FACTSHEET 1

Sustainable e-mobility

SESA
Smart Energy Solutions for Africa

Figure 1: **Electric Boda Bodas** (Zembo, 2020)

About the Sustainable Energy Solutions Catalogue

The Sustainable Energy Solutions Catalogue provides an introduction to the solutions deployed during the SESA project. The catalogue targets energy practitioners, policy makers and civil society, especially at local level. In the catalogue, readers can find key facts about specific sustainable energy solutions (technologies, business models, impact areas), and learn about approaches and concepts that help ensure the viability and long-term success of sustainable energy in the African context.

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1 Introduction

Sustainable electric mobility (e-mobility) encompasses a set of solutions in which innovative electric vehicle technologies and business models are combined to improve mobility services in cities, peri-urban and rural areas. Though e-mobility solutions are only recently emerging in Africa they are likely to play a key role in the transition to sustainable and inclusive mobility in the region.

The factsheet focuses on light electric vehicles (EVs) such as e-motorcycles, e-tuk-tuks or tricycles, e-bicycles, and e-cargo bikes. These are the most common types of EVs deployed in African urban and rural areas, where 2- and 3-wheeled vehicles represent an important means of transport. It is estimated that by year 2040, 2-and 3-wheelers will make up around half of the total vehicle fleet in Sub-Saharan Africa (SSA) (Conzade et al., 2022).

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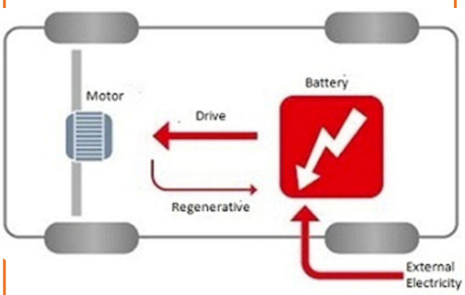
2 The technology

Sustainable e-mobility solutions are based on different types of technologies related to vehicles, but also to charging infrastructure, power sources, energy storage, and Information and Communication technologies (ICT).

2.1 Electric vehicles

Electric vehicles (EVs) are fully propelled by electric motors, using energy stored in rechargeable batteries and obtaining their electricity from an external source (see Figure 2).

Figure 2: **Schematic description of Battery Electric Vehicle** (Omazaki Group, 2019)



The following are some of the key technological features of EVs:

Regenerative braking enables the vehicle's kinetic energy to be recovered and converted back into electrochemical energy. Through this mechanism, the electric vehicle's energy efficiency can be improved.

In the context of e-mobility, the driving range of an EV plays an important role. The driving range is the distance that an EV can be driven with the energy stored in its battery. It can depend on battery capacity and battery ageing, how the vehicle is driven, external conditions such as hot temperatures, and the weight of the vehicle. The driving range influences the choice of vehicle and technology. It also directly influences the choice of the business model that is used, for example battery swapping models can be a viable option to extend driving range, especially for off-grid, rural areas (see also Business Models) (Roam Motors, 2021).

While the focus of this factsheet is on fully electric mobility, it is important to note that other technologies, such as hybrid EVs - where part of the power comes from an Internal Combustion Engine (ICE) - are currently under development for the African market (ESI-Africa, 2022).

2.2 Power Source

The source of electricity to power EVs defines their economic viability and environmental impact. Two major ways of producing low-carbon electricity for e-mobility are:

- **Grid-tied electricity**: Grid electricity is currently the most commonly used source for powering EVs in Africa. Importantly, the grid-based electricity mix of many African countries has a high share of renewables. However, grid reliability can pose a challenge in some countries.
- **Off-grid renewables**: Decentralised renewable energy sources such as solar photovoltaics (PV) can be used to charge EVs, and this can be combined with other uses for the electricity, such as household or productive use applications (ESI-Africa, 2022b). The charging of EVs can also be managed strategically to optimize the economic viability of solar mini-grids. For more details, consult the Productive Use of Energy factsheet of the Energy Solutions Catalogue.

Examples of application in the African context 1

Zembo (Zero Emission Motorcycle Boda), Kampala (Uganda)

The idea: Zembo sells and leases electric motorcycles to boda-boda drivers.

The power source:
- High capacity, lithium technology battery
- Recharged in solar stations and via grid electricity

The business model:
- Lease-to-own: drivers lease the motorcycles with a payment period of 2 years to reach full ownership
- Affordable weekly fees, free maintenance services, and battery recharging rates lower than regular fuel costs

The impact:
- Assembly of motorcycle parts in Kampala: improvement of local technical skills and high-quality on-site maintenance and repairss
- Boda-boda lower both fine particles and CO_2 emissions, as well as noise pollution

For further information visit:
→ www.zem.bo

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2.3 Energy storage

The key component of EV technology is the battery. Battery costs alone can make up to 50% of total vehicle costs (König et al., 2021) and ultimately represent a key criterion for the economic viability of the solution. Lithium-ion (Li-ion) batteries, which are mainly produced in Asia, currently dominate the African market, with new technology trends such as silicon or lithium anodes, solid state cells or new cathode materials on the horizon (Siemens Stiftung, 2020). Key characteristics of batteries include:

- **Li-ion batteries** have one of the highest energy densities of any battery technology today. They also have comparatively low maintenance needs and do not require scheduled cycling to maintain their battery life. The prices of Li-ion batteries are constantly falling, having dropped by roughly 89% since 2010 (Sono Motors, 2021). As research in electrochemistry is booming, the prices will most probably keep on falling, making EVs using Li-ion batteries more affordable.

- **Lead-acid batteries** are more affordable up front, but they require regular maintenance and have a shorter lifespan than Li-ion batteries (Unbound Solar, 2020). The improper recycling or handling of used lead-acid batteries has considerable health and environmental impacts.

When an EV battery reaches the end of its life, it still keeps a substantial share of its original storage capacity and it is often still possible to use it in less demanding energy-storage applications like stationary solar off-grid systems (see Sustainability impacts as well as the factsheets on E-waste and second Life batteries).

2.4 Charging Infrastructure

Adequate planning of EV charging infrastructure is a prerequisite for the widespread adoption of e-mobility solutions. There are different charging technologies, such as wired (conductive) and wireless systems. They can be placed at public or private/home charging stations. Battery swapping, mainly for light EVs, is a viable solution in urban areas with high density of EVs, where charging time is a limitation, as well as in off-grid or weak grid markets.

The selection of charging infrastructure technologies influences the business models (see Business Model section below).

2.5 ICT components

Information and Communication technologies (ICT) and Internet-of-Things (IoT) -based technologies are key enablers for sustainable electric mobility and are at the core of the innovative business models that are being deployed in African cities and rural areas, for example in the SESA living labs (described in SESA examples section below).

Real-time battery charge levels, location of nearest charging infrastructure, route options to optimise battery performance and energy price in a given charging area are some of the examples of information that makes the whole EV system efficient and economically viable. Meters and sensors are not only integrated in the vehicle but also in the power source (e.g., solar mini-grids) and batteries (IoT-based battery monitoring, remote immobilisation capabilities).

In terms of shared mobility, digital platforms - app-based, on-demand transportation services that connect the driver and the users - are also common, with both local and global Transportation Network Companies (TNCs) like taxifier, Uber, and Lyft in use in African e-mobility markets.

The success of mobile or cashless payment options for e-mobility also relies heavily on ICT systems.

Unsplash / Anders

3 Business and financing models

E-mobility businesses in the African context use a range of models that are designed to respond to the existing barriers of EV adoption, high up-front costs for lithium-ion batteries and EVs and limited availability of charging infrastructure.

Many EV business models in Africa are centered around passenger services such as 2-wheelers and 3-wheelers, which serve as taxis. Other business models target the transport of goods, or vehicles that are used by service providers, healthcare services, or tourist guides.

Business models vary significantly depending on the type of customer and local market context. User needs and the ability to pay are crucial initial factors to be considered while designing an appropriate and sustainable business model.

The following are some key common elements of e-mobility business models in the African context.

3.1 Vehicle sharing

E-mobility business models in the African context rely strongly on shared economy approaches to make the solutions affordable to users. Direct sales of EVs to private households are rare and sharing a vehicle is common. ICT facilitates the shared vehicle approach (see Technology section above). Vehicle-sharing apps offer around the clock access to vehicles to registered customers, and users only pay for the mobility service.

3.2 Battery swapping and leasing

Battery-swapping (Figure 4) is an essential element of e-mobility business models in Africa. In this approach, charged batteries are rented out to electric 2- or 3-wheeler drivers until they are discharged, and the driver returns to a battery swapping station. This is a viable model for commercial riders who do not have much time between vehicle charges (Mobile Power, 2022). Swapping batteries in small 2- and 3-wheel vehicles is relatively easy and time-efficient. The advantage of battery swapping is a shorter vehicle downtime (in the range of minutes), compared with a current 3 to 4-hour charging time.

3.3 Consumer financing: PAYGO, lease-to-own and pay-per-use

In recent years, the Pay-as-you-Go (PAYGO) consumer financing model, which is already common in Solar Home Systems, has been increasingly adapted to e-mobility in Africa. The PAYGO model is suitable for customers who cannot afford paying for EVs upfront, but can pay in customisable monthly, weekly or daily instalments when the customer wants to use the

Figure 4: **Mobile Power battery swapping** (Mobile Power, 2022)

service or is able to pay for the service. The companies therefore not only provide the product and services, but they also provide the necessary finance to consumers (Energypedia, 2022). The customer can also use the PAYGO approach to finance the purchase of the vehicle ("lease-to-own"), meaning the customer finally owns the asset at the end of a certain period.

The pay-per-use or fee-for-service (FFS) concept is also relevant for e-mobility. It does not include eventual ownership, but is interesting for many customers, most of all if a vehicle is not used on a daily basis (Siemens Stiftung, 2020). The downside of the FFS approach is the high investment required for the service provider, namely purchasing and installing of devices as well as establishing the necessary service infrastructure. It takes a relatively long time to amortise the investments through the revenues from services (Energypedia, 2022).

Examples of application in the African context 2

Bodawerk, Kampala (Uganda)

The idea: Power packs that enable different e-mobility and energy storage solutions.

The power source:
- Smart Battery that is based on cylindrical Lithium-Ion cells
- Built-in battery management system (BMS) to turn on/off and check the batteries charge and health via Bluetooth

The business model:
- Conversion of existing Internal Combustion Engine (ICE) vehicles to EVs
- Subscription-based business model: battery packs available to rent by e-boda boda drivers

The impact:
- Education through mentoring program
- Women empowerment through targeting of women-owned businesses
- Inclusion of disabled people through e-wheelchairs

For further information visit:
→ https://bodawerk.com

4 Socio-economic and sustainability impacts

The impacts of sustainable e-mobility solutions cover the areas of health, climate change, circular economy, gender-equality and inclusion, among others. These areas are treated here in turn.

4.1 Health and climate change

Across Africa, rapid urbanisation is leading to an increase in emissions of local pollutants and greenhouse gas (GHG) emissions from the transport sector. The lack of public transport coupled with imports of high-emission vehicles has severe health impacts. Premature deaths in Africa from outdoor air pollution increased by almost 60% between 1990 and 2017 (Gurzu, 2021). EVs have a key role to play in addressing this challenge. The particulate matter emissions of EVs on a person-km basis are lower in comparison to other transport modes, even when including lifecycle emissions (Bakker, 2019).

Sustainable e-mobility can also contribute to reducing GHG from the transport sector. The choice of electricity source significantly influences the climate change impacts of EV mobility. The most significant improvements emerge when EVs use electricity produced through renewable energy sources. In Thailand, it is estimated that replacing conventional motorcycles with e-motorcycles would result in a 42% to 46% reduction of two-wheeler life cycle GHG emissions (Bakker, 2019).

4.2 Circular Economy

An increased uptake of e-vehicles can potentially lead to an increase in extraction of scarce minerals, as well as contribute to growing streams of e-waste. The latter are already a significant challenge in many African countries. Apart from the e-waste produced in Africa itself, the continent has become the primary destination for the export of used electrical and electronic equipment (Asante et al., 2019).

Appropriate treatment of e-waste avoids the health risks caused by the exposure to harmful substances (WHO, 2022). Efforts are underway to develop the needed legislation, infrastructure, value chains and skills for appropriate end-of-life treatment of e-waste and used batteries in Africa, and many e-mobility businesses integrate solutions to this challenge.

One key disposal option is battery reuse, as mentioned above. Batteries can also be recycled and raw materials extracted for second use (EPA, 2019). For more information on these topics, please consult the Second-life Batteries, E-waste and Circularity factsheets of this catalogue.

4.3 Gender equality and inclusion

Sustainable e-mobility solutions can potentially increase inclusion in the provision of mobility services. Lack of time, financial resources, vehicle frequency or a higher risk of exposure to crime and violence are some of the factors impeding access to mobility (SUTP, 2018). Lack of access to mobility is especially pronounced for women, for whom access to mobility is essential to reach educational and health facilities and gain access to markets (Women Feed Africa, 2022).

Different business models for e-mobility in the African context are geared towards women as drivers or passengers and aim to meet the specific needs of low-income households, rural populations or marginalised groups. E-mobility startups that focus on women living in rural areas (e.g., Mobility for Africa, see Figure 5) try to encourage female drivers and passengers by providing affordable renewable-energy charged EVs (Mobility for Africa, 2022).

4.4 Employment creation

The lack of affordable mobility solutions hinders people from accessing jobs. By implication, affordable e-mobility can facilitate the participation in the job market (Siemens Stiftung, 2020). Furthermore, e-mobility can potentially create employment opportunities in local assembly, manufacture, conversion and maintenance of vehicles. Local vehicle assembly can also boost national and regional supply chains (Conzade et al., 2022).

Examples of application in the African context 3

Roam (previously: Opibus), Nairobi (Kenya)

The idea: Started by converting off-road vehicles to run on electric motors, before converting buses and designing its model of electric motorcycle.

The power source:
- Off-grid solar and grid electricity
- Lithium batteries

The business model:
- Conversion of Internal Combustion Engine (ICE) vehicles to EVs
- E-motorcycles have a detachable battery for battery-swapping

The impact:
- Job creation through local design and manufacture
- Replication potential through partnering with Uber

For further information visit:
→ www.roammotors.com

Figure 5: **Sustainable e-mobility solutions can potentially increase inclusion in the provision of mobility services** (Mobility for Africa, 2022)

5 Scaling-up

The African continent has one of the lowest vehicle ownership levels in the world, and at the same time faces one of the fastest growth rates. Sustainable e-mobility has significant scale-up potential: in six countries that make up around 70 % of Sub-Saharan Africa's annual vehicle sales and 45 % of the region's population (South Africa, Kenya, Rwanda, Uganda, Ethiopia, and Nigeria), the vehicle fleet is expected to grow from 25 million vehicles today to approximately 58 million by 2040 (Conzade et al., 2022).

Realizing the scale-up potential will require investments in the local value chain as well as skills development, legislation, and enabling environment. In early-stage markets, policies for e-mobility should be directed toward overcoming entry barriers in the market. This can be achieved by a mix of financial incentives and standards, expanding EV model availability, accelerating EV deployment across public and private fleets, developing charging infrastructure and raising public awareness.

6 Sustainable e-mobility solutions in SESA

Implemented in nine African countries, the EU-funded SESA project is developing and testing solutions to accelerate the energy transition in Africa. The focus of the project is on the exploration of innovative technologies and services in urban and rural contexts. SESA partners in various countries are working on sustainable e-mobility solutions. Their activities are briefly outlined below.

6.1 Kenya Living Lab

SESA partner WeTu is developing innovative solutions for e-mobility as part of the SESA Kenya Living Lab. The main objective in this Living Lab is to demonstrate sustainable energy access solutions that are relevant for both urban and rural contexts in Africa, centred around solar PV off-grid electricity generation for multiple uses (fishing sector, water pumping, water purification, e-mobility), e-waste management, and integration of local Info Spots for digital access to information on energy, climate change and digital skills.

The Living Lab comprises two project sites: Kisegi, a rural village in Homa Bay County, and Katito, a peri-urban community in Kisumu County. The solar charging hub in Katito uses a lead-acid battery bank and conventional inverter system, while Kisegi tests a hybrid inverter system with Li-ion storage and "hot swapping" system. The generated energy is used for a range of needs within the local communities, among others the powering of e-motorcycles in the Katito site (see Figure 6). The e-motorcycles are converted from internal combustion engines to electric drive trains. The Living Lab will also demonstrate the repurposing potential of EV batteries for stationary storage applications (for more details, please consult the Second-life Batteries factsheet of the catalogue).

6.2 South Africa Living Lab

The SESA South Africa Living Lab is located in two sites: the Eastern Cape township of Alicedale and the semi-rural area KwaNonzwakazi on the outskirts of Alicedale. Although the areas have access

Figure 6: **E-motorcycle at the Katito Hub in Kisumu County** (Own image, 2022)

to electricity, the supply is unreliable and there are prolonged blackouts. Access to reliable, affordable mobility is also a challenge for the majority of the population. Furthermore, there is a lack of access ICT infrastructure.

In the Living Lab, SESA partner u-Yilo deploys solutions for sustainable electricity production and storage. The Living Lab comprises a containerised off-grid renewable energy system, a local Info Spot for internet access, and two micro-utility EVs: one passenger vehicle and one cargo vehicle. The vehicles can be charged in the containerised off-grid hub. The Living Lab will also demonstrate the repurposing potential of EV batteries for stationary storage applications (for more details, please consult the Second-life Batteries factsheet of the catalogue).

6.3 Morocco Living Lab

The goal of the SESA Moroccan Living Lab is to provide e-mobility options for low-income female students from areas surrounding Marrakech, where current public transport modes are often expensive and unreliable. The SESA partner Green Energy Park will improve access to mobility via the provision of e-vehicles, an e-share leasing concept, and a digital platform for tracking and monitoring of performance, online payment and publicity. The charging infrastructure will be based on a battery swapping system.

Examples of application in the African context — 4

ThinkBikes, Ibadan (Nigeria)

The idea: Micro-mobility company that manufactures 2- and 3-wheelers locally for last mile transportation of goods and people.

The power source:
- Two Lithium-ion battery packs, using recycled battery cells recovered from old laptops and other electronic devices

The business model:
- Up-front sale of 2- and 3- wheelers with recycled batteries, manufactured in Nigeria, therefore lowering the price
- Leasing service/subscription model in which its customers can rent a bike on a daily, weekly or monthly basis
- Customers can buy the bikes without batteries (the most expensive component), and then lease or rent the packs from ThinkBikes

The impact:
- Promotion of circular economy approach via recycling of battery cells
- Job creation through local design and manufacture

For further information visit:
→ http://bike.thinkelectricafrica.com.ng

Examples of application in the African context — 5

WATTSC, Casablanca, Morocco
(Company selected in the "SESA Call for Entrepreneurs 2022")

The idea: Digitalisation of energy supply and energy efficiency. In SESA, Wattsc will design a digital platform for managing EV charging stations.

The technology:
- Online tool geared at EV drivers for location and management of EV charging and battery swapping infrastructure

The business model:
- Owners of charging stations can list their stations on the map
- Partnering with property owners to install charging stations on their property
- EV owners can subscribe to the platform

The impact:
- Opens up business opportunities for property owners to install charging stations
- Facilitates uptake of EVs

For further information visit:
→ https://wattsc.com/en

7 Climate-proofing

Climate proofing is a term that refers to the process of mainstreaming climate change into mitigation and adaptation strategies and programmes (Climate Policy Info Hub, 2022). The goal of climate proofing is to ensure that climate-related risks and opportunities are integrated into the design, operation, and management of products and infrastructure. In order to do this, solutions have to be screened for climate risks, vulnerabilities and opportunities in the early design stage.

The climate-proofing of sustainable e-mobility solutions will depend on the location and context. However, some general guidelines include:

- **High ambient temperatures can accelerate battery aging and cause premature failure** (Riello Elettronica, 2022). The optimal capacity of a battery over its lifetime is based on an optimum operating temperature. Increases in temperature above this recommendation result in a reduction in service life. This fact should be taken into consideration in the selection of batteries in e-mobility businesses as well as in the definition of the operation and maintenance programs.
- **Power sources used to charge EVs are vulnerable to climate change** (IAEA, 2019). The main threats to power infrastructure associated with e-mobility include changes in radiation and ambient temperature and phenomena that could cause physical damage to the infrastructure such as extreme weather events, floods or forest fires.
- **Roads can also be affected by climate change**, reducing their safety or limiting their accessibility due to road damage or closures (ADB, 2011). These risks should be taken into account in the design of e-mobility solutions in areas with highly vulnerable infrastructure.

Dreamstime / Inge Hogenbijl

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8 Relevant tools and capacity building materials

Solutions Plus E-mobility Toolbox
The Solutions Plus e-Mobility Toolbox is an online information portal that supports the development, implementation and monitoring of innovative electric mobility solutions. The platform contains tools and information materials in various areas, including: vehicles, business and finance, demonstrations, integration, operation, policy, sustainability, and users.
→ https://emobility.tools

Digital toolkit for energy and mobility
This toolkit addresses the energy and mobility nexus and helps to bridge the gap between the transport and energy sectors when developing sustainable, and energy-efficient mobility projects. It looks into three policies and global experience available to take action on the transport and energy sector nexus, including "Promote Public Discussion on New Mobility Solutions", "Expand Public Transport Infrastructure", and "Plan for Integrated Multimodal Transport Networks".
→ www.sum4all.org/data/files/digital_toolkit_for_energy_and_mobility_complete.pdf

UNEP Global Electric Mobility Programme
The Global Electric Mobility Programme by UNEP (United Nations Environment Programme) supports more than 50 low-and-middle-income countries with the shift from fossil fuel to electric vehicles. The programme encompasses three working areas: electric 2- and 3- wheelers, electric light-duty vehicles, and electric buses. Within the programme, UNEP publishes reports and tools, such as the eMob calculator which estimates the national potential of electric vehicles and calculates the costs associated with a shift to electric mobility.
→ www.unep.org/explore-topics/transport/what-we-do/global-electric-mobility-programme

Sustainable Urban Mobility Plans (SUMP) Toolkit
SUMP is a process based on the definition of common objectives and use of collaborative planning tools to deal with design, implementation, financing, and monitoring of mobility-related measures and projects. This mobility planning approach has been successfully implemented in various contexts around the world. This toolkit is targeted at technical planners and consultants in cities where Sustainable Urban Mobility Plans are being developed. It provides information on how a SUMP (or other related strategic mobility planning document) is best structured and what information should be contained to achieve compliance with international SUMP standards.
→ www.changing-transport.org/wp-content/uploads/2020_annotated_outline_sump.pdf

Gender Sensitive Mini-Bus Services & Transport Infrastructure for African Cities: A Practical Toolkit
This toolkit provides minimum standard guidelines and practical tools for creating safer and more accessible public transport systems for women and other vulnerable commuters in African cities. Its content is mainly relevant for minibus transport organisations, policy makers and civil society actors. The toolkit is based on primary and secondary information from two case studies conducted in Nairobi, Kenya, as well as a literature review to identify best practices on gender and urban transport.
→ https://unhabitat.org/sites/default/files/download-manager-files/Gender%20Toolkit.pdf

International Transport Forum Gender Analysis Toolkit for Transport
The ITF Gender Analysis Toolkit for Transport offers a hands-on method on how to incorporate a gender-inclusive perspective into transport projects, plans and policies. It comprises three tools which together enable an uncomplicated gender analysis, (i) The Gender Checklist, (ii) The Gender Indicators, and (iii) The Gender Questionnaire. The toolkit is useful for everyone who plans, manages, implements or evaluates transport projects, especially governmental actors, international organisations or contractors.
→ www.itf-oecd.org/gender-toolkit

Toolkit for Child Health & Mobility in Africa
Developed by the University of Cape Town (UCT) and the Institute for Transportation and Development Policy (ITDP) with support from the UN Environment Share the Road program and FIA Foundation. It aims to guide local and national governments, practitioners and citizens in the planning, design and implementation of interventions to improve the healthy and safe mobility of children. The toolkit combines various interventions, ranging from infrastructure design to funding and advocacy, supported by case studies from around the world.
→ www.childmobility.info

Climate Proofing Toolkit: For Basic Urban Infrastructure with a Focus on Water and Sanitation
The Climate Proofing Toolkit is a set of steps, tasks and tools that was developed by UN-Habitat, building on the experiences gained in climate change-related programmes by UN-Habitat and development partners. Its overall goal is to make sure that climate-related risks and impacts are considered in the design, construction, location and operation of current and future basic urban infrastructure, with a focus on water and sanitation. Thus, the toolkit is mainly targeting policymakers, planners, practitioners, engineers and utility managers involved in urban infrastructure development.
→ https://unhabitat.org/climate-proofing-toolkit-for-basic-urban-infrastructure-with-a-focus-on-water-and-sanitation

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FACTSHEET 1

Sustainable e-mobility

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