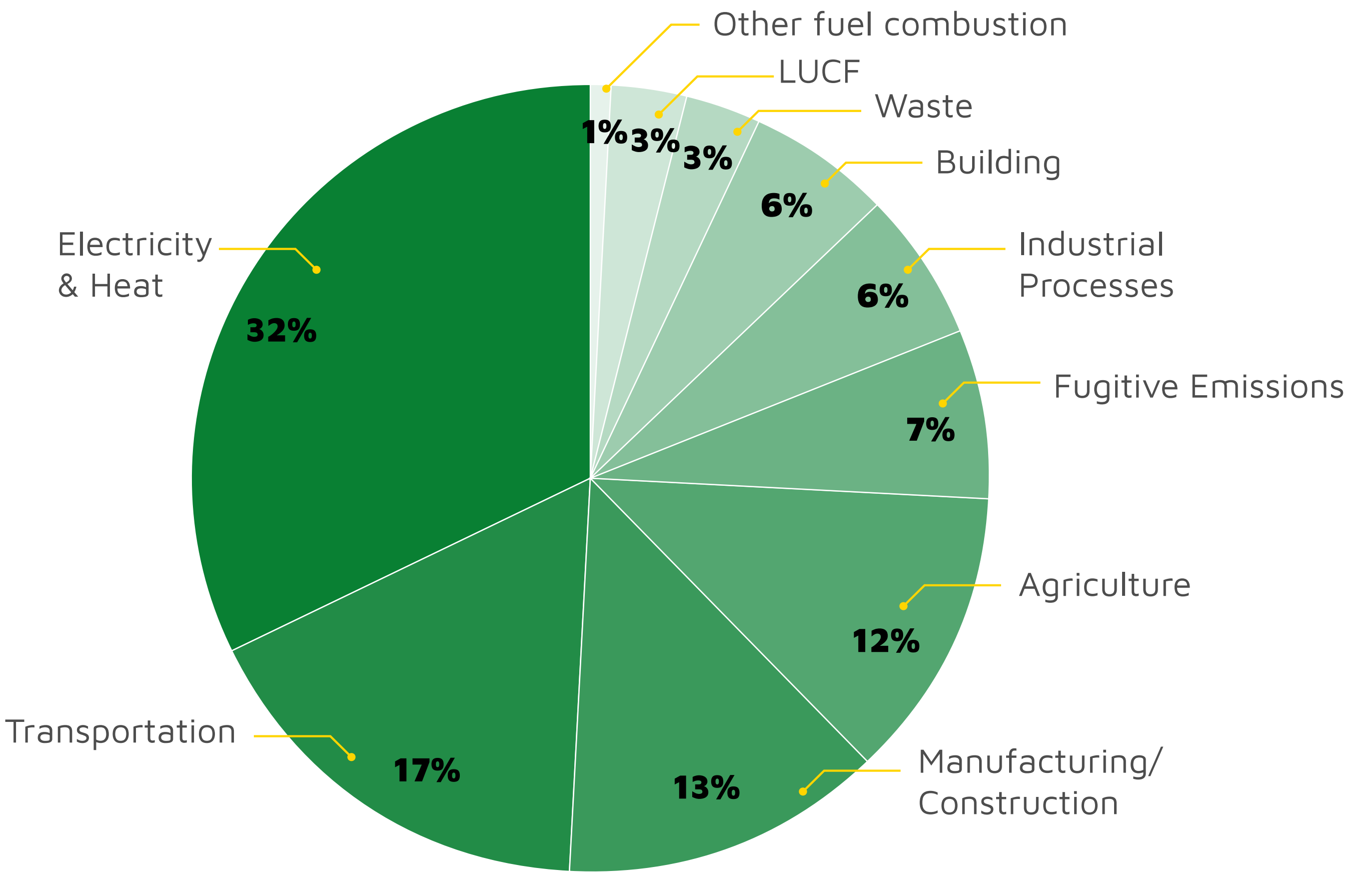

Figure 1: Distribution of greenhouse gas emissions worldwide in 2019, by sector

than eight years left until the achievement of the United Nations (UN) SDGs, urgent action is therefore needed to cut down on GHG emissions at a global scale.

The e-mobility revolution in emerging economies

Mobility challenges in emerging economies such as the lack of infrastructure, financial barriers and regulatory environment impact economic and social development. According to the International Energy Agency (IEA), the development of EV markets in emerging countries are still slow except for China.[7] The mobility sector plays a crucial role in such emerging economies by acting as the cornerstone of the economic activities. To facilitate national and international trade, the movement of people, and the transport of goods, a well-developed, sustainable and low-carbon mobility sector is vital.

Despite the ongoing growth of EVs on a global scale, renewable energy use in the transport sectors remains low with the majority (approx. 96%) of energy needs being met through fossil fuels (oil/petroleum), 0.9% non-renewable electricity and only 3.3% from renewable biofuels.[8]

7 IEA, Global EV Outlook, 2022, (online)

8 IEA, Tracking Transport, 2021, (online)

DRE-powered e-mobility solutions

While there is an urgent need to move away from fossil fuels, access to electricity equally remains a major challenge in many emerging economies. In 2020, 733 million people around the world did not have access to electricity, with the majority of people suffering from energy poverty located in rural and peri-urban areas.[9] As electricity demand increases further with the use of EVs, DRE systems can both supply electricity and enable the uptake of various e-transport options for rural communities. As a result, a global sustainable mobility transformation can be achieved.

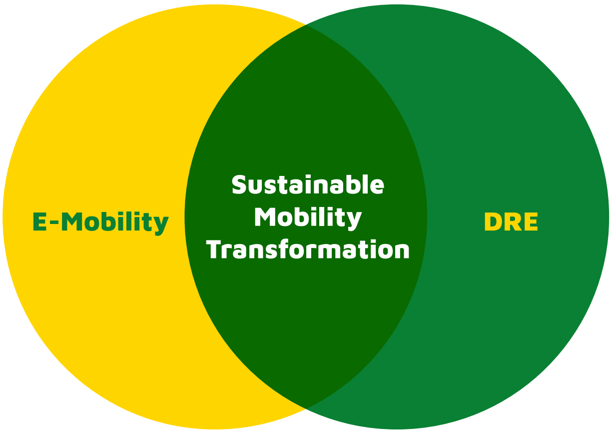

Figure 2: Sustainable mobility transformation

> DRE systems can be understood as the independent power generation and distribution units which are run by clean and renewable energy sources like solar, hydro, wind, geothermal, bioenergy and other clean sources.

DRE solutions are gaining traction in the electrification of remote population centres in rural and peri-urban regions. DRE solutions, such as clean energy mini-grids and solar home systems have significant environmental, practical, economic, and socio-economic merits over grid expansion in a majority of cases. According to a recent study, DRE systems offer a compelling value proposition based on three parameters[10] namely cheaper cost of deployment, cleaner than grid extension, and by being smarter, faster, and more reliable. The electric vehicles can act as mobile batteries balancing DREs by storing electricity in the times of high electricity production and can reduce the stationary battery needs.

Thus, to accelerate a sustainable mobility transformation, a shift to e-mobility coupled with innovative DRE solutions is optimal (see figure 2). The case studies in this publication outline various stakeholders who are involved in this interplay between DRE and e-mobility playing different roles, for instance, transport users, manufacturers and supply agents, private companies, governments or municipalities, civil society, and renewable energy providers. Collective and individual efforts are instrumental in establishing and scaling up successful DRE-driven e-mobility projects in emerging economies.

9 IEA, IRENA, UNSD, World Bank, WHO, Tracking SDG 7: The Energy Progress Report, 2022, (online)

10 ARE, Position Paper - Off-Grid Renewable Energies to achieve SDG-7 and SDG-13: Cheaper, Cleaner and Smarter, 2020 (online)

2. Upscaling the e-mobility sector through DRE solutions

The case studies included in this publication are located in a variety of different environments which require adaptable technologies. The table below presents an overview of the companies, project locations, the DRE charging technologies used, e-mobility solutions along with their usage and applications.

Company	Country	Charging infrastructure	E-mobility solutions	Usage & applications of e-mobility solutions	Outcomes
Asantys Systems	Tanzania	Solar PV system	Retrofitted electric safari vehicles	Safari expeditions to national parks and clean energy access in safari camps	• Reduced energy costs for the lodge by powering the lodges with solar panels • Reduced emissions and noise pollution for the animals and visitors • Reduced CO_2 emissions by moving away from conventional fuel
Ben & Berni Mobility Solutions	Ethiopia	Rooftop solar PV system + main grid	Electric car	Public and private transportation	• Raised awareness of alternative transport solutions • Avoided air pollution • The vehicle can potentially be used as a power source during blackouts
Bodawerk	Uganda	Solar PV system	Electric motorcycles, boats, tricycles and tractors for industrial applications	Private and commercial transportation of people and goods	• Facilitated increased income for motorcycle and tricycle riders as well as fishermen through reduced operational cost • Increased agriculture productivity and income for farmers • Avoided environmental pollution • Created local employment opportunities for youth and women • Became an enabler for many local EV start-ups by providing after-sales services to their EV fleet
ENGIE Equatorial	Uganda	Solar PV system	Electric outboards for fishing boats	Electrification of fishing boats	• Created local employment opportunities • Achieved reduced operational costs for fishermen • Avoided conventional fuel usage and hence improved the local air quality and steered clear of pollution • Providing power to residential, commercial and productive use customers
EURIST	Uganda	Solar PV system + main grid	Electric bicycles	Clean mobility for health centres, cargo transport, delivery services and tourism	• Created local employment opportunities • Achieved socio-economic improvements locally • Achieved reduction of air and noise pollution • Empowered women groups • Avoided environmental pollution • Long-term prospects of providing more services at the solar service centres

Mobility for Africa	Zimbabwe	Solar PV system	Three-wheeled electric vehicles (hambas)	Off-road transportation of people and goods	• With blended financing, enabled affordability for women to use mobility as a service • Facilitated improvement in local quality of living • Enabled access to increased and improved healthcare for locals • Provided local employment and opportunity for local agents to acquire skills
TryKe	Kenya	Solar PV	Electric motorcycles	Passenger and goods transportation	• Improved livelihoods by increasing profits and providing an alternative source of income • Avoided environmental pollution • Provided access to electricity to refugee households and businesses through the mini-grid
Volta View	The Gambia	Solar PV	Electric fishing boats	Electrification of fishing boats and clean water production	• Reduced costs of operation for fishermen and increased their net income • Provided access to electricity and clean drinking water • 'Battery to Go Cases' enabled other residential usages apart from powering boats, acting as a power source to provide microbusiness opportunities for women and their families • Avoided environmental pollution
Zembo	Uganda	Solar PV	Electric motorcycle (boda boda)	Transportation of passengers and light goods	• Local employment opportunities as well as lease-to-own agreements • Engagement with female drivers and other female staff to increase gender equality in the sector • Avoided environmental pollution • Maximised incomes for the local drivers • Plans to enhance the local assembly supply chain
Anywhere. Berlin	South Africa	Main grid	Electric cargo bikes	Cargo transportation	• Improved reliability of logistics for delivering food • Enabled socio-economic development for the community • Avoided environmental pollution • Created local employment opportunities
Biliti Electric	India	Battery swapping	Electric van	Delivering goods for local and last-mile logistics	• Established a clean and efficient delivery system • Cost per delivery significantly reduced • Built many mobile battery-swapping stations to support long-distance delivery routes
E-Trails Kenya	Kenya	Battery swapping	Electric bicycles	Public transportation and cargo ovements in hilly terrain	• Facilitated parcel deliveries locally • Enabled employment creation and capacity-building facilities for the locals • Avoided air pollution
GerWeiss	The Philippines	Main grid	Electric tricycle / tuk-tuk	Public transportation	• Addressed the issues related to noise pollution and air pollution Improved the safety of public transport and ensured comfort for passengers • Enhanced the income of the local drivers
betteries	Belize & Zambia	Solar PV	Various electric vehicles	Passenger and goods transportation	• Delivered affordable and clean energy and mobility solutions to highly remote, rural communities • Helped the farming community to improve farming output, reduce post-harvesting losses and generate substantial additional income • Improved mobility enables community access to health facilities and improved standards of living

3. Challenges, recommendations and way forward

The challenges are summarised here under the different barrier types of project planning & procurement, technology & infrastructure, regulatory, economic, capacity, partnership, social, and global to provide specific recommendations in the emerging economies context for project developers from different fields, private sector, technology providers and international development organisations.

Type	Challenge	Recommendation
Project planning & procurement	**Project planning:** Addressing problems with novel solutions calls for detailed planning considering specific risks in developing countries	• Incorporate risks related to lack of institutional capacity or trained personnel to execute projects • effectively into the project design • Ensure detailed planning considering the full project life cycle, investors for liquidity, coordination with stakeholders including government and civil society and lastly, gain the trust of beneficiaries • Technology providers should be prepared to swiftly adapt to the market needs as the situation changes • Keep innovating technologically and commercially to remain flexible
	Supply chain disruptions: The unavailability of appropriate equipment and products can hinder overall delivery of the project	• Plan the procurement to meet the needs on time and support development of technology partnerships and foster domestic supply chains for manufacturing of EV components in emerging markets
Technology & infrastructure	**Charging stations:** The lack of an easy and affordable charging infrastructure can have a significant negative impact on the adoption of the e-mobility solutions	• Develop appropriate charging stations for users to charge their EVs or batteries conveniently and inexpensively. Aim to establish charging station(s) at proximity for easy access e.g., battery swapping, DRE mini-grid, and/or national grid connection. • Consider using strategic location selection tools available e.g., geographic information system (GIS) mapping
Regulatory	**National e-mobility frameworks and policies:** The absence of appropriate policy in emerging economies leads to poor decision-making, time delays, loss of opportunities, and delayed market penetration	• Make it a priority to develop an enabling environment with conducive policy frameworks for DRE and e-mobility solutions • Form up national committee and working groups consisting of relevant ministries, departments, public sector organisations, private sector, project developers, academia and civil society representatives to drive the evelopment of enabling regulatory environment
	Threats of competition from an unregulated market: Counterfeit and low-quality products may be common, which poses threats to the market and in the long run, affects customer confidence negatively	• Ensure quality assurance of products and equipment by procuring them from certified suppliers with help of qualified procurement agents • Support the quality infrastructure of e-mobility and DRE components e.g., standards development, import regulations, test laboratories
	Heavy import taxes and bureaucracy: Import of products may be subjected to high levy and custom restrictions e.g., Li-ion batteries	• Consider tax exemption on imported e-mobility components to make e-mobility widely accessible and more affordable at a local context

Economic	**Access to finance:** High CAPEX costs impede the commercial viability of the e-mobility solutions and hinder the long-term sustainability of the projects	• Introduce incentives for technology providers to enable provision of their e-mobility solutions at lower CAPEX costs to unlock end-user affordability e.g., leasing • Consider selling price subsidies to make EVs commercially viable until market penetration is achieved • Always target high asset utilisation (shared and circular economy principles)
Capacity	**Technical know-how and skills:** Lack of technical knowhow for product development, local manufacturing, local maintenance and repairs	• Develop and impart training programmes to build the capacity of the local people to develop, maintain and troubleshoot the e-mobility solutions locally thereby creating jobs. This is crucial to save time, costs and ensure the smooth functioning of the projects and make them sustainable. • Consider supporting youth ntrepreneurship through incubation, mentoring, seed funding etc. to accelerate the market development
	Local research & development (R&D) and awareness: Lack of proper understanding of local needs and constraints causes difficulties in the project	• Invest time and resources in the foundation of the project first by identifying the main objectives of a typical e-mobility solution • Promote site-specific R&D and involve local stakeholders to adapt technology and projects to local contexts
Partnership	**Reliable local partnerships:** Lack of effective collaboration with the local stakeholders can result in project failure	• Identify and establish long-term partnerships with qualified local partners and civil society active in the field. • Engage with global programmes and initiatives in the field e-mobility and DRE to benefit from existing knowledge products and lessons learned (e.g., Global Electric Mobility Programme[11])
Social	**Consideration of vulnerable groups:** The voice of women and youth in the local context is important as only involving part of the population can result in limited uptake, improper management and project failure	• Conduct consumer needs assessment to ensure a good foundation for the project • Collect inputs and feedback from all concerned local stakeholders equally. This will lead to the development of customised solutions ensuring faster technology adoption locally. • Ensure community engagement to reduce social risks • Apply gender-lens investment principles[12] • Ensure that vulnerable groups (women, people with disabilities and youth) can benefit from e-mobility solutions such as making the public transport vehicles and infrastructure safe, accessible and affordable
Global	**Force majeure risks:** Project delays and inefficiency caused by natural/human-induced extreme events e.g., the COVID-19 pandemic	• Have a contingency plan in place, allowing for project duration flexibility, insurance, remote access and operation etc. • Prepare for global risks (pandemics, supply chain disruptions), climate induced disasters and geopolitical risks

11 UNEP, Global e-mobility programme, (online)

12 ILO, EU, UN Women, Guiding Principles for Promoting Investment with Gender Lens, 2021 (online)

4. Case Studies

4.1

E-mobility solutions with in-house DRE technology

This case study chapter outlines the projects which have access to DRE power generation facilities to power their e-mobility solutions at the time of this publication.

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Sunlight & batteries

fuelled eco-safari

Location
Serengeti National Park, Tanzania

Total project budget
< 1,000,000 EUR

Company
Asantys Systems (solar system integrator)

Partners
- Tanganyika Expeditions (safari lodge)
- Harald Olk (energy consultant and project developer)
- Elektro Fleck (provider of the individual solution to convert fuel cars to e-cars)

Project period
January 2018 – ongoing

Context

Disconnected from the Tanzanian utility grid, Tanganyika Expeditions operates its safari lodges in Serengeti using solar energy and lead battery storage.

E-mobility solution

The eco-safari has converted some of their safari vehicles from diesel to electric vehicles. Both the safari and service vehicles are charged using the solar power system provided by Asantys Systems.

Max capacity of vehicle(s)	• Toyota Landcruiser safari and service vehicles with a capacity of five to eight seats were used. High-quality modifications were made to the vehicles giving them a second (more sustainable) life.
Decision on target market	Site selection was based on factors including: • Saving fuel costs, reducing harmful emissions and distance from the nearest petrol station (60 km) Benefits of the solution: • No noise and engine smoke at the safari, reduced maintenance costs due to less wear and tear and eco-tourism
Local community engagement	• Strong interest and good communication with Tanganyika Expeditions who runs the safari • Engaged the community with steps such as, including needs assessment, implementation, training on solar photovoltaic (PV) and storage systems as well as EVs
Energy requirements for individual vehicles	• Battery capacity of 40-80 kWh depending on the electric safari vehicle model
Max operating distance per single charge	• 130-240 km depending on the electric safari vehicle model
Battery type	• Lead acid batteries for stationary power systems • Lithium-ion Phosphate ($LiFePO_4$) battery for the vehicles

DRE solution

Inhouse DRE capacity to power e-mobility solution	• Two systems with 55 kWp solar plant and 220 kWh battery system with SMA Tripower PV inverters • A solar and battery system was used to power the lodges and charge the cars
Energy storage & backup power	• 220 kWh battery for each solar power system with SMA SunnyIsland battery inverters

Outcome

- Lowered costs to run the lodges
- Reduced emissions and noise for the animals and visitors
- CO_2 emissions avoided
- Independence from conventional fuel usage
- Powering the lodges with clean solar energy

Key recommendations

- Find capable local partners
- Ensure long-lasting partnerships with the local stakeholders including beneficiaries
- Ensure quality assurance of products

Challenges & solutions

- Environmental and noise pollution was addressed by replacing conventional vehicles with e-vehicle solutions
- Landcruisers' retrofitting was resolved by finding a suitable company to provide this service

Contact

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Ben & Berni Mobile Development

Location
Addis Ababa, Ethiopia

Total project budget
10,000 EUR (equity)

Company
Ben & Berni Mobile Development

Partners
- Bernhard Glaser (design engineer)
- Ben Christ (financing partner, project coordinator)

Project period
July 2016 - ongoing

Context

A small solar-powered electrical vehicle prototype was developed. Electrical energy is generated through solar modules which were integrated into the roof of the car. The generated energy is stored in the batteries, which help drive the electrical motors.

Due to its proximity to the equator, Ethiopia is exposed to high solar radiation which is equally distributed over the calendar year. Therefore, there is a huge potential for public and private transportation to be powered with e-vehicles.

E-mobility solution

A solar-powered electric car was introduced as a viable e-mobility solution. The main features include:

- A tuk-tuk like car with a pick-up option
- Made-to-fit for the purpose of Ethiopian transport
- Ability to cover short distances (e.g., 100 km per day)
- Adaptable for rural transportation
- Zero fuel consumption
- Removal of gears as an electrical hub-motor is used
- Solar modules mounted on the roof of the car

Max capacity of vehicle(s)	• Vehicle empty weight = 320 kg/Max weight = 600 kg • Max load = 280 kg (max 4 persons or fewer persons with additional transport of goods)
Decision on target market	• The tuk-tuks offer a fuel-independent rural transport solution • Solar PV has proven to work sufficiently to drive small vehicles (applicable in tropical regions only because of intense solar radiation availability) • Ethiopia was chosen as the stakeholders were based in Ethiopia

Local community engagement	• Meetings with the local community • Explanation of the working principle and function of e-mobility • Vehicle performance shows showcasing the benefits • Free test drive opportunities for the local community
Energy requirements for individual vehicles	Average energy consumption of vehicle = 5.9 kWh/100 km at low speed (20-25km/h) and on flat terrain/medium load
Max operating distance per single charge	• 55 km (on a very sunny day, per solar charge) • 20 km (on a rainy day, per solar charge)
Battery type	Ordinary lead-acid starter batteries: 4 x 12 V/70 Ah

DRE solution

Inhouse DRE capacity to power e-mobility solution	• The vehicle gets its charge through the mounted solar PV rooftop (900 Wp) • The vehicle can also be charged through a 230 V AC/48V DC socket charger • Simultaneous charging with the above-mentioned sources is also possible • Generation capacity is estimated to be 3.8 kWh/day (on sunny days only) • During daylight hours the vehicle charges itself • In rural off-grid areas (with no AC 230 V available), the self-charging mechanism is an outstanding feature • While the vehicle is stationary (or moving), part of the generated/stored energy can be used to power various applications – via a 230 V AC inverter port
Energy storage & backup power	70 Ah/48 V = 3.36 kWh (with 50% usable capacity amounting to 1.68 kWh)

Outcome

- Awareness raising on alternative transport solutions
- Fuel usage avoided: 2.5 l of petrol/100 km
- CO_2 equivalent avoided: 5.75 kg CO_2/100 km
- In times of national grid blackouts, the vehicle (in stationary mode) can be used to pump domestic water and/or run a refrigerator, deep freezer, LED TV, charge mobiles, laptops, grind coffee etc.

Challenges & solutions

- Importing components into Ethiopia can be prohibitive as customs restrictions apply and there is a high import tax (often 45% of goods value)
- The EVs solution presented in the case study is not (yet) formally registered and has not at this stage been allowed to drive on public roads

Key recommendations

- Promote the integration of e-mobility solutions in emerging economies
- Policymakers should consider e-mobility as an alternative transportation solution and enable a favourable environment for e-mobility solutions

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Shareable & circular Li-Ion batteries for Africa

Location
Uganda

Company
Bodawerk

Total project budget
> 1,000,000 EUR (self-financed & boot-strapped)

Project period
March 2017 - ongoing

Context

Bodawerk has developed a multi-purpose Lithium-ion (Li-ion) battery pack powering different applications. The transition from oil to renewable energy requires the introduction of new energy storage at scale. Bodawerk believes in the potential of Li-ion batteries in the African context.

Motorcycles, tricycles, fishing boats, tractors, solar, and mobile energy systems require affordable and long-lasting batteries to make the energy transition a reality. The company has developed a standardised battery pack to unlock economies of scale for all of these applications. In addition to that, the battery is designed according to the principles of a circular economy allowing for easy reuse, repair and recycling.

E-mobility solution

The following e-mobility solutions were introduced:

- E-motorcycles
- E-tricycles
- E-tractors & other agricultural machinery
- E-fishing boats
- Hybrid e-car (pilot)

Max capacity of vehicle(s)	• E-motorcycle: 250 kg (including one rider and one passenger or more) • E-tricycles: 500 kg confirmed (product still in development) • E-tractors: varying transportation capacity ranging from 150-1,000 kg (with a trailer) • E-fishing boats: around 250-500 kg of fish
Decision on target market	• Bodawerk targets industrial (productive) applications that are currently powered by petrol • The existing cash flows going into fuel, oil, maintenance, and spare parts provide the most viable business case for the deployment of battery-powered solutions
Local community engagement	• Bodawerk is based in Uganda. Testing and development of the batteries with a consumer-centric approach together with the end-user was followed.

Energy requirements for individual vehicles	• E-motorcycles typically require between 4-6 kWh of energy per day to cover 100-150 km • E-tricycles require 2-3 times the amount of energy depending on the load • E-tractors require about 8 kWh of electricity per acre of land ploughed (4,000 m^2) • E-fishing boats require about 8 kWh of energy for 30 km of range on the lake
Max operating distance per single charge	• E- motorcycle single rider: 170 km • E- motorcycle productive use case: 120 km • E- tricycle: 50 km (1 battery) • E- fishing boat: 30 km (2 batteries)
Battery type	• Li-ion batteries, 48 V DC • Li-ion NMC cell chemistry

DRE solution

Inhouse DRE capacity to power e-mobility solution	• Various solar hybrid systems ranging from 2-36 kWp are available for EV/battery charging. The total collective generation capacity is close to 100 kWp. • The batteries can also be charged with solar energy or on the grid
Energy storage & backup power	• Solar hybrid system is connected to the national grid

Outcome

- Motorcycle riders: increased income through reduced operational cost
- Tricycle riders: increased income through reduced operational cost
- Agriculture: increased income, less effort, higher productivity
- Fishermen: increased income through reduced cost
- Environment: less pollution
- About 2.5 t CO_2 per motorcycle per year, about 5 t CO_2 per tricycle per year and up to 35 t CO_2 per fishing boat avoided
- The project develops, produces, maintains and recycles batteries locally creating green and decently paid jobs in future industries with a focus on youth and women
- The company is an enabler for many local EV start-ups providing after-sales services to their EV fleet

Challenges & solutions

- The products imported are often not fit for the local market. The project addressed this through local product development.
- No incentives for EVs in place
- High level of bureaucracy for start-ups stifling development
- The project has integrated pay-as-you-go (PAYGO) technology to make application batteries financeable

Key recommendations

- Local development to achieve product-market fit
- Always target high asset utilisation (shared and circular economy principles)
- Financing must be part of the solution
- Training and capacity building to ensure proper maintenance of technology

Contact

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E-outboards for fishermen

on Lake Victoria

Location
Lolwe Island, Namayingo District, Uganda

Total project budget
244,880 EUR (grant funding by Powering Renewable Energy Opportunities (PREO) Programme, co-funded by IKEA Foundation and UK Aid via the Transforming Energy Access platform)

Company
ENGIE Equatorial Ltd. (ideation, design, implementation and execution - own and operate)

Partners
- IKEA Foundation (co-funder via the Transforming Energy Access platform)
- UK Aid (co-funder via the Transforming Energy Access platform)
- STIMA Lab – University of Massachusetts Amherst (technical partner for data acquisition)
- Energy4Impact (support on Monitoring & Evaluation (M&E) of the project outcome)

Project period
August 2020 - November 2022

Context

ENGIE Equatorial, an integrated energy services provider, commissioned a solar hybrid mini-grid in the Lolwe island, bringing power to > 3,800 households and businesses and powering a productive hub. In this context, the e-mobility pilot aims to deploy and test 15 electric outboards for fishing applications to reduce the environmental impact of polluting Internal Combustion Engines (ICE). The project will test the economic and technical feasibility of different business models, strictly focused on fishing applications on Lake Victoria.

Academic papers and blog posts are publicly available to share experiences and lessons learned with a focus on the technical, environmental, social, economic and commercial aspects of the systems. By sharing their experience, ENGIE Equatorial intends to support similar projects and other developers to accelerate the global transition towards more sustainable and low-carbon mobility.

E-mobility solution

15 boats equipped with electric outboards and Li-ion battery banks were introduced as the e-mobility solution.

Max capacity of vehicle(s)	• A fishing boat can weigh up to 2 t. The weight of the catch varies between 200-500 kg, depending on the season. • The electric outboard and the batteries are around 100 kg • Usually, two people take part in a fishing trip

Decision on target market	• ENGIE Equatorial installed a mini-grid in the project site to provide electricity services as well as to enhance the livelihood of local people • Fishing activities take a large share of e-transportation on the lake • The mini-grid project supporting the e-mobility is one important aspect of the company's business model among others • E-mobility solutions introduced an anchor load to the mini-grid
Local community engagement	• Several surveys and community-engagement meetings were held to assess the community's needs • A cohort of e-mobility ambassadors was selected within the fishing community to test the systems, provide feedback and share the experience. In effect, a Human-Centred Design (HCD) approach was utilised.
Energy requirements for individual vehicles	• Each electric outboard consumes between 5-7 kWh of electricity for each trip, with an average electric power demand between 3-4 kW • The recharge is provided through chargers connected to the mini-grid
Max operating distance per single charge	The maximum operating range observed so far is between 20-45 km depending on the speed, loading and weather conditions on the lake
Battery type	Li-ion batteries

DRE solution

Inhouse DRE capacity to power e-mobility solution	• Solar hybrid mini-grid, consisting of 600 kWp of PV capacity • The batteries for e-mobility are charged via the distribution grid of the solar hybrid mini-grid • The charge happens exclusively during the daytime, so the energy source is 100% solar • The mini-grid supplies power to the entire island • E-mobility charging is just one of the electricity-related services covered by the PV plant • Other services/products include the production of ice for fish storage, fish drying and potable water purification unit
Energy storage & backup power	• 360 kWh Li-ion storage for night-time consumption and a 200 kVA backup diesel generator • For e-mobility applications, recharge is allowed to take place exclusively in the daytime with direct solar charging • Fishing activities are predominately overnight while the batteries are charged during the day

Outcome

- Creation of three local permanent part-time jobs for battery recharge and asset management
- Reduction of operation costs for fishermen by an estimated 20-60% (depending on cases)
- The approximate amount of gasoline saved would be between 1,628 and 2,750 l per year per boat
- The estimated amount of CO_2 emissions saved would be between 57 and 96 t per year
- Access to energy for > 3,800 households and businesses, one water purification facility, one fish drier and four ice machines

Challenges & solutions

- Equipment costs are high, but the economic viability of the business is possible
- Engines suffer heavy use and outboards as well as accessories are prone to damage. This is fixed by replacing the current outboard propellers with more robust material and engaging the community on best practices to maintain these assets.
- It is feasible to design a battery-swapping model, but it involves the removal of the modules from the boat at every recharge, which is not easy to perform on the dock. Thus, it is recommended to adopt battery modules of max 30 kg each.
- Batteries are expensive, and their duration is crucial for the economic sustainability of the project. They should therefore be handled with a lot of care.

Key recommendations

- Development of local know-how on maintenance and troubleshooting is essential
- Keeping a stock of spare parts is recommended
- Equipment manufacturers should develop a more robust and resilient design for this type of application, to reduce the occurrence of damages and increase equipment lifetime

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E-bikes transporting people and goods in urban and rural areas

Location
Uganda

Total project budget
193,146 EUR (grant), 193,146 EUR (material costs + in-kind contribution)

Organisation
European Institute for Sustainable Transport (EURIST) e.V. (project and network coordination, representative for project promotion, contact person for dealer and sales network, R&D in the energy supply area for bike operation with sustainably obtained solar energy, contributed to new African e-bike design)

Partners
- First African Bicycle Information Organisation (FABIO) (project management Uganda, coordination of service centre, training in assembly and two-wheeler mechanics, R&D in the energy supply area for bike operation with sustainably obtained solar energy, contributed to new African e-bike design)
- Kreditanstalt für Wiederaufbau (KfW DEG) (project financer)
- HNF Nicolai (Germany) (e-bike design and development coordination)
- HERO Cycles Limited (India) (e-bikes supplier and financier)

Project period
November 2020 – October 2022 (project period extended due to COVID-19)

Context

As the African continent is expected to grow substantially in the upcoming years, a series of challenges will come along if the mobility sector does not provide an alternative and sustainable means of transport for people and goods in the near future. As more people will populate the continent, the demand for transport will increase, which will foster further urban mobility issues, such as congestion, and air and noise pollution. An increase in the population also means a higher demand for local jobs and economic opportunities.

Therefore, the AfricroozE, an innovative, affordable and modular e-bike capable of carrying a payload of up to 100 kg was designed by HNF Nicolai in cooperation with FABIO and EURIST. The solar-powered AfricroozE has various use cases and can be used as a taxi, a delivery vehicle or in the tourism sector.

Besides being independent of fossil fuels and rising fuel prices, the solar energy component of the e-bike facilitates rural mobility through the local installation of PV panels. This enables more social use cases by using the e-bike as an ambulance or a water transporter - even on rough terrain, thanks to its off-road capabilities.

E-mobility solution

Robust e-bikes were introduced.

Max capacity of vehicle(s)	• High loading capacity of 100 kg on the rear carrier with a speed of up to 30 km/h • Long tail carrier to carry people or goods
Decision on target market	Target groups were chosen based on a combination of: • Providing an environmentally friendly, low-cost mobility option to marginalised groups that have no access to mobility • Providing alternative options to groups that depend on CO_2-emitting fossil fuel-powered mobility • Creating access to employment (taxis & delivery e-bikes as well as mechanics) Uganda was the market of choice due to: • Significant experience working in the country • Longstanding and reliable local implementing partner
Local community engagement	• Local implementing partner FABIO was established as the first point of contact in Uganda for issues relating to sustainable goods • FABIO has been operating a bicycle centre (workshop, bike shop and rental) since 2015 • FABIO is also an expert in community engagement projects
Energy requirements for individual vehicles	• 0.5 kWh needed per single charge of a battery (36 V battery) • For the 80 e-bikes within the project, assuming that on average batteries are charged every second day and that users take a day off each week to rest, the energy requirement of one e-bike would correspond to 78 kWh and to 6,240 kWh per year for the whole project
Max operating distance per single charge	50 km
Battery type	• 36 V Li-Ion batteries • Recharged by solar energy from established solar service centres

DRE solution

Inhouse DRE capacity to power e-mobility solution	• Construction of two local solar hubs with integrated e-bike repair and rental station • Each hub is equipped with solar panels and batteries for overnight charging • The first one is a DC-DC system equipped with a total of 1,980 W (6 x 330 W panels) providing approx. 8.2 kWh per day • The second smaller one is a DC-AC system equipped with a total of 1,020 W (3 x 340 W panels) providing approx. 4.1 kWh per day • A DC-DC system allows quick repair of single parts without compromising the full system and charging of other e-bikes (e.g., easy replacement of step-up booster or charge controller) • A DC-AC system involves fewer parts, which are easier to find in local markets • Total generation capacity: 12.3 kWh • DC-DC systems are not yet widely distributed in Uganda and other African countries • Opting for the DC-DC system technology gives insight into new perspectives and encourages/enables the uptake of this innovation
Energy storage & backup power	• Both systems are equipped with four and two 100 Ah/12 V batteries, respectively, allowing overnight charging • Backup power through the centralised grid with 84 % hydropower

Outcome

- Creation of local employment opportunities
- Improvement of living conditions e.g., access to health services, access to markets, access to (cleaner) water sources, micro-transportation
- Reduction of air and noise pollution
- Improvement of rural public services (ambulance, water provision, resilience)
- Empowerment of women groups through the provision of water carrier e-bikes and increasing their mobility
- Saving money by avoiding conventional fuel usage
- Depending on the model split, the net CO_2e reduction per year of one e-bike ranges between approximately 2.5 and 2.9 t CO_2e. The CO_2e savings per bike is approximately five times higher than the production of an e-bike.
- Long-term prospects are to provide access to services (such as Wi-Fi and computers to use, phone charging, and printing) at the solar service centres
- Social benefits as service centres become safe spaces for the local population to congregate

Challenges & solutions

- COVID-19 delays were addressed by receiving an extension
- Technical inadequacies during pilot phase were addressed by revising designs of the e-bike in these areas
- Multinational partners' coordination with differences in working structures and expectations were addressed by encouraging open, frequent and clear communication
- Extremely high import tax on e-bike mobility in Uganda was addressed through the application of a tax exemption by the KfW

Key recommendations

- E-bike mobility is relatively new to the African continent and therefore, political and institutional support is vital
- In the long-run, combined interregional tax exemption efforts need to be organised by different institutions to make e-bike mobility accessible and affordable to the African population
- Cohesive regional policy, specifically on import regulations, would encourage more funding and investment in this sector

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Hamba fleet mobility solution

Location
Chipinge, Zimbabwe

Total project budget
900,000 EUR (grant), 350,000 EUR (equity)

Company
Mobility For Africa (MFA)

Partners
- We Effect (development partner)
- Zimbabwe Diary Farmers Association (ZDFA) (local partner)
- Dairibord (local partner)
- Zenergy (technology provider)
- Toyota Mobility Foundation (financier)
- EEP Africa (financier)
- AECF (financier)
- Dubai Expo Live (financier)

Project period
August 2022 - ongoing

Context

The lack of access to reliable, safe and efficient last-mile solutions in rural Africa is a key barrier to socio-economic and healthcare improvements.

Physical isolation prevents large areas of the continent from reaching their true agricultural potential. A farm's profits will never increase without the ability to transport produce to markets. Poor terrain means that urban transport solutions are not fit for purpose: fewer than 40% of rural Africans live within 2 km of an all-season road.

Designs of existing transport options are tailored to men and exclude women. Rural women spend long hours carrying heavy loads to market with crops rotting in the process, women die during childbirth due to lack of access to a health centre, children cannot access education and economic opportunities are missed due to the considerable distances from resources.

Available modes of transport are flawed: second-hand cars are costly economically (purchasing and operating) and environmentally (running on fossil fuels), bicycles/motorcycles limit the ability to carry heavier items, bike/trailer alternatives like tuk-tuks are not suitable for rural off-road needs.

E-mobility solution

MFA leases out and finances a fully serviced fleet of GPS-enabled three-wheeled electric vehicles (hambas) as a safe and robust alternative to withstand the unique off-road conditions and is energy-efficient. This solution will be able to service the daily transport needs of farmers, move larger quantities of commodities to the market and do so at reasonable costs. MFA also provides all the after-care services to ensure that the farmers and other users are never immobile.

Max capacity of vehicle(s)	Up to 400 kg
Decision on target market	• Small-scale dairy farmers were targeted due to their daily needs to commute to the dairy collection which needed affordable and environmentally friendly mobility solutions • Farmers for Dairibord to support them with efficient milk collection to avoid wastage and enhance income for locals

Local community engagement	• Established partnerships with WeEffect, ZDFA and Dairibord • Identified communities with suitable customers • Introducing chosen participants to training such as MFA's driver training programme
Energy requirements for individual vehicles	5 kW for each battery
Max operating distance per single charge	100 km
Battery type	Tailor-made 48 V Li-ion battery

DRE solution

Inhouse DRE capacity to power e-mobility solution	• MFA has installed a purpose-built charging station to enable battery swapping • The charging station with DRE powers 50 tricycles • 15 kW solar system designed and installed on site, comprising 48 by 535 W monochromatic solar panels and supporting hardware • The standardised nature of this model is highly beneficial and replicable • Currently, 25 tricycles are deployed, with expansion in the process
Energy storage & backup power	The batteries themselves can be utilised as backup power when needed

Outcome

- MFA strives to bring behavioural change surrounding sustainable mobility, increasing green jobs opportunities, especially for women (24 full-time employees)
- Women in rural areas benefited from blended finance from a range of stakeholders, enabling these women to pay an affordable price for mobility as a service
- Healthcare campaigns using hambas have increased the number of people reached, treated and minimised vast walking distances
- Provided employment and capacity building for local agents in driving, repairs, maintenance, renewable energy and battery management
- Created incentives for people to stay in rural areas rather than move to urban areas in search of work and employment
- Estimated 6 t CO_2e/year saved
- Tailor-made 48 V Li-ion battery, can plug into the hamba as well as a range of farm appliances

Challenges & solutions

- Limited funding to test new models and R&D
- Threats of competition from substitute products and unregulated industry
- Local skills development
- Lack of a policy framework to regulate the EV space in the country was addressed by working with and advising the Zimbabwean government on their e-transport policy

Key recommendations

- Long-term investment and patient capital local R&D, capacity building, market testing and demonstrating proof of concept
- Challenge of fragmentation in policy decision-making in e-mobility as it requires the involvement of many different Ministries from the Industry, Transport, Energy and Local Government that requires building alliances with different public and private stakeholders

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Smart Communities Coalition Innovation Fund (SCCIF) Project

Location
Kakuma Refugee Camp & Kalobeyei Settlement, Turkana County, Kenya

Total project budget
120,000 EUR (grant)

Company
Solar e-Cycles Kenya Ltd (TryKe)

Partners
- Smart Communities Coalition (USAID, EnDev and PowerAfrica) (financing partner)
- EnDev/GIZ (implementing partner)
- UNHCR (humanitarian organisation in charge of the refugees)
- Turkana County Government (collaboration, permits and licences)
- Kakuma Riders' Group Association (beneficiary)
- Choro Farmers' Cooperative (beneficiary)
- Kalobeyei Farmers' Cooperative (beneficiary)

Project period
April 2022 - July 2023

Context

Unfortunately, many consider self-sufficiency for refugee communities improbable. Solar e-Cycles Kenya (TryKe) through the SCCIF project is resolute on disapproving of this stance. Having explored economic activities in Kakuma, TryKe settled on smallholder farming and rural mobility as areas ripe for evolution.

Rural small-holder farmers struggle to bring their produce to markets to sell due to an inefficient, expensive and fragmented transportation network. Traders experience the same challenges, spending up to 50% of profits on logistics and often, running at losses or near losses. TryKe is set to provide smallholder farmers and traders the benefits of electric mobility, especially in reduced operational expenses, when compared to conventional fuel-powered mobility solutions. TryKe will provide smallholder farmers with their own autonomy in mobility, thus empowering them to control their own logistics.

Secondly, TryKe will leverage the existing "boda boda" operator network, by leasing electric motorcycles to local boda boda operators who will serve the local farmers and traders through dedicated gig-matching. Lastly, TryKe will implement a robust asset monitoring system to provide predictive maintenance and consequently, even lower operational costs for the electric tricycle and motorcycle operators. Therefore, TryKe is resolute on economic empowerment, through the reduction of costs but also, increase of revenue and consequently, the profitability of business ventures within poor communities, especially, those in rural, off-grid environments.

E-mobility solution

TryKe is planning to deploy 15 electric motorcycles for both passenger and goods transport. The electric motorcycles are built from the popular T.V. Sundram Iyengar and Sons Ltd. (TVS) motorcycle parts. TVS is the prevalent model used in Kakuma. This way, the new technology will be more familiar to the users. Additionally, five e-tricycles will be deployed for goods transport.

Max capacity of vehicle(s)	• An e-motorcycle can carry a maximum of three people with a maximum weight of 250 kg • An e-tricycle can carry a maximum of one person with a maximum weight of 300 kg
Decision on target market	• TryKe is a company that is dedicated to serving the rural off-grid community in sub-Saharan Africa • Kakuma and Kalobeyei were a good fit for the company's vision of being both rural and underserved
Local community engagement	• Kakuma has a motorcycle association as well as farmer cooperative groups. TryKe will work with these organisations to bring these vehicles to their members. • The vehicles will be available for lease to introduce it to the community before being sold to them
Energy requirements for individual vehicles	42 kWh (daily demand)
Max operating distance per single charge	• E-motorcycle: 70 km • E-tricycle: 65 km
Battery type	• Battery chemistry: 3.2 V 6,000 mAh $LiFePO_4$ cells. E-motorcycle battery rating: 51.2 V 42 Ah. Tricycle battery rating: 60 V 30 Ah • Motors installed on the e-tricycle are between 1.5 and 3 kWp, as part of ongoing research and development into the different ways of providing value to our customers • They are also fitted with on-board data/power management systems (similar to the thin-film transistor TFT100) for dedicated customer support, fleet and real-time maintenance tracking by connecting via the Internet of Things (IoT), mobile money, Global System for Mobile communication (GSM) and Global Positioning System (GPS)

DRE solution

Inhouse DRE capacity to power e-mobility solution	The project is supported by the mini-grid with 560 kWp by Renewvia Energy

Outcome

While the project is still in the planning stages, TryKe hopes to achieve the following:

- Improved livelihoods by increasing profits and providing an alternative source of income
- Mitigate the effects of climate change by reducing the number of ICE motorcycles on the road
- Access to electricity to refugee households and businesses through its mini-grid

Challenges & solutions

The customer needs assessment in Kakuma will be addressed by a full-time team, present on the ground.

Key recommendations

- Liaising with local stakeholders is vital
- Customer needs assessment is extremely important for the success of the project

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Sun-e-Boat

Location
The Gambia

Total project budget
40,000 EUR (grant), 60,000 EUR (equity)

Company
VoltaView GmbH

Partners
- VoltaView GmbH (applicant and general project management)
- United Experts Ltd. (project manager in The Gambia)
- Sub-Saharan United Vehicles Ltd. (SUV) (provider of Charging as a Service (ChaaS), container owner)
- Fraunhofer HHI, Goslar (technical support)
- Panneh Ngoneh, intracen.org (media support)
- Bamba Saho (upcoming honorary consul in Berlin for The Gambia)
- United Energies AG (financier)
- Kohlhoff GmbH (provider of Torqeedo outboard e-engines)
- Encory GmbH (provider of Li-ion cells)
- Deutsche Energie-Agentur (DENA RES) - Renewable Energy Solutions Programme (grant provider)

Project period
June 2022 - ongoing

Context

Even today there is no access to fresh water and electricity for the people of the island of Jinack, The Gambia. Their main source of income is fishing. Today they spend up to 600 EUR per month for gasoline to run their outboard engines. These engines are old, need a lot of maintenance and pollute the atmosphere and water.

This problem is addressed by introducing electric outboard engines and Li-ion batteries operating their fishing boats. E-engines are provided by Torqeedo and Li-ion batteries are developed by Fraunhofer Fraunhofer Heinrich-Hertz-Institut (HHI) as a novel "battery to go" concept. Li-ion batteries are accommodated in an IP67 sealed case and can be plugged easily into the e-outboard engine. Charging of the Li-ion batteries is done with the container-based VoltaView mini-grid system. This provides electricity through photovoltaics (30-50 kWh per day) but also produces clean drinking water (up to 2,000 l/day).

The investment to equip 10 fisher boats with e-outboards, Li-ion batteries (5 kWh capacity) and a VoltaView clean energy clean water mini-grid is around 60,000 EUR. With 10 clients, a leasing concept of 150 EUR per month will refinance the investment within five years. About 50 families will benefit since typically 4-5 persons are operating one fisher boat.

E-mobility solution

E-fishing boats have been introduced as an e-mobility solution.

Max capacity of vehicle(s)	4-5 fishermen per boat

Decision on target market	• The business partners of the applicant are from The Gambia • Jinack is a small island close to the capital Banjul and therefore an ideal location for the promotion of this new technology • The major business is fishing
Local community engagement	• The European Union (EU) has organised a working group in the Gambia to discuss and explore new innovations in the transport sector, especially e-mobility on the ground but also on the water. The community engagement happens through this working group.
Energy requirements for individual vehicles	• 5 kWh battery capacity enables a travel distance of 50-70 km depending on weather conditions. This is achieved by two "to go" battery modules per boat • In this pilot project, 20 "battery to go" modules with a total capacity of 50 kWh serving 10 boats are used • This capacity will be charged by one VoltaView mini-grid system
Max operating distance per single charge	The typical operating distance per single charge is 40-50 km
Battery type	• Standardised Li-ion battery modules. The "Battery to Go Case" is a robust 24 V battery pack in a mechanical and water-resistant (IP67) case • Each 10 kg case has about 2.5 kWh capacity at a nominal voltage

DRE solution

Inhouse DRE capacity to power e-mobility solution	• Charging of the "Battery to Go Cases" is done with the container-based VoltaView clean energy clean water mini-grid system through a simple plug-and-play system • Complete (100 %) charging takes about 5 h • A solar-powered PV power plant of 4.8 kW – mounted on top of the container modules charges a Li-ion batteries storage system (30-50 kWh) which is then used as a buffer to charge the "Battery to Go Cases" for the e-outboard engines. The same system will be installed at Jinack Island in Winter 2022/Spring 2023. • The VoltaView mini-grid container not only generates electricity but also drinking water. Because of its modular concept, it can easily be extended by adding additional container modules serving as a new centre on the island for business, health, communication and transport.
Energy storage & backup power	Li-ion batteries storage system (30-50 kWh)

Outcome

- The usage of e-outboard engines will reduce costs for the operation of fisher boats by more than 50% compared to today's gasoline operation making the fishing business more competitive and enhancing the net income of the fishermen's families significantly
- No additional costs for everyday use and maintenance of the boats
- New e-outboard engine with a three-year warranty
- Access to electricity and clean drinking water after the installation of the VoltaView clean energy clean water mini-grid serving about 50 families on the Jinack Island
- Besides operating the e-engine of the fishing boat, the "Battery to Go Cases" can also be taken home and be used for electricity-producing light at night and charging mobile phones. For example, by producing electric-

ity to operate sewing machines, women can establish micro businesses and, in doing so, support their families with additional income.

- Today's average consumption of gasoline per fisher boat is 10-20 l/day. Replacing 10 boats with e-outboard engines will save up to 50,000 l of gasoline a year assuming 250 working days.

Challenges & solutions

- Finding investors after a successful demonstration of the "Sun-e-Boat" project at the Jinack Island will be addressed through a wide promotion campaign in The Gambia and West Africa and presentation of the project in exhibitions and other promotional mediums
- Convincing traditional fishermen to adopt the new technology will be done before the project at a show demonstration of the technology in The Gambia in Autumn 2022. Here, the first e-outboard engine and "Battery to Go Case" will be shown to fishermen of the Jinack Island, which they can test by themselves.
- Technical support of the new technology will be done in collaboration with the University of The Gambia and the consortium partner SUV and the Fraunhofer HHI will provide an educational training programme

Key recommendations

- The first demonstration of the e-outboard engine with a traditional fisher boat will already change the behaviour of the fishermen because the e-engine does not make any noise, is easy to operate, does not pollute water and atmosphere and does not require additional operating costs
- The power comes from the sun. The fishermen and their families have access to electricity and clean drinking water through the mini-grid system, thereby improving their living conditions significantly.

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Zembo e-motorcycles

Location
Kampala, Uganda

Total project budget
1,700,000 EUR (grant), 681,000 EUR (debt), > 3,000,000 EUR (equity)

Company
Zembo Motorcycles SMC Ltd (development and operations)

Partners
- InfraCo Africa (a PIDG -Private Infrastructure Development Group company) (equity investor)
- DOB Equity (equity investor)
- Mobility 54 (equity investor)
- KCCA (Kampala Capital City Authority)/ European Union (EU) (grant provider)
- Shell (grant provider)
- EEP Africa (grant provider)
- BPI (Business Partners International) (grant provider)
- USAID (United States Agency for International Development) (grant provider)
- ADEME (French Environment and Energy Management Agency) (grant provider)
- PREO (Powering Renewable Energy Opportunities) (grant provider)
- GIZ (German development agency) (grant provider)
- FFEM (French Facility for Global Environment) (debt provider)
- Bond'innov (debt provider)
- URSSAF (Unions de Recouvrement des Cotisations de Sécurité Sociale et d'Allocations Familiales) – (debt provider)

Project period
December 2021 - ongoing

Context

Uganda is among Africa's most populous countries and is seeing a growing trend towards greater urbanisation. Access to affordable public transport is limited, and people largely use informal petrol-powered "boda boda" motorcycle taxis to travel around Kampala and into peri-urban areas.

Driving these taxis is a key source of employment. As a fast, easily accessible mode of transport, the number of boda bodas on Uganda's roads is expected to nearly triple by 2050, potentially adding to existing health and environmental challenges presented by air pollution and GHG emissions.

As battery prices continue to fall sharply, there is increasing interest in the potential of electric vehicles to support cleaner transport across Uganda including rural and peri-urban areas. Zembo is pioneering the introduction of electric boda boda taxis in Kampala and its surroundings, with ambitions to expand to other parts of Uganda and ultimately, other parts of Sub-Saharan Africa.

E-mobility solution

Electric (boda boda) motorcycle taxis are designed to transport passengers and light loads.

Max capacity of vehicle(s)	Two people, 150 kg of goods (for optimal usage and safety)

Decision on target market	• Boda boda riders are low-income micro-entrepreneurs. Zembo allows them to increase their revenue as they can pay for their motorcycle on loan (PayGo basis) and are not vulnerable to fuel price instability. • Zembo started its operations in Uganda where it offered a good alternative to high fuel prices. The demand and willingness of drivers to accept e-mobility are high and the environmental impact of e-mobility is low. Uganda's energy mix is 90% hydro, and solar is widely accepted
Local community engagement	• Zembo partners with the local community to open swap stations based on a franchise model. Local shop owners are encouraged to host a station in which e-mobility users can swap their empty batteries for fully charged ones. • Furthermore, Zembo uses a bottom-up approach to make company decisions. Clients (local boda boda drivers) are consulted upon changes and are invited to co-develop the Zembo solution.
Energy requirements for individual vehicles	Each battery requires 2.2 kWh per full charge. With a monthly average of 12,000 swaps at 70% usage, Zembo requires 20,000 kWh monthly to operate.
Max operating distance per single charge	60 km per full battery charge depending on acceleration and road conditions
Battery type	Li-ion batteries, 72 V

DRE solution

Inhouse DRE capacity to power e-mobility solution	• Zembo has established 27 charging hubs to date, averaging 12,000 battery swaps per month • The project will expand Zembo's charging infrastructure to circa 60 hubs by 2023 • Charging stations are solar-powered or are connected to Uganda's national grid which is fuelled by 92% renewable energy • Solar PV capacity: 92.5 kW peak (in total, at eight stations) • The addition of new off-grid solar PV charging stations will enable the company to expand its geographical range • Zembo is the only Uganda e-mobility company providing PayGo payable motorcycles and a battery swap service around Kampala. The battery-as-a-service model allows clients who do not have access to electricity to use their motorcycle for work without interruptions (2 min only for a battery swap).
Energy storage & backup power	Energy storage capacity: 19 kWh/48 V (in total, at eight stations)

Outcome

- The project will see over 2,000 electric motorcycles available to buy or access on a lease-to-own basis by mid-2023, with further significant growth planned in subsequent years
- As it expands, Zembo will provide local employment opportunities for boda boda drivers. Lease-to-own agreements are negotiated in local currency to reduce exchange risk for drivers.
- The project also seeks to engage with female drivers and other female staff to increase gender equality in the sector
- The project will reduce air and noise pollution in the region to contribute significantly to the reduction of greenhouse gases
- Easy and quick battery swapping for drivers at Zembo's battery swap stations
- Low maintenance costs of EVs compared to

conventional vehicles, enabling drivers to maximise their incomes

- Zembo currently imports electric engines and motorcycle components to Uganda, assembling the bikes in a dedicated facility in Kampala. As it expands, it will increase employment in this local assembly supply chain.
- By establishing economies of scale, it is anticipated that the project will attract further private sector investment to Uganda's sustainable transport sector, enabling Zembo to expand into rural areas of the country where public transport is more limited and access to fuel for traditional vehicles can be costly and unreliable
- Zembo could be reduced up to 2,400 t CO_2 emissions per year

Challenges & solutions

- Premature battery failure due to low battery quality: Zembo faced a shortage of batteries, affecting its operations and leading to sales suspension
- This is a direct result of a lower cycle life of the batteries than expected. Zembo has now improved the current version of the battery (predictive maintenance is now possible) and is developing a second
- Zembo has also diversified its battery suppliers and is now sourcing from three different countries. Furthermore, Zembo is reassembling batteries with selected cells from faulty batteries.
- The lack of government incentives (high tax on imported motorcycles and high energy prices) was addressed. As the batteries were categorised as solar batteries, they are not taxed upon import, allowing the company to financially manage its operations.

Key recommendations

- Find funds dedicated to R&D only
- Do not underestimate the manufacturing and lead time of suppliers
- Grant access to certified battery suppliers
- Encourage local government to put in place incentives

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4.2

E-mobility solutions aspiring to integrate DRE technology

This case study chapter outlines the projects which do not have access to DRE power generation facilities and are dependent on national grid to charge their e-mobility solutions directly or via battery swapping at the time of this publication.

Rockin' the Kasi*

Location
Sharpeville, Gauteng, South Africa

Total project budget
220,000 EUR

Company
Anywhere.Berlin

Partners
- Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) (grant provider)
- Deutsche Gesellschaft für Systeminnovation GmbH (GESI) (consultancy)
- SKDP - Sharpeville Kasi Development Projects (local implementing organisation)
- Anywhere.Berlin GmbH (project leader covering design, supply and management)
- Gauteng Department of Roads and Transport (counterpart political entity in joint agreement and cooperation with BMU and promoting project locally - situated in Johannesburg)
- Council of Science and Industrial Research (CSIR) (South Africa) (data framing, collection and analysis)

Project Period
September 2018 - ongoing

Context

Anywhere.Berlin has three active locations in Africa: Kenya, Senegal and South Africa. The Sharpeville pilot near Johannesburg was the first and is the most mature. It was instigated to demonstrate the viability of using distributed manufacturing techniques to produce Light Electric Vehicles (LEVs) in emerging economies. These design imperatives required that the vehicles be robust and tailored to specific technologies to achieve replicability for mini and micro-factories. It also served as an introduction of front-loading electric cargo bikes to South Africa and LEVs in general.

E-mobility solution

Robust electric cargo bikes with 160 kg payload capacity, averaging 30-35 km/charge and equipped with Li-ion NMC of 850 Wh each were introduced inside townships with an effort to provide clean mobility services to the marginalised rural communities. This project ensured engagement with all local stakeholders including at all levels of politics, from local forums to the Ministry of Transport, Gauteng Province. The project is grant funded by BMUV, Germany with support worth 220,000 EUR.

Locally maintained and warranted, the bikes were used for many different logistics applications, e.g., 60,000 meals were delivered during the first year of the COVID-19 lockdown. Thereby, enabling socio-economic development for the community and avoiding environmental pollution.

* Kasi is slang for township in South Africa

Challenges

Major challenges include supply chain hurdles (import of Li-ion batteries), uncovering full commercialisation trajectory and political intransigence, which were all addressed with patience and perseverance.

Key recommendations

- Excellent local team leadership
- Proper supply chain coordination
- Ensuring commercial uptake
- Availability of subsidies for market penetration

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All electric hub

for grocery delivery

Location
Hyderabad, India

Total project budget
350,000 EUR

Company
BILITI Electric

Partners
- BILITI Electric (EV & logistics partner)
- Flipkart (Walmart) (client)

Project Period
April 2022 – ongoing

Context

The objective of the project was to cut down the last-mile delivery costs for Flipkart Groceries in India. The idea was to set up a 100% EV hub, for last-mile grocery distribution and deliveries.

Highlights of the project are:

- Initiated in the city of Hyderabad, India
- 1,500 orders processed on a daily basis
- > 60 e-vans for last-mile deliveries from a single station
- Dedicated battery swapping station to reuse the e-van fleet in multiple shifts
- Reduced the cost per order from >100 INR (1.22 EUR) to 48 INR (0.59 EUR) per delivery
- Mobile battery swapping stations to support long-distance routes
- Optimised human resource usage by reducing to two persons in diesel vans (1 driver + 1 delivery agent) to 1 person in an e-van (driver as well as delivery agent)

E-mobility solution

BILITI Taskman is an e-van designed to deliver goods for hyper-local and last-mile logistics with a payload capacity of one driver > 600 kg goods, averaging 85 km per charge and equipped with a 7 kWh Li-ion battery. The EV solution proved to be a perfect solution for last-mile grocery deliveries in a developing country such as India.

The project was funded with debt financing from the vehicle financiers amounting to 250,000 EUR and additional equity of 100,000 EUR. Thanks to this intervention, the cost per delivery was reduced and optimal human resource management was achieved. 650 kg CO_2 emission is avoided daily improving the air quality locally.

Challenges

The major challenge of vehicle fleet parking management in a prime area of the city was addressed by introducing the battery-swapping initiative.

Key recommendations

The project recommends a proper roadmap for battery-swapping initiatives to thrive. In the long run, this enables riders to become micro-entrepreneurs by owning their vehicle.

The company also calls for the financiers to extend their support to the battery swapping and interoperability ecosystem to build the network of the supply chain to boost EV adoption, which in turn will impact a faster transition.

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Affordable, durable and repairable e-cargo bicycles

Location
Nairobi, Naivasha, Nanyuki

Total project budget
30,000 EUR

Company
E-Trails Kenya (financer, developer, marketer)

Project Period
July 2022 – ongoing

Context

E-Trails Kenya has been renting out electric bicycles since 2019. When electric bicycles became "mainstream" in 2021, the company quickly realised that many initiatives lacked sustainability for a multitude of reasons.

They are highly dependent on subsidies and/or sell products that are:

- Unfit for heavy utilitarian use
- Unable to provide adequate battery power for a full day's work
- In violation of Kenyan traffic law or international e-bike standards (they are overpowered and/or self-propelled)
- Fully dependent on centralised specialised workshops for repairs/maintenance

In response, E-Trails developed an affordable e-cargo bike, built for intensive use, easy to maintain/repair and fully compliant with all national/international regulations. For additional power, the customers (delivery riders) can rely on a battery-swapping infrastructure in Nairobi Central Business District (CBD).

E-mobility solution

The e-bikes with a 36V, 16 Ah Li-ion battery have a 55-70 km range/charge and can hold up to 60 kg of payload with a driver. The customers are Nairobi-based delivery riders, upcountry horticultural farms and upcountry hotels in search of bicycles that can handle Kenya's hilly terrain. The mechanical and electrical parts of the cargo bike were developed with a focus on affordability, durability and easy maintenance. The modular plug-and-play set-up is a concept that can easily be extended to a wide variety of bicycles. Local stakeholder groups were engaged in the project from the scratch and ensured constant innovation with their feedback to develop the prototype until its perfection.

Battery swapping services are currently in place for this project due to their easy applicability, easy-to-install infrastructure and user-friendliness. The project of 30,000 EUR is fully self-financed. Thanks to this project, an economically viable clean mobility solution is operating in Nairobi CBD now which not only facilitates local parcel deliveries but also further enables employment creation and capacity building for local youth. It is also ensuring air quality improvement by saving around 3 t CO_2 emissions every year per bike.

Challenges

E-Trails Kenya outlines fiscal penalisation on Li-ion batteries as one of the major challenges.

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Key recommendations

The company suggests that opening the tax door to a local assembly of lithium battery packs is essential if e-mobility is to become a genuinely sustainable alternative to fossil fuels.

It argues further that casing and Battery Management System (BMS) have a much longer service life than battery cells, so repacking is cheaper/more eco-friendly than importing complete replacement packs.

Finally, the company strongly believes in the economic advantages of locally adapted e-mobility solutions and encourages donors to always put (long-term) economic viability first when they subsidise e-mobility projects.

Electric vehicle ecosystem

Location
Boracay Island, The Philippines

Total project budget
950,000 EUR

Company
GerWeiss Motors Corporation

Partners
- GerWeiss Motors Corporation (manufacturer, operator and financier)
- Municipality of Malay (city of operation and issuer of permits)
- Tricycle Operators (local public transportation drivers and beneficiaries of the vehicles)

Project Period
December 2011 – ongoing

Context

In the Philippines, gasoline-powered tricycles (tuk-tuks) are major contributors to extreme air and noise pollution and often are equated with poverty. More than 5 million tricycle drivers in the Philippines are living below the poverty line earning about 5 EUR daily after working for 16 hours per day.

According to an ADB study, gasoline-fuelled tricycles produce over two-thirds of the air pollution generated by the transport sector. In 2018, a study by the WHO reported 45.3 air pollution-related deaths for every 100,000 people in the Philippines. Tackling this grave problem, GerWeiss approached the issue by redesigning and converting the vehicles to electric, making them efficient, safer and more comfortable. To ensure sustainability, the project created an expansive ecosystem to support an efficient, effective, affordable and reliable operation.

E-mobility solution

E-tricycle (tuk-tuk) with a maximum nine-passenger capacity and equipped with Lithium-ion Phosphate ($LiFePO_4$) and Nickel Manganese Cobalt (NMC) battery packs, averaging 70 km/charge were introduced. The local government, in its efforts towards sustainability, endorsed this project.

Mr. Frolibar S. Bautista, Municipal Mayor, Malay, Aklan said that "the local government fully endorses and supports the replacement of conventional tricycles with electric trikes (e-trikes) to reduce the carbon footprint of Boracay Island in the Philippines to tackle climate change. There is no Planet B. We must take care of the one we have."

Battery swapping infrastructure has been installed for the charging solution and the main grid has renewable resources contributing to the country's energy mix. 950,000 EUR were injected into this project, all self-financed by GerWeiss Motors Corporation. The introduction of the e-mobility solution addressed the issues related to noise and air pollution, improved the safety of public transport and ensure comfort for passengers, and lastly enhanced the income of the local drivers. About 1.9 t of CO_2e is avoided per year with the introduction of these e-tuk-tuks.

Challenges & solutions

The major challenges include an extreme lack of local and international funding which led to bootstrapping for the past 11 years by the company. GerWeiss is now raising venture capital funds as well as leveraging carbon credits by working with carbon registry partners to scale

up financing for the project. EVs initially did not have a basis for registration with some national offices which eventually got addressed by working with the Land Transportation Office.

Key recommendation

The company calls for financial support to further scale up the project in the country and recommends the donor community invest in such novel e-mobility solutions.

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4.3

Expert interview

Introduce your DRE-powered e-mobility project

Many rural communities around the world lack access to affordable and sustainable power as well as transport solutions. betteries has developed a system of renewable power solutions based on mobile, modular and cloud-connected up-cycled (2nd-life) Electric Vehicle (EV) batteries. The portfolio of system components includes everything from solar battery charging hubs and mobile AC power kits (to replace diesel generators) in Productive Use of Energy (PUE) applications to electric, multi-purpose 3-wheelers with swappable batteries. These electric, short-range vehicles are completely emission-free and can be used for multiple transport tasks – from taxi services to the transport of agricultural goods to local markets.

These e-mobility solutions bring numerous benefits to the local community – cost savings, generation of additional income and an overall improvement of livelihood. For instance, in Belize, we partnered with Zenna AG, who installed PV mini-grids in a rural area which was not covered by the national grid. Our mobile batteries are charged at the mini-grids and are then transported to local customers in the region where they supply electricity for multiple purposes. The batteries are transported by using small electric mini trucks, which illustrates the importance of mobility, especially in off-grid regions.

What were the major challenges you faced during the whole project cycle?

Deploying innovative solutions in a rural environment of developing countries comes with multiple challenges, e.g., planning needs to be done in great detail to avoid unnecessary surprises and project delays (in particular logistics) during deployment. In addition, a blended financing scheme needs to be set up, which ideally covers the CAPEX cost of the project, as quite often rural communities can only cover the OPEX cost with the income generated. Furthermore, the deployment must be de-risked by identification and strong cooperation with local partners and reporting must start with an honest and detailed baselining to be able to measure the improvements (impact) delivered by the intervention.

To what extent the local partners were involved in the project implementation?

Strong local partners are the key to success! There is no way to successfully deliver, operate and maintain these solutions without local partners. In another case in a project in Zambia, we are very lucky to work with SOS Kinderdorf e.V. which has its headquarters in Germany but also operates a local team based in Zambia. In the selection process, we (as a start-up) pitched our solution to all SOS country organisations, but the ones interested also pitched to us in a second round. That way it is guaranteed that the right partners come together and cooperate successfully from the very beginning of the project.

What is needed to make a project commercially and environmentally viable?

First of all, the beneficiary i.e., the village or community which will receive the energy hub and e-mobility solution needs to take ownership of the idea and the solution. Together, a business plan needs to be developed which is based on stretching, but achievable assumptions. In particular, the proposed revenue streams need to be validated ahead of the project (pricing etc.). Risk contingencies need to be established at a sufficient level to be able to cover the inevitable unknown(s). In addition, a financing plan needs to be established which takes these revenue potentials into account, e.g., as already mentioned, there is a need for a subsidiary or blended finance solution for the CAPEX element of the project.

Your key recommendations for future project implementers?

Stay focused on the core elements of your proposed solution. Accept setbacks, dust off yourself and keep going – it's worth it!

What is the impact of your project?

Together with our project partner, we deliver affordable and clean energy and mobility solutions to a highly remote, rural community. This intervention will help the farming community to improve farming output, reduce post-harvesting losses and generate substantial additional income for multiple entrepreneurs utilising the now available PUE. Improved mobility will improve the community health and livelihood of hundreds of families.

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List of abbreviations

AC: Alternating Current

ADEME: French Environment and Energy Management Agency

AECF: Africa Enterprise Challenge Fund

Ah: Ampere hour

ARE: Alliance for Rural Electrification

BESS: Battery Energy Storage Systems

BMS: Battery Management System

BMUV: Federal Ministry for Environment, Nature Conservation and Nuclear Safety (Germany)

BT: Breakthrough Technology

CAPEX: Capital Expenditure

CBD: Central Business District (Nairobi)

ChaaS: Charging as a Service

CO_2: Carbon Dioxide

CO_2e: Carbon Dioxide equivalent

CSIR: Council of Science and Industrial Research (South Africa)

DC: Direct Current

DENA RES: Deutsche Energie-Agentur - Renewable Energy Solutions Programme

DRE: Decentralised Renewable Energy

EEP Africa: Energy and Environment Partnership Africa

E-Mobility: Electric Mobility

EnDev: Energising Development (an international flagship programme for providing energy access)

EU: European Union

EUR: Euro

EURIST: European Institute for Sustainable Transport

EV: Electric Vehicle

FABIO: First African Bicycle Information Organisation

FFEM: Fonds Français pour l'Environnement Mondial

Fraunhofer HHI: Fraunhofer Fraunhofer Heinrich-Hertz-Institut

g: gramme

GESI: Deutsche Gesellschaft für Systeminnovation GmbH

GHG: Greenhouse Gas

GIS: Geographic Information System

GPS: Global Positioning System

GSM: Global System for Mobile Communications

GW: Gigawatt

h: hour

HCD: Human-Centred Design

HQ: Headquarters

ICE: Internal Combustion Engine

IoT: Internet of Things

KfW: Kreditanstalt für Wiederaufbau

kg: kilogramme

km: kilometre

kVA: kiloVolt Ampere

kW: kiloWatt

kWh: kilowatt-hour

LEV: Light Electric Vehicle

Li-ion: Lithium-ion

$LiFePO_4$: Lithium-ion Phosphate

LUCF: Land-use Change and Forestry

mAh: milliampere hour

MFA: Mobility for Africa

MW: Megawatt

NGO: Non-Governmental Organisation

NMC: Nickel Manganese Cobalt

OEM: Original Equipment Manufacturer

OPEX: Operational Expenditure

PAYGO: Pay as you go

PREO: Powering Renewable Energy Opportunities

PSH: Peak Sun Hours

PUE: Productive Use of Energy

PV: Photovoltaic

R&D: Research and Development

RE: Renewable Energy

RoI: Return on Investment

SCCIF: Smart Communities Coalition Innovation Fund

SDG: Sustainable Development Goal

SKDP - Sharpeville Kasi Development Projects

SUV: Sub-Saharan United Vehicles Ltd.

t: Tonne

TFT: Thin-Film Transistor

TryKe: Solar e-Cycles Kenya Ltd

TVS: T.V. Sundram Iyengar and Sons Ltd.

UN: United Nations

UNHCR: United Nations High Commissioner for Refugees

UNIDO ITPO: UNIDO Investment Technology Promotion Office

USAID: United States Agency for International Development

V: Volt

VC: Venture Capital

W: Watt

Wp: Watt peak

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