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Report on Component 1 of the Project: "E-micromobility in Ghana - Promoting Local Business Models for Electromobility and Decentralized Energy Systems " (81274624)

12.12.2021

Dear Mrs. Safdari,

We present to you and your team the on the component 1 of the E-micromobility in Ghana project which covers work packages pertaining to the Pan-African Mobility Alliance.

We express our gratitude to the team for the opportunity to work together on this pilot project and envision a longer-term cooperation in the development of sustainable mobility and its potential for job creation in Ghana. The report focusses on the objective of analyzing the feasibility of providing an alternative mobility offer on the campus of Kwame Nkrumah University of Science and Technology (KNUST) powered by renewable energy sources. It further focuses on the possibility of a commercial model for the conversion of fossil-powered motor bikes to electrically powered models on the campus of the University of Energy and Natural Resources (UENR).

The focus of knowledge transfer and operationalization of research in the fields of electromobility is not lost on us, hence the inclusion of models for makerspaces dedicated to these thematic areas in in the report. These makerspaces are designed to be intersectional points between academia, private sector and governmental support in line with the Ghanaian policy of Innovation and Research Commercialization Centres (GIRC) proposed by the Ministry of Environment, Science, Technology and Innovation.

It is our hope that the submitted report addresses these thematic areas and provides a roadmap for sustainable mobility propelled by local research, academia and private sector and further supported by the Ghanaian government.

We look forward to the implementation of these concepts to further embed sustainable mobility in Ghana´s economic development and sustainable job creation efforts.

Warm regards,

Frederick Adjei

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Introduction

The population and prosperity of the Republic of Ghana is growing. With the economic development, the demand for mobility services is increasing, which exists mainly for cars and mopeds. At the same time, these vehicles cause and add to high environmental pollution, which creates opportunities for more environmentally friendly alternatives through e-mobility. However, in order to improve the environmental impact, it is important that the energy required for supply is obtained from a renewable source.

Despite the positive economic development, unemployment and especially youth unemployment is both a societal and political problem in Ghana. The problem is particularly pronounced in the formal sector where economic growth across board has not translated into increased number of jobs. It is therefore prudent to look at solutions that cover the needs of mobility, energy access and supply whiles having a positive impact on employment. This represents the areas of intervention which are covered by the E-micromobility in Ghana project.

The E-micromobility in Ghana project aims at finding solutions to growing mobility demands and environmental stress by deploying solar charging stations and smart mini-grids to charge electric cargo bicycles and electric-scooters, as well as makerspaces on the project site Kwame Nkrumah University of Science and Technology, Kumasi, University of Energy and Natural Resources and the Tema Export Processing Zone. The project further aims at commercializing the electromobility to a large population with a focus on job creation, knowledge transfer and private sector promotion.

Academic Partners

The Kwame Nkrumah University of Science and Technology (KNUST) is situated approximately on a sixteen square-kilometer campus, about seven kilometers away from the central business district of the city of Kumasi. There are six Halls of residence and a number of hostels in the University. They are Queen Elizabeth II, Unity, Independence, Republic, University, and Africa with a student population of over 40,000.


Figure 2: College of Engineering KNUST

Figure 1: College of Engineering KNUST

The University of Energy and Natural Resources (UENR) was established by an Act of Parliament, Act 830, 2011 on December 31, 2011. The University is a public funded national institution which seeks to provide leadership and management of energy and natural resources and be a center of excellence in these critical areas. The University approaches its programmes and research emphasizing interdisciplinary collaboration and taking into account, areas such as economics, law and policy, management, science, technology and engineering as well as social and political issues affecting energy and natural resources.

Figure 4: Campus of University of Energy and Natural Resources

Figure 3: Campus of University of Energy and Natural Resources

In order to reach the goals of this project, a total of six work packages (Component I) were defined. The following chapters depict a detailed description of the results of each work package.

Part 1: Report on the results of Work Packages

Work Package 1: Concept Planning and Device Deployment

Objective	Successful Deployment and Integration of E-Cargo Bikes, e-moped and Solar Charging Station KNUST, UENR
1.1	- Analysis of local conditions in the target location and determination of user requirements for mobility devices and power requirements - Identification of other fields of application and local value creation networks - Analysis of the catalogue of criteria for the evaluation of the product system from an economic, ecological and social perspective - Quantification of environmental and economic benefits of the product system
1.2	Design and concept development of an E-Mobility Makerspace under the STC model of MESTI in UENR or KNUST
1.3	Procurement and deployment of e-mobility devices and Solar Charging stations at the project sites.
Result	Concept paper, Analysis of criteria catalogue, Makerspace Concept

Analysis of local conditions in the target location and determination of user requirements for mobility devices and power requirements

Economic inequality and overpopulation in urban centers have created a situation of air pollution, increased green-house emissions and congestion on Ghanaian roads. Low energy access in rural areas and low transport infrastructure presents limitations in mobility. The potential exists for a more sustainable mobility offer in Ghana in the form of light electric vehicles (LEV) to address transport situations for urban and rural use cases. Such systems are applicable in a shared system which should be adapted to suit local Ghanaian conditions. It is necessary to investigate the status quo of transportation in Ghana, possible factors that influence the use of conventional motorbikes (closest to e-mopeds in the country), and factors that would influence the use of sharing systems for e-vehicles. Specific information along the lines of social, demographic, economic, technological acceptance and environmental awareness are required. The findings of the investigation will influence decisions on the adaptations of existing e-vehicles to the Ghanaian transportation needs and local boundaries, the market entry strategy to enhance social acceptance and as well the design of sharing systems to enhance mass usage at reduced costs. The concrete research questions to be answered are as follows:

- What factors are likely to influence the social acceptance of electromobility vehicles in Ghana?
- What factors are likely to influence the social acceptance of a sharing system for light electric vehicles in Ghana?

In order to analyze local conditions in the target location as well as user requirements for mobility devices, a survey was conducted at KNUST campus. The survey was based on acceptance research methodologies with a focus on technology acceptance, and included a set of social, technical and economical questions, as well as questions that would allow conclusions regarding ecological relief and social acceptance.
The survey included a total of 34 questions and was initiated on December 7th. The survey questions are listed in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table 1: Survey questions

Question	Possible answers							
What is your gender?	Male	Female	No Answer					
How old are you?	19 or younger	20-29	30-39	40-49	50-59	60-69	70 or older	
How far away from campus do you live?	5 km or less	6-10 km	11-15 km	16-20 km	21-30 km	More than 30 km		
Which means of transport do you currently use to get to university?	Walking	Car	KNUST Shuttle Bus	Motorbike	Bicycle	Other - please specify: ___		

Why did you chose this particular means of transport?	It is the most comfortable option	It is the cheapest option	It is the fastest option	I don't have an alternative	Other - please specify: ___			
How much do you currently spend on transportation to university (per ride)?	up to 2 GHS	up to 5 GHS	up to 10 GHS	up to 20 GHS	up to 30 GHS	up to 40 GHS	more than 40 GHS	
How long does it take you to get to campus?	15 minutes or less	16-30 minutes	31-45 minutes	46-60 minutes	More than one hour			
How do you currently move around on campus?	Walking	Car	KNUST Shuttle Bus	KNUST Taxi	Bicycle	Other - please specify: ___		
How much do you earn per month?	500 GHS or less	501-1000 GHS	1001-1500 GHS	1501-2000 GHS	2001-3000 GHS	More than 3000 GHS		
On average, how many times per day do you require transportation in campus, e.g. between departments/hostels?	1 to 2	3 to 4	5 to 6	More than six times				
Do you think more transport options should be available on campus?	Yes	No						
If your answer to the previous question was "Yes", could you explain why?	*Open text field*							
Are you interested in learning more about repair and maintenance of electric vehicles?	Yes	A little	No					
If there was a space on campus where you could learn how to repair and maintain vehicles, would you use it?	Yes, often	Yes, sometimes	Yes, in rare occasions	No, never				
Do you have a driver's license?	Yes	No						
Do you currently or did you in the past own or regularly use a motorbike?	Yes	No						
If your answer to the previous question was "No", could you explain why?	It is too expensive	It is not safe	I don't have a driver's license	I don't enjoy motorbikes	Other - please specify: ___			
What did you like about your experience with the sharing system	*Open text field*							

and the motorbikes?								
Do you have any suggestions for improvement for the sharing system and the motorbikes?	*Open text field*							
If there was a software or an app that would allow you to rent and operate the motorbikes yourself, would you use it?	Yes	No	I am not sure					
Do you think the sharing system on campus could improve your daily transport experience?	Yes	Maybe	No					
Did you experience any difficulties during the ride?	No	Yes - please specify: ___						
How would you rate the overall experience with the motorbikes?	Very unsatisfied	Unsatisfied	Neutral	Satisfied	Very satisfied			
Do you feel the sharing system is overall convenient for you?	Yes	It is somewhat convenient	No					
If your answer to the previous question was "No", could you explain why?	*Open text field*							
How would you rate your experience regarding the following aspects while riding the motorbikes?	Posture while on the motorbike	Sense of safety	Suspension	Turning manoeuvres	Acceleration	Braking	Comfort	Agility
How much would you be willing to pay for a ride with the motorbike?	up to 1 GHS	up to 2 GHS	up to 3 GHS	up to 4 GHS	up to 5 GHS	more than 5 GHS		
How far would you be willing to walk to the next rental station?	Less than 2 minutes	2-5 minutes	6-10 minutes	More than 10 minutes				
How often do you think you will use the sharing system in the future?	Never	Less than once a month	Once or twice a month	Once or twice a week	Almost daily	Daily		
Do you think other students will benefit from the sharing system?	Yes	Maybe	No					

Could you explain why?	*Open text field*							
Please indicate if you agree with the following phrases.	A sharing system would have a positive influence on my life in general.	A sharing system can improve my flexibility.	I have better access to motor-bikes due to a sharing system.	A sharing system can affect my economical situation in a positive way.	A sharing system leads to a better access to public services.			
How important are the following aspects to you regarding the motorbikes?	safety	design	power	range	load capacity	environmental sustainability	comfort	quality
How important are the following aspects to you regarding the sharing system?	price	reliability	easy usage	location of the rental stations				

In order to analyze local conditions in the target location as well as user requirements for mobility devices, a survey was conducted at KNUST campus. The survey was based on acceptance research methodologies with a focus on technology acceptance, and included a set of social, technical and economical questions, as well as questions that would allow conclusions regarding ecological relief and social acceptance.

The survey included a total of 34 questions and was answered by 51 participants. This group can be subdivided into 9 females and 42 males. The age division is depicted in Figure 5.

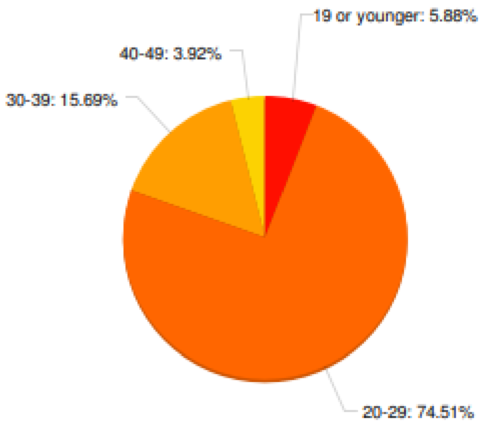


Figure 5: Age division among the survey participants (source: own illustration based on umfrageonline.com)

Among others, the survey showed that the majority of the participants are walking to get around at KNUST campus. The other means of transport that are used are KNUST Shuttle Bus, Cars and KNUST Taxi.

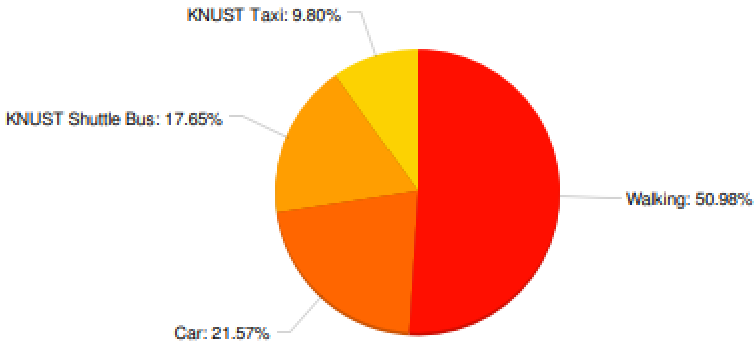


Figure 6: Selected modes of transport (source: umfrageonline.com)

The results of the survey question "Do you think the sharing system on campus could improve your daily transport experience?" strongly support the core idea of the *E-micromobility in Ghana* project. The responses indicate that more than 90% of participants approve, while only about 8% of participants are of the opinion that a shuttle bus service would maybe improve their daily transport experience. Not a single participant thinks that a sharing system would negatively influence the daily transportation experience.

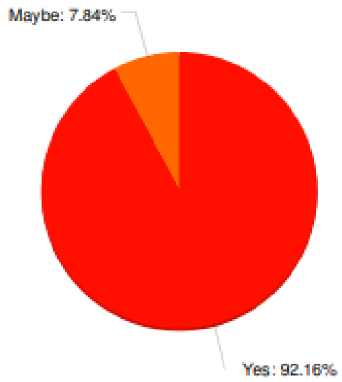


Figure 7: Do you think the sharing system on campus could improve your daily transport experience? (source: umfrageonline.com)

Participants were also given the opportunity to explain why they think that students would benefit from a sharing system on the campus. The provided answers indicate that most people assume that that a sharing system would reduce stress and current transportation alternatives are not sufficient for a fast mobility on the campus. The demand for additional mobility solutions becomes even more evident when looking at the results of the following question: "*How often do you think you will use the sharing system in the future?*"

About 80 per cent of the participants stated that they will use a sharing system on their campus daily or almost daily. Only eight per cent would use this mobility option less than twice a month.

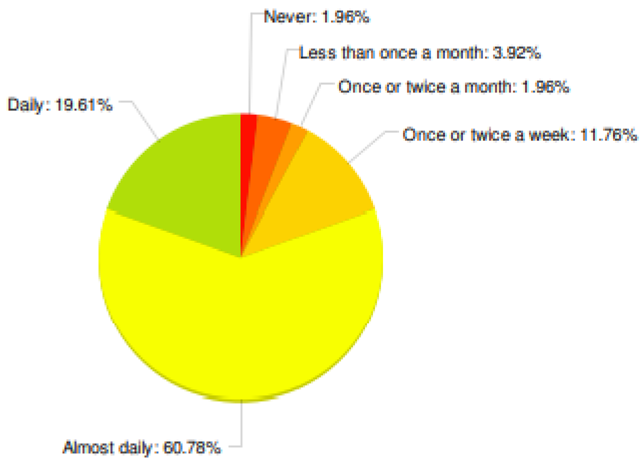


Figure 8: Amount of usage of the sharing system (source: umfrageonline.com)

The assumption that a sharing system on the campus would be used a lot by students is further supported by the result to the question *"Do you feel the sharing system is overall convenient for you?".* The outcome of the question shows that 88 per cent of all participants think of the sharing system as a convenient mobility option. Only four per cent have an opposite feeling.

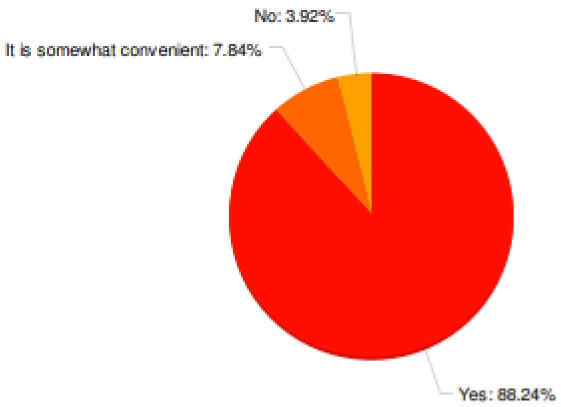


Figure 9: Do you feel the sharing system is overall convenient for you? (source: umfrageonline.com)

The full report including all results can be found in Annex 2.

Identification of other fields of application and local value creation networks

The development of a sharing service for e-scooters and e-cargo bikes, as well as the implementation of solar charging stations at the campuses of the KNUST and UENR universities, brings forth far-reaching possibilities for further fields of application. As can be seen from Figure 10, the main field of application is in the development and implementation of a sharing system for e-scooters, e-cargo bikes, and the appropriate charging infrastructure through solar charging systems. Through the implementation of this system, however, other fields of application can also be identified that are strongly linked to sharing in terms of content, but nevertheless represent a separate business area and make use of other local value creation networks.

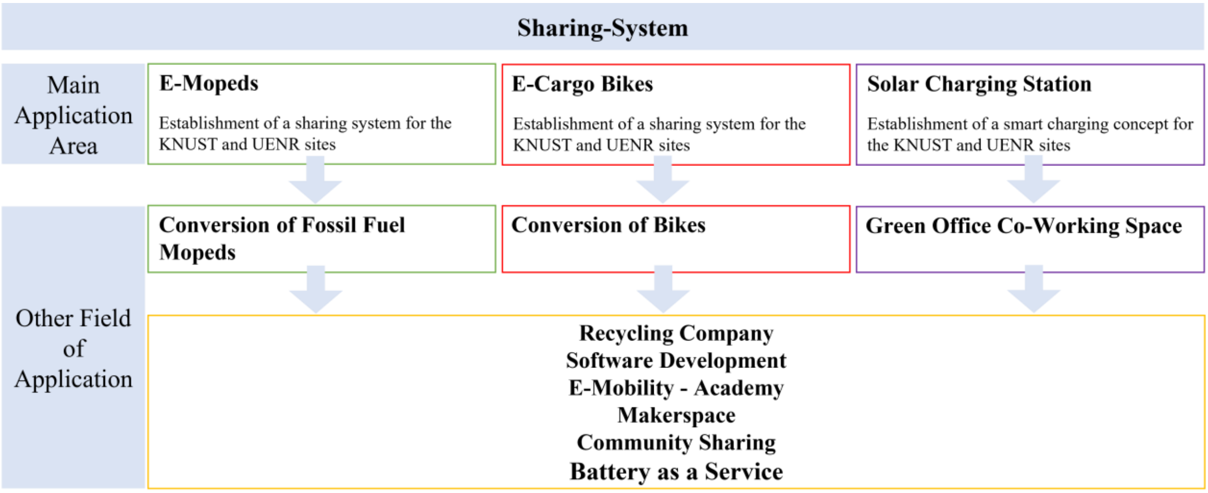


Figure 10: Other Fields of Application (Own Source)

There are the areas of application that only apply to the individual areas and those that can be applied to all three (E-mopeds, E-cargo bikes, solar charging station). The e-mopeds and e-cargo bikes of a sharing system must be maintained as well as repaired. This requires skilled employees and a workshop in which the equipment can be maintained and repaired. Due to this already existing infrastructure, a conversion of fossil fuel mopeds and bicycles to the respective E-variant can also take place here. That conversion forms another application area, which can be offered without large investments within the sharing enterprise. Shared costs (rent, employees, equipment) lead to cost reductions and deeper know-how transfer between employees which forms together great advantages. The solar charging station offers an area of application beyond the topic of mobility. The charging station could be designed and installed in such a way that it is not only possible to charge one's e-bikes and e-mopeds there, but also to offer a solar-powered co-working space at the same time. Combining this with the offer to charge one's own e-mopeds and e-bikes there, the waiting time in the co-working space could be spent productively.

Areas of application that can be applied to all three areas can be seen in the yellow field in the figure. In order to design sustainable e-mobility solutions, the entire life cycle must always be considered. A major problem is often the recycling of the various components of the different mobility systems. As a sharing service provider, the recycling application field can and should be directly included here. In the case of a joint venture, a recycling company from Ghana can be involved in order to take care of the best possible recycling at the end of life. In order to be able to recycle as much of the mobility systems as possible, thought should be given in advance during the design phase as to how this can best be implemented. The introduction of a makerspace can help here, where different ideas and visions can be tried out. Of course, the makerspace offers even more functions, which are described in detail in work package 2. As already mentioned, expert employees are needed to keep the sharing system and the devices running. To train and educate these employees, it makes sense to establish an e-mobility academy. This academy should also provide training for external persons and thus have an impact beyond the boundaries of the own company. Cooperations with the universities KNUST and UENR are to be regarded as meaningful. Currently, the software provided by Solar Taxi is to be used for the sharing service. It is important to find out whether the further development and operation of this software should be aimed at by a joint company, in order to think along the best possible contents for each user scenario from the beginning. The catchment area of the sharing system is currently in the immediate area of the universities KNUST and UENR and the target group is especially students of these institutions. With this system, anyone who wants to and has the app can use the e-mobility systems. Another possible field of application could therefore be the creation of a sharing service per defined community. Members of the community pay a fixed fee per month or year and can use the e-mobility systems as often as they want. A community could be for example, a certain residential area or a certain group of people within a company.

Analysis of the catalogue of criteria for the evaluation of the product system from an economic, ecological and social perspective

Shared micro mobility solutions are said to offer the potential to positively impact sustainable urban development. Private car traffic could be reduced and thus air and noise pollution or individual mobility could be accessible to more social classes. To evaluate the sustainability performance qualitatively and quantitatively, a multi-criteria evaluation based on a selection of key figures and indicators is required.

For this, a set of criteria has been identified and replenished by appropriate metrics and potential data sources. In a later project phase, we intend to expand this system into a more differentiated, 5-point reference scale: +2 (best in class), +1 (continuous improvement beyond generally acceptable situation, continuous improvement), 0 (generally acceptable situation), -1 (unacceptable situation but improving), -2 (unacceptable situation, no improvement). The collected data will then be re-evaluated and compared to a larger data pool.
Given the short amount of time for this first project phase, the five-point reference scale was simplified and converted to a three-stage evaluation:

Table 2: Scoring system

Score	Explanation
+1	Beyond generally acceptable situation
0	Generally acceptable situation
-1	Unacceptable situation

This system excludes any past or future improvement efforts, as for this a longer period of time is necessary to observe changes or evaluate past processes.
To evaluate the overall sustainability performance of the system, the total number of each achieved evaluation will be counted and an average will be provided by dividing the total score sum by the number of evaluated criteria. If the result exceeds zero, the system can be evaluated as overall acceptable. If it remains below zero, further improvement will be necessary.

The required data for the three-stage evaluation were collected using different methods and data sources, such as the aforementioned survey, interviews or manufacturer information. Table 2 provides an overview about the criteria catalogue. It includes data that is required to compute each criterion as well as the data sources that are intended to be made use of. Lastly, the table shows the results that have been achieved and an evaluation of each criterion.

Please note that some figures do not apply to the product system per se, but to the entire company. Given that the same standards apply to the employees in the product system, this does not affect the score.

Table 3: Overview of required data and data sources

Dimension	No.	Criteria	Necessary data	Data sources	Result	Score
Economic indicators	1	Affordability	Average monthly income	Survey (users)	850 GHS on average	-1
			Average transportation costs per 5 km ride	Profitability analysis	6,8 GHS (sharing system) and 3,1 GHS (current transportation)	
	2	Local employment	# of additional employees in the product system	Interview with provider	No information	Cannot be evaluated
	3	Convenience	# of users who perceive the product system as convenient	Survey (users)	88	+1
	4	Fair salary	# of employees who receive at least minimum wage	Interview with provider	45 (in the entire company)	+1
			Total # of employees	Interview with provider	45 (in the entire company)	
	5	Tax generation	# of passenger km per year (all users)	Interview with provider	60,000,000 (for the entire company)	Cannot be evaluated
			Taxes per year	Interview with provider	No information	
	6	Rentability	Yearly costs	Interview with provider	No information	Cannot be evaluated
			Yearly revenue	Interview with provider	400,000 GHS on average	
	7	Infrastructure development	Existence of urban development plans	Interview (local authorities)	Yes, constant contact with government agencies	+1
			Compatibility with urban development plans	Interview with provider	Yes	
Ecological indicators	1	Air quality	Air pollution per passenger km	Life cycle assessment	No information	Cannot be evaluated
			Substitution rate	Survey (users)	Approx. 5%	
	2	GHG emissions	# of passenger km per lifetime (all users)	Interview with provider	480,000,000 (for the entire company);	+1
			Emissions arising during life cycle of the product system	Life cycle assessment	16,4 g/km (compared to currently 86 g/km)	
	3	Noise pollution	Substitution rate	Survey (users)	Approx. 5%	-1
			Noise of usage	(Lelong, 2014)	Up to 10 db less than a car, up to 60 db more than a pedestrian	
	4		Substitution rate	Survey (users)	Approx. 5%	0

		Space occupancy	Space demand while driving	(Brunner, 2018)	10.3 m^2 (compared to currently 7.5 m^2)	
			Space demand while parking	(Brunner, 2018)	2.0 m^2 (compared to currently 2.5 m^2)	
	5	Use of renewable energy	Percentage of renewable energy sources	As targeted as part of the project	100%	+1
	6	Life span of the motorbikes	Life span of the motorbikes	Manufacturer data + Interview with provider	50,000 km / 7-8 years	+1
Social indicators	1	Accessibility	# of charging points in the study area	As targeted as part of the project	2 solar stations	-1
			# of students + # of students living on campus	Interview with university administration	87,444 in total (2021), approx. 7,200 living on campus	
			# of motorbikes	As targeted as part of the project	2	
			# of charging stations from provider	Interview with provider	0	
			Campus area	(Agyemang, 2020)	19 km^2	
	2	Safety	# of accidents per year	Interview with provider	Approx. 240 $\rightarrow$ far below 1%	+1
	3	Social benefits	# of employees who receive a minimum standard of social benefits	Interview with provider	45 (in the entire company)	+1
			Total # of employees	Interview with provider	45 (in the entire company)	
	4	Further training opportunity	Average # of hours of training per employee per year	Interview with provider	No information	Cannot be evaluated
			Existence of a training concept	Interview with provider	Yes	
	5	Freedom of association and bargaining	Existence of a policy that allows freedom of association and bargaining	Interview with provider	Yes	+1
	6	Child labor/ forced labor	Existence of a policy that prohibits child labor and forced labor	Interview with provider	Yes	+1
	7	Data privacy	Existence of a data privacy policy	Interview with provider	Yes	+1
Total score divided by number of evaluated criteria						0,53

As can be seen in Table 3, the average score of the product system is 0,53. Given that the overall score exceeds zero, the overall product system can be evaluated as sustainable. Key indicators like the substitution rate will need to be conducted further in order to optimize the criteria catalogue. Other improvements, especially looking at criteria such as Accessibility, seem necessary as well.

However, it is worth noting that all criteria will require a re-evaluation, and some a more differentiated evaluation at a later project stage. For instance, the different policies and concepts (social criteria 4-7) should be revised carefully to analyze reliability and completeness.

Quantification of environmental and economic benefits of the product system

In order to quantify the economic and ecological impact of the e-mopeds, a life cycle assessment (LCA) as well as an economic assessment were conducted. The aim of this analysis was to identify the potential benefits that can be achieved by substituting diesel powered modes of transport, which are currently in use, with electrically powered mopeds. Our approach as well as assumptions and results are depicted in the following chapters.

Life Cycle Assessment

Life Cycle Assessment "is an instrument for quantifying the environmental impact of technical systems (e.g., product systems) or services throughout their entire life cycle." (Schelte, et al., 2021) All production, use and end of life phases are considered in this assessment. When looking at different transport modes, an LCA encompasses among others:

- "the manufacture of the vehicle, raw materials and components (cradle to gate), including the manufacture of the vehicle itself (gate to gate),
- the use phase of the vehicle (well-to-wheel), including the generation provision of the drive energy (well-to-tank) and the conversion into kinetic energy to operate of the vehicle (tank-to-wheel),
- and the treatment or recycling of the vehicle and its components to recover raw materials (end-of-life)." (Schelte, et al., 2021)

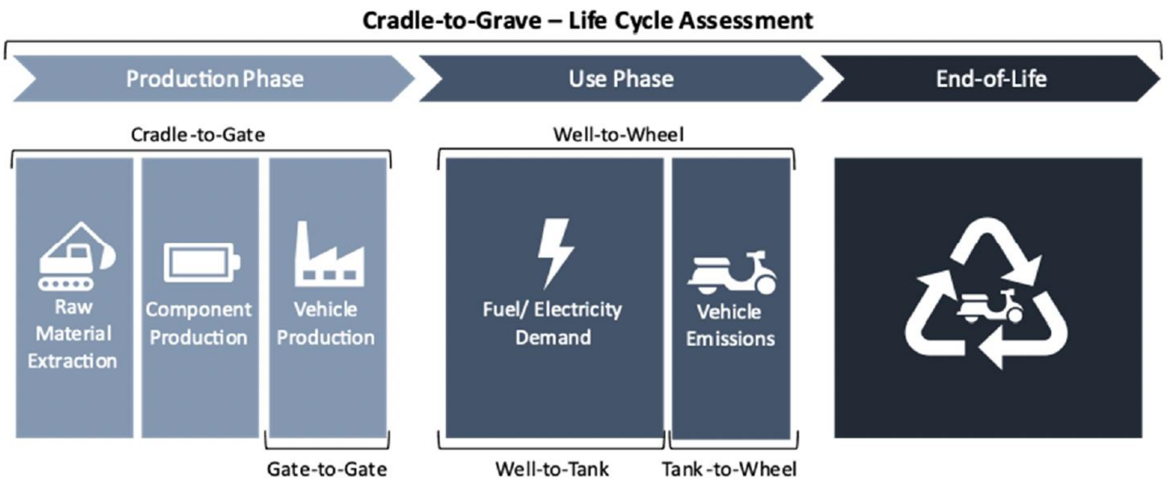


Figure 11: Phases of cradle to grave Life Cycle Assessment of vehicles ((Schelte, et al., 2021) based on (Howe & Jacobsen, 2019))

Goal and Scope

The goal of this study is to examine the life cycle environmental impact of the e-mopeds on KNUST campus. The main technical characteristics of the analyzed e-mopeds are shown in Table 4.

Table 4: Technical characteristics of analyzed e-motorbike (Schelte, et al., 2021)

Technical characteristics	**Unit**	**Kumpan, 1954 Ri** (e-bility GmbH, 2021)
Vehicle mass (including one battery)	kg	102.0
Power	kW	4.0
Battery capacity	kWh	1.479
Certified range	km	186*
Real world range	km	125*
Certified energy consumption	kWh/100 km	2.385*
Real world energy consumption	kWh/100 km	3.550*

*when using three batteries

Figure 12 shows the system boundaries. We used pkm as the functional unit, and CML method (version of 2016) was used as method of impact assessment.

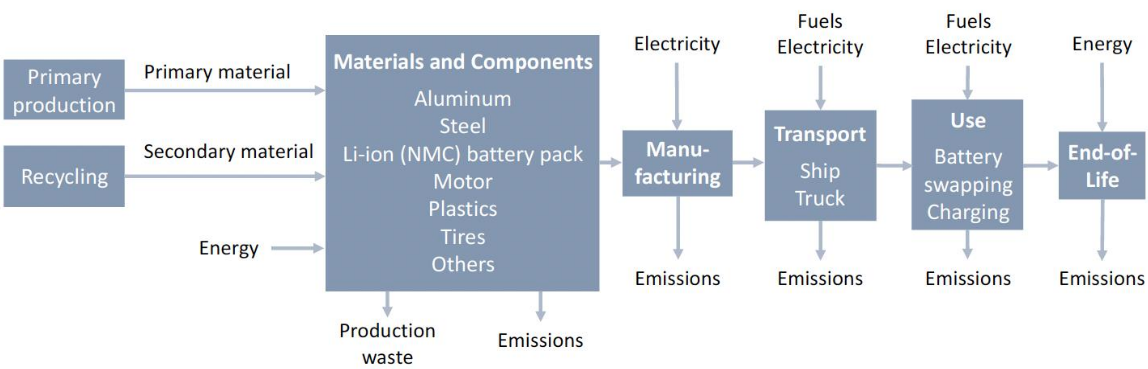


Figure 12: System boundaries

Inventory data

For our LCA study, we used a bill of materials (BoM) which was provided by the manufacturer (e-bility GmbH) to the Sustainable Technologies Laboratory for a different project. The data is depicted in (Schelte, et al., 2021) and will be used for this assessment.

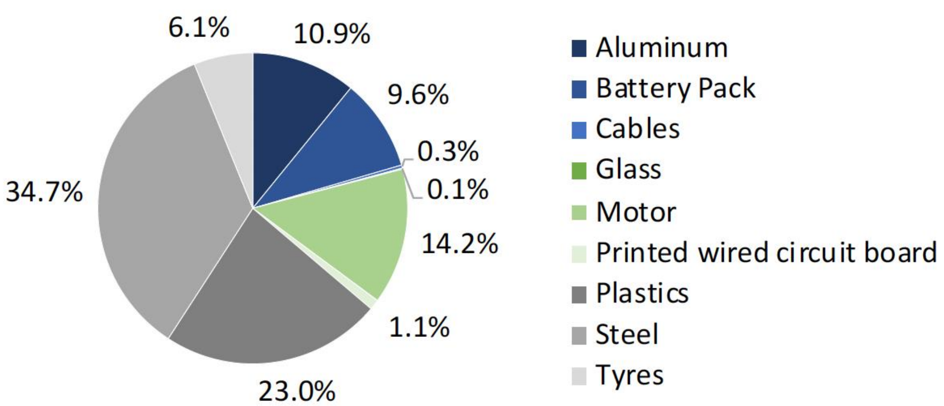


Figure 13: Share by weight of materials/components of the Kumpan 1954i (source: (Schelte, et al., 2021))

The production of the different components takes place in various countries. For this reason, the grid mix of the respective countries is used. Most components are produced in China, Germany, South Korea, Spain, and Slovenia. The transportation from South Korea is assumed to be done by container ship, while all other trips are made on the road. The assembly of the battery pack and the e-moped is assumed to take place in Germany, with an energy consumption of 3.9 kWh.

Assumptions

The analysis was conducted based on a set of assumptions, which are listed in . Those assumptions were made based on both literature reviews and a bill of material, which was provided by the manufacturer (Schelte, et al., 2021).

Table 5: Basic assumptions for the usage phase (Schelte, et al., 2021)

Parameter	Value
Average distance per day [km]	18.1
Average distance per ride [km]	4.9
Average ride time per trip [min]	16.7
Lifetime of the moped [km]	50,000
Lifetime of the battery [km]	40,000
Lifetime of a tire set [km]	15,000
Utilization rate [person]	1.3

Electricity prices currently amount to 0.1135 € per kWh from the Ghanaian grid. For the assessment, we assumed a consumption of 0.034 kWh/km.

According to (Schelte, et al., 2021), for end-of-life the e-moped is shredded. No credits are accounted.

Solar Charging Station

The calculations for the greenhouse gas (GHG) emissions of the solar charging stations are based on the results of (Schelte, Straßberger, Severengiz, Finke, & Felmingham, 2021). The GHG emissions strongly depend on the utilization rate and the performance ratio (PR). The utilization rate is the ratio of used energy and the produced energy since it is an off-grid system. The PR describes the overall efficiency of the system. The results of the LCA are shown in Figure 14:

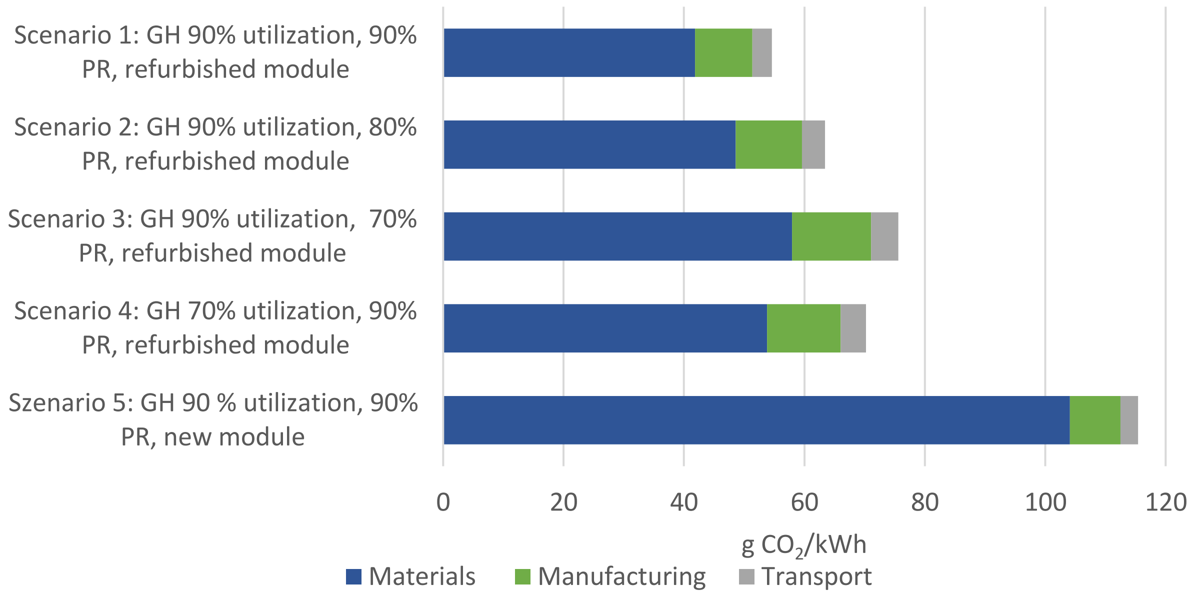


Figure 14: GHG emissions of the solar station regarding different utilization rates and performance ratios

Main Findings

The e-mopeds can either be charged using the Ghana Grid-Mix (0,389 g CO_2e/kWh see component 2) or the electricity from the solar charging stations where we assumed that scenario 2 (0,063 g CO_2e/kWh) is the most likely. According to the survey, the current modal split is with 51 % mainly walking followed by Taxi and car with 31% and bus 18%. We assumed that taxi and car (50% petrol and 50% Diesel driven) emit the same amount of GHG emission (ICCT, 2021). Due to a lack of data for Ghana we used data from India in order to estimate the GHG emissions for the passenger cars. For the diesel bus please refer to the report for component 2. Hence, Figure 15 depicts the life cycle GHG emissions of the different transport modes considered.

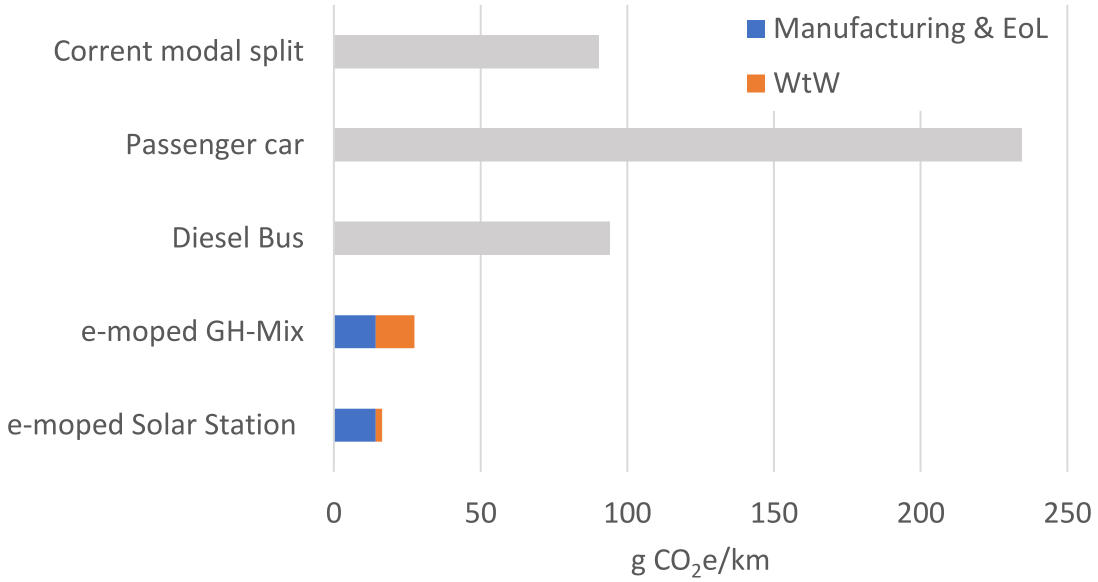


Figure 15: Comparison of the life cycle GHG emissions of different transport modes

The GHG emissions for both the e-moped with the Ghana Grid-Mix and the electricity for the solar charging station is significant lower (82% and 70% respectively) than the current modal split.

Work Package 2: Electromobility Sharing Offer

Objective	Concept for rental system for e-vehicles is set up and piloted
2.1	Technical development of the software solution for the operation of the rental system
2.2	Design of and set-up of an E-Mobility Makerspace under the STC model of MESTI in UENR or KNUST
2.3	Engagement of external service provider for the commercial use of the e-mobility offer on the project sites with a clear demonstration of job creation, maintenance of assets and knowledge transfer. Key focus on cooperation model with academia and EU private sector partners particularly members of PAMA
Result	- Concept paper, Evaluation Report

Technical development of the software solution for the operation of the rental system

Work package 2 aims at developing a concept for a rental system for the e-vehicles on campus of Kwame Nkrumah University of Science and Technology. The sharing system can only function seamlessly if supported by a well-developed software. For this, the first step is to identify a reliable application or software so that the rental system can be operated.

The software that will ultimately be selected for the operation of the rental system has to meet certain requirements:

1. Most importantly, the software has to run on all conventional smartphones and tablets to guarantee barrier-free usage.

2. Following installation of the app, users should have the possibility to create an individual user profile which should consist of selected personal data, such as first and last name, date of birth, contact information etc.
3. The app should allow for an automatic validation of the user's driver's license. If users cannot provide a valid license, the app has to automatically block them until they can do so.
4. The app should allow the sharing system providers to block certain users, e.g., in case of repeated payment issues.
5. Payments should be processed directly in the app. A third-party system needs to be fully integrated so that users can pay for their rides using their credit cards or mobile money. This process has to function automatically, without any intervention by the provider.
6. The app should allow for automatic motorbike unlocking following a confirmed booking process by a user. This requires a constant and stable connection between the motorbikes and the app.
7. It is crucial that the provider of the sharing system can access user information and generate statistics on different use patterns at all times.
8. In order to be able to track whether the vehicle was returned in proper condition after each trip, the app must allow photos to be uploaded to the system at the end of each trip. Without this photo, the user cannot complete the rental period. In addition, the photos can be used to ensure that the vehicles do not cause traffic obstructions because they were not parked properly. Whenever this occurs, employees of the sharing provider can take care of the issue and move the vehicle.
9. Lastly, given the core idea of this project, users should have the option to see how many CO_2 emissions they saved by using the sharing system.

After careful evaluation, two possible software providers have been identified. One option is the software solution offered by SolarTaxi, who have already developed and implemented their own software for their sharing system. For this reason, it makes sense to consider using their solution. However, it has to be taken into account that their software was designed for a different kind of sharing system and will hence require further adaption to our purposes. Therefore, it must be possible for the requirements described above to be integrated into the software. The costs for the adjustments will need to be identified in a later stage of this project.

The app is available on Google Play Store and runs on mobile devices using Android 4.0 or higher. Solar Taxi has already published a small number of screenshots on the Google Play Store, of which we included a selection in this report (Figure 16, Figure 17, Figure 18).

Unfortunately, the software could not be tested during the field trip to Ghana due to technical difficulties. Instead, we collected information material and organized a meeting with the internal software lead of the company who provided a deeper insight into the software as well as relevant figures.

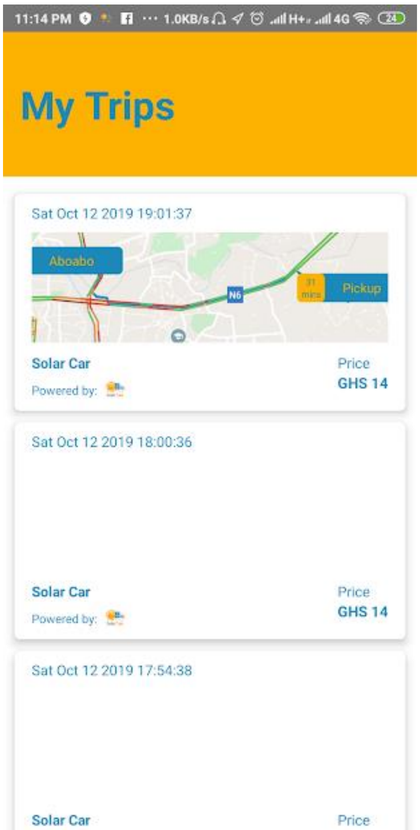


Figure 18: Screenshot Solar Taxi app (Source: (Google Ireland Limited, 2021)

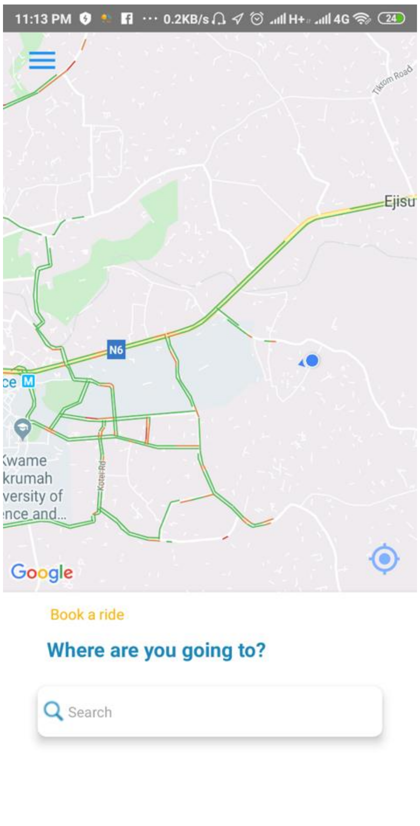


Figure 16: Screenshot Solar Taxi app (Source: (Google Ireland Limited, 2021)

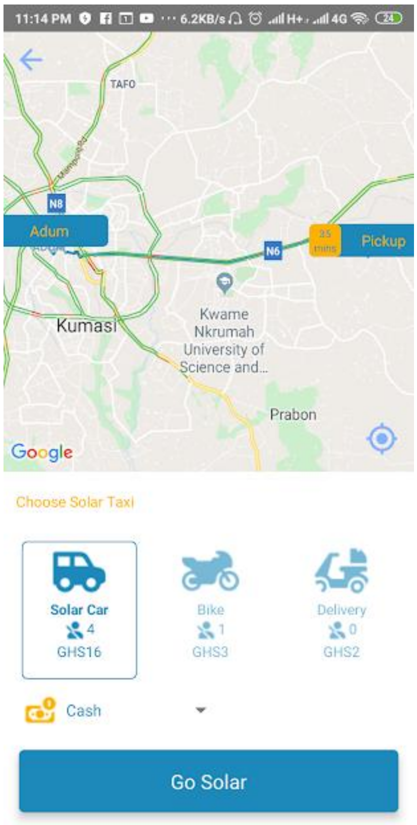


Figure 17: Screenshot Solar Taxi app (Source: (Google Ireland Limited, 2021)

After installation and initial opening of the app, users can create their own profile. This includes personal data such as first and last name, phone number, gender and email address. Once the user profile is completed, users can start using the app, which allows them to book a ride or rent a vehicle. If they chose to order a taxi, they are required to first enter their desired pick-up and drop-off location before processing the payment. Users have the option to either pay the drivers in cash or via the app using the so-called “solar credit”. The latter is based on a third-party payment system which is installed in the app. This system allows users to transfer a certain amount of money (in GHS) to the app, which is then converted into solar credit. This credit can be used for booking rides or renting vehicles.

The drivers are equipped with GPS trackers, which allows users to monitor the location of the driver after booking the ride. This way, users are always aware of the remaining distance to the pick-up location, and they can see the estimated time of arrival.

One of the crucial advantages of using the app from SolarTaxi is the local job creation potential this would allow.

As an alternative, we considered the German software *MoQo*. This software can be adapted to different kinds of sharing systems, and allows providers to customize the app as required. The app can be used to rent and pay for motorbikes. Both processes run automatically and do

not require any support by the provider. Users can create their own user profile, and the provider can block certain users if they do not fulfill the required criteria. This could be an invalid driver's license, which the app recognizes automatically. Only once a valid driver' license has been provided can a user start renting the motorbikes.
If the user requires support in finding the rental station, the app will help him or her navigate. Additionally, MoQo offers marketing support and can provide further accessories for the motorbikes, such as phone holders.

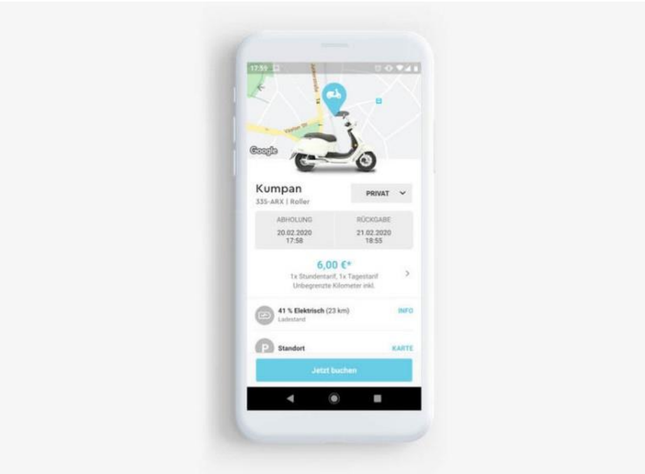


Figure 19: Screenshot from the MoQo app

A major disadvantage of this app is the price. At 39.00€ per moped and month, this is adapted to the price structure in Germany and is therefore currently not suitable for our project.

Taking the information from this chapter into account, the following must be clarified in the further course of the project:

- Can the SolarTaxi app be customized according to our requirements? If so, what is the pricing structure here?
- Or does it make more sense to have our own software developed in Ghana that is tailored to our requirements?

Design and concept development of an E-Mobility Makerspace

The conceptualization and design for a makerspace is a joint effort between the participating universities, HSBO, UENR and KNUST. Coordinating these efforts and ensuring the availability of best practice examples is the firm MotionLab who join as a partner to the E-micromobility in Ghana project. A detailed conceptual report is attached in the annexes of this report. The architectural floor plan (Figure 32) is included in this report and shows 1,500 sqm for the ground floor with the same replicated for the second floor.

It is the recommendation of the project team to lay emphasis and focus on the makerspace in the University of Energy and Natural Resources. This is due to its focus on the converted model and the job creation potential which comes with it. The attached concept therefore covers this makerspace in particular. However similar costs are envisioned for KNUST should there be a decision to construct both makerspaces.

Work Package 3: Mobility Conversion Model

Objective	Prototype of conversion of motorcycles with internal combustion engines to electric motorcycles
3.1	Development of a converted prototype converted motorbike suitable for Ghanaian conditions (To be reported on fully by 30.11.2021)
3.2	- Local and international patenting of finalized product between academia and private sector (To be further investigated in 2022) - Commercialization of conversion model
Result	- Minimum Viable Product Developed - Conversion center designed with input from MESTI

Electric vehicles although not a new invention is relatively new to the African ecosystem. This is largely due to the lack of technical know-how in the inner workings of the subsystems that make up an electric vehicle. In this report we explore the processes and design requirements necessary to convert a Haojin 125-32 (150cc) engine powered motorbike into an electric motorbike as well as the needed tools, equipment and infrastructure to set up a makerspace dedicated to working on electric vehicles. The next interim will explore the job creation potential of the converted motorbike taking into consideration the direct and indirect job opportunities. The ecological analysis of Internal Combustion Engine (ICE) fuel motorbike and converted motorbike will also looked at and reported on int the next interim report.

The economic analysis of the project revealed that, although the converted motorbikes required high initial investment to build, it had a long-term financial benefit than the ICE fuel motorbike. This is because the ICE fuel motorbike incurred extra cost in high cost of fuel, frequent oil change, frequent maintenance and many more over the vehicle's useful life, but that was not the case with the converted motorbike. Further information about the economic analysis can be found in work package 4.

Status Quo of Motorbike Conversion Technology

The call to convert a fuel motorbike to an electric motorbike is one part of a broader project that is to be executed hand-in-hand with the University of Energy and Natural Resources (UNER) located in Sunyani with the purpose of examining the feasibility and scalability of such a conversion process. The learning from this project will lay down the ground work for further collaboration between industry and academia in terms of building capacity in the electric vehicle space. Training and knowledge acquisition will therefore become indispensable tools as well as being integrated into the various institutes of higher learning. Solar Taxi's contribution is to fully convert a fuel bike into electric motorbike using reproducible methods which will in turn be tested scientifically by the University of Energy and Natural Resources. The components of electric bike include the following:

i. Frame
ii. Swingarm
iii. BLDC motor
iv. Electronic Speed Controller (ESC)
v. Lithium-ion battery pack
vi. Power transmission
vii. Steering
viii. Wheels
ix. Braking system.
x. Dc–Dc converter
xi. Accessories

Conversion Process

Given the teams prior knowledge and familiarity with the conversion process, the setup was completed within 2 weeks. The conversion process can be broken down into 3 major sub processes namely:

i. Mechanical fabrication which includes but not limited to welding, cutting, motor installation etc
ii. Battery pack development
iii. Electrical rewiring

The premise was to utilize most of the already installed subsystems of the fuel motorbike and only add on the parts needed to make it electric, thus the physical product still houses its original parts. The parts that were replaced are:

i. the engine
ii. starter battery
iii. other electrical wiring that was not needed
iv. Throttle
v. Clutch lever
vi. Dashboard

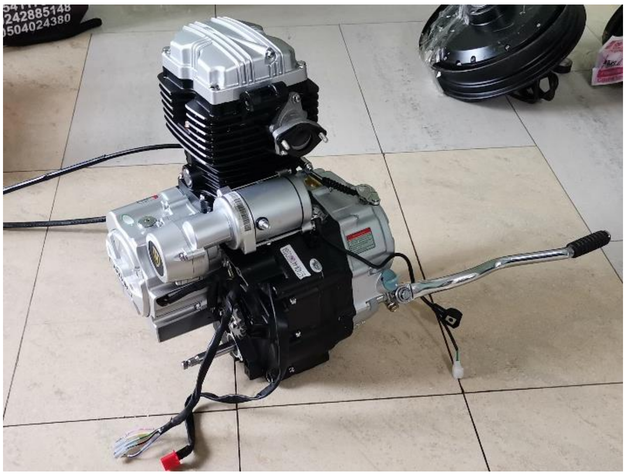
These parts were replaced with:

i. 5kW chain driven motor
ii. 50Ah Li-ion battery pack
iii. Motor controller
iv. Hall sensor throttle
v. Necessary wiring
vi. Electronic dashboard

Aside these, all other parts not mentioned were maintained as they were still in good condition, robust and fit the use case.

Mechanical Fabrication

New ICE fuel motorbike to be converted to electric motorbike

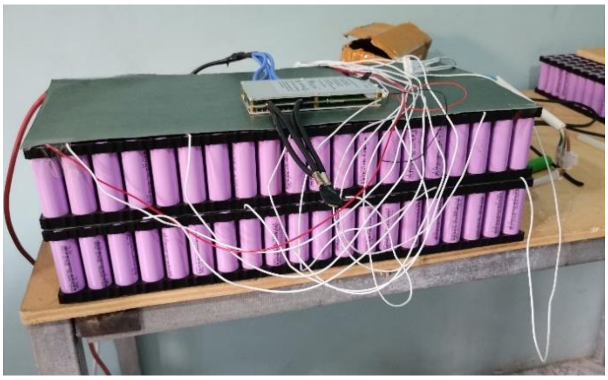


ICE fuel motorbike engine removed from the motorbike

This step involved creating a platform to seat the electric motor firmly, creating a housing to house the battery pack, platform to mount the motor controller and a platform to mount the electronic dashboard. This was the most challenging part of the entire build mainly due to space constraints. As shown in the before and after images, the former location for the engine now contains the electric motor and the battery pack mainly because this is the largest space that exists within the motorbike and in order to preserve the shape and durability of the original build we needed not to tamper with that design. Aside that, the former location for the battery that powers the starter now houses the motor controller which translates actions such as turning the throttle into forward or backward movement.

Battery Pack Development

Since the electric motor runs in batteries, the team had to build a robust battery pack that could run the motor effectively. Contained in this vehicle is a 72V nominal 50Ah battery pack developed using 21700 lithium-ion cells providing a total capacity of 3.6kWh. The choice of cells and packaging was determined again based on the amount of space available. The pack contains a total of 160 cells arranged in series and parallel alternately. To manage the state of health of the pack, a smart Battery Management System (BMS) is included in the pack. With the corresponding app which runs on both Android and IOS platforms, the behavior of the cells is preset and monitored once in close proximity to the pack.

Lithium-ion battery pack built by Solar Taxi for the converted motorbike

Electrical Rewiring

One major drawback in the usage of electric vehicles is the availability of spare parts locally in the advent of breakages. To cater for that drawback, the wiring system that came with the original build was remapped to suit this purpose. In this regard, we can use off-the-shelf spare parts for the same vehicle should there be any breakages. The wiring was equally challenging as it involved retracing every single wire to ascertain its functionality before re-purposing it. The use of color codes and labeling was employed to make it easier for a second party to navigate during maintenance and repairs. Proper insulation was also used to guard against unforeseen shorts that may occur. Cable sizing was another factor that was considered.


Electrical rewiring of the ICE fuel motorbike

Table 7: Comparison between the before and after conversion of the motorbike (SolarTaxi 2021).

	Bike before conversion (Fuel)	**Bike after conversion (Electric)**
Source of Power	Petrol	Li-ion cells
Propellant	4 stroke engines	Permanent Magnet Synchronous Motor
Drive Method	Chain drive	Chain drive

Brake (front)	Hydraulic plate	Hydraulic plate
Brake (rear)	Drum	Drum
Accessories working voltage	12V	12V
Distance covered	unknown	63km
Energy Capacity	9L of fuel	50Ah battery pack

Fuel converted bike with electrical components

Fuel motorbike

Job Creation Potential

Employment remains a sensitive topic for discussion in Ghana, especially after the finance minister made it clear that the government sector was full and edged the youth and graduates to venture into entrepreneurship. According to the International Labor Organization (ILO) cited on the trade economics website[1] Ghana's unemployment rate stands at 4.5 percent of the active labor force and this is expected to remain the same or slightly increase to 4.7 percent in 2022. The scalability of this project has the potential of opening new job opportunities to absorb some of these unemployed population. The scalability of the conversion process is expected to generate about 150 direct jobs and 400 indirect jobs across the e-motorbike conversion value chain for a 20 bike conversion per day production line.
This includes:

a. **Direct jobs**
   i. Facilitators to lead the training process
   ii. Mechanical and electrical and electronic engineers trained to lead the conversion processes across the country
   iii. Fabricators and welders to redesign the mechanical parts to accommodate the e-motorbike components
   iv. Local logistics companies to ensure the importation of the parts

[1] https://tradingeconomics.com/ghana/unemployment-rate

b. Indirect jobs

i. Local electrical component suppliers
ii. Motorbike accessories suppliers
iii. Satellite e-motorbike engineers responsible for maintenance of the converted motorbikes.

As indicated by the trade economics website[2], the annual growth rate of Ghana in 2021 is 5 percent. To estimate the yearly employment creating for the next 5 years, we would have adopted the International Labor organization's (ILO) employment by sector formula which is

Employment = output / productivity

However, there is not enough data to ensure the computation of these employment figures. Based on this, the provided figures are assumed estimates of jobs to be created annually. It is however assumed that the assumed baseline data will double every year.

Table 8: Estimated job creation avenues for the next five years (SolarTaxi 2021)

Type of jobs	Year 1	Year 2	Year 3	Year 4	Year 5
Direct Jobs					
Facilitators	3	6	12	24	48
Mechanical and Electrical Engineers	7	28	104	320	1200
Fabricators and welders	3	12	54	100	150
Local logistics companies/riders[1]	250	550	2500	5500	13,000
Indirect Jobs					
Motor accessories suppliers	5	10	20	40	80
Electrical component suppliers	8	16	32	64	128
Satellite engineers for maintenance	10	20	40	80	160
SMES and Food vendors[1]	200	500	2000	4000	10,000

1: Speculative figures based on population estimations

Work Package 4: Project Evaluation

Objective	Scientific evaluation of the environmental benefits and the social and economic impact of the e-mobility transportation system. - What environmental benefits does the developed product system offer?
4.1	Survey of the local population on social acceptance of e-mobility devices with a focus on
4.2	Profitability analysis
Result	- Work package report

[2] https://tradingeconomics.com/ghana/forecast

Survey of the local population

The project system is expected to offer benefits on all three dimensions of sustainable development. The use of electrically powered mopeds which are charged by means of solar panels allows for environmental, but also economical relief. This statement is supported by the results of the Life Cycle Assessment as well as the profitability analysis.
The results of the survey conducted at KNUST campus provide additional insights into the benefits a sharing system with e-mopeds on student campuses can bring. Besides from improving the environmental impact of the local mobility by substituting cars and buses with combustion engines for electrically powered mopeds, such a sharing system will also help to accelerate rides on the campus and thereby minimizes delays in lessons, according to the participants. The social benefits go far beyond more teaching time, as students will also make experiences with maintaining and repairing electrically powered vehicles directly on their campus, which is an important skill in future mobility systems. The interest of the participants to learn such skills as well as a broad analysis of the survey in general can be found in Annex 2.

Ecological analysis of converted motorbike vs. fossil ICE fuel bike

Climate change is a serious threat to humanity, and these are usually caused by human activities especially, emissions from vehicles. In the view of Redman (2015), powered two wheelers (PTWs) release several hazardous compounds like (carbon monoxide, nitrogen oxide and Sulphur) into the atmosphere, most of which are unrestricted by legislation, depletes the ozone layer. He further espoused that the total air pollution in dense urban areas is largely caused by PTWs. These have serious health implications like asthma, chronic obstructive pulmonary disease, bronchitis, lung damage and the likes on these urban dwellers. The fossil ICE fuel motorbike to be converted produces about 96.7 grams of CO_2 per mile, which has an adverse effect on the environment and health of the people in the long run. On the other hand, the converted electric bike produces an average of about 3.8 grams of CO_2 per mile. This shows that the electric bikes produce CO_2 that are about 2500 times lesser than fuel powered motorbikes.

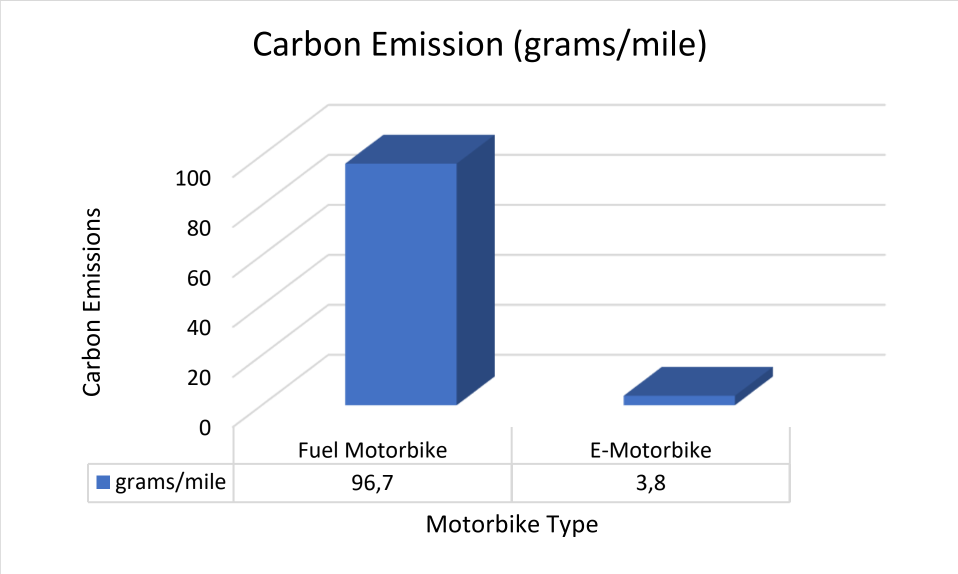


Figure 20: Carbon emission between fuel motorbike and e-motorbike (SolarTaxi 2021)

In the 2020 World Health Organization's report on the Economic cost of air pollution in Accra, Ghana, they indicated that there were about 1790 deaths resulting from air pollution especially caused by fumes from cars. This figure could be more as one travels farther away from the capital to areas with limited health infrastructure and services.

On the other hand, the introduction of converted motorbikes, although the technology is quite new in Ghana, has the potential of addressing most of the issues caused by the fuel motorbikes. The electric motorbikes are powered using batteries that store electrical energy, and its usage does not produce fumes and toxic emissions that pollute the environment, be it air pollution, noise pollution or ozone layer depletion that causes climate change. This basically translates into improved health and economic standing of the people.

Based on this analysis, it is clear that the benefits accruing from the usage of converted motorbikes outweighs that of the fuel motorbikes. This was made evident in converted motorbike reducing the ecological footprint to protect the environment and safeguard the health people.

Profitability analysis

E-Moped Sharing System

The financial plan is the heart of every business plan. A meaningful and detailed financial plan is particularly important for start-ups and young founders. It serves as a structured comparison of expected costs and revenues. It thus becomes clear whether the foundation or an investment in the business is worthwhile. At the same time, it provides founders with information about the most important aspects for profitability. In order to have a concrete scenario for the profitability analysis, the possibility of an e-moped sharing system at the KNUST University in Kumasi is highlighted in the following. Its campus is very suitable for the chosen e-moped sharing system, as it has a size of eight-mile square (= 20,72 square kilometre) and approximately 40.000 students studying there (Homepage University 2020).

The purpose of this venture is to provide sustainable, low-emission and affordable mobility options for the university's students, offering an alternative to traditional transport options.

The overall idea is to provide an access to mobility for everyone on that campus. Regarding this, the affordability and use of renewable, clean energy is important. Furthermore, the investments will strengthen the Ghanaian economy, build up long-term, cross-project partnerships for further operations and create jobs.

Since there is no comparable sharing service in Ghana, as we want to build up with the e-mopeds, assumptions had to be made in advance for the profitability analysis. These assumptions have been estimated based on conversations with experts[3], findings out of documents as well the results of a survey that took place at beginning of this year.

The assumed data is explained below:

- **40 e-mopeds:** Based on expert knowledge that e-mopeds should be available every 500 m and the representation of the campus (see Figure 21) 40 scooters correspond to a first optimal number.
- **10 rides per scooter a day:** The e-mopeds have an average speed of 45 km/h, a driving distance of 135 km with a charged battery and a charging time of 4 hours. Theoretically the e-moped could be driven for 12 hours a day. Based on the assumption that an average ride takes 8 min and that there is a break of 10 min in between the rides there could be three rides per hour. Therefore, the first calculation used 1,5 rides per hour (18 rides per day) in case that the students do not accept it as good as possible. However, the expert mentioned that already 5-7 rides a day are good and realistic. Therefore, the assumption was set to the lower number of 10 rides a day.
- **1,5 new e-mopeds per year:** It is estimated that 1,5 new e-mopeds must be purchased every year to compensate for the loss caused by theft, vandalism, and total damage. The assumption is based on the expert's knowledge and literature research.
- **50,000 € Software development:** Currently, there is no software offered by any company in Ghana that has all the features needed for a sharing service we like to offer. German software alternatives with which other projects have already taken place are too expensive for the current project. For this reason and related to the goal of creating more jobs in Ghana, programming by a local company makes sense. There are already ongoing discussions about this, but no exact numbers could be given by the time the report was submitted. For this reason, we have taken a reference value of a similar project.

[3] Marvel Astonish Aryee, Managing Consultant at MEK Consult & HR Essentials, e-mail correspondence
Jorge Appiah, SolarTaxi, e-mail correspondence
Peter Russ, City Manager at TIER Mobility GmbH, Zoom Meeting

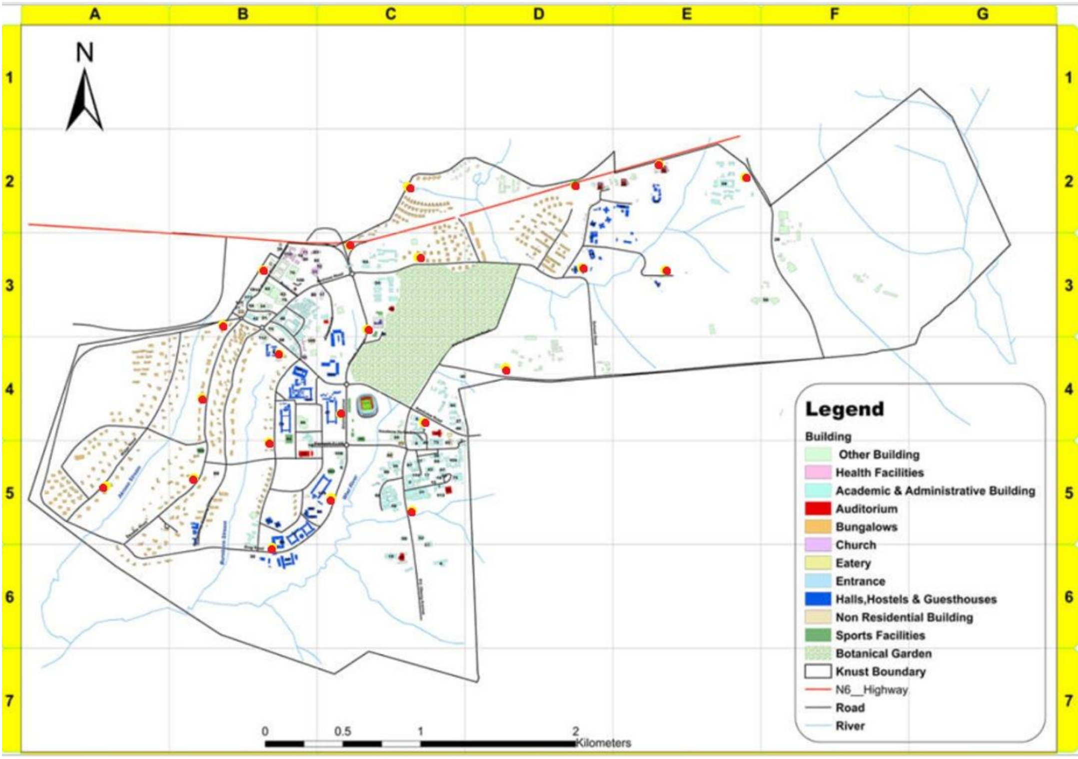


Figure 21: Scooter availability KNUST

The following tables list the costs of the sharing system. The costs are divided into onetime expenses, fixed costs per month, variable cost per month and costs per ride.

Table 9: Onetime expenses sharing system (own source)

Onetime Expenses						
Type of Cost	**Cost description**	**Unit**	**Costs/Unit**	**Quantity**	**Total Costs**	**Cost/Moped**
E-Moped	SolarTaxi	Piece	2.115,00 €	40	84.600,00 €	2.115,00 €
Charging Station		Piece	1.400,00 €	20	28.000,00 €	700,00 €
Installation	Technical Service&Consultion in €/day	h	794,00 €	6	4.764,00 €	119,10 €
Truck	For the collection of e-mopeds	Piece	8.000,00 €	1	8.000,00 €	200,00 €
Office Equipment	Technical Equiptment + Furniture	Workplace	700,00 €	4	2.800,00 €	70,00 €
Software	Programming of an own software solution for the sharing system	Piece	50.000,00 €	1	50.000,00 €	1.250,00 €
				Total	**178.164,00 €**	**4.454,10 €**

Table 10:Fixed cost per month sharing system (own source)

Fixed Cost Month						
Type of Cost	**Cost description**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**	**Cost per day/Scooter**
Rent	all incl. Water, Internet…	day	26,30 €	30,417	800,00 €	0,66 €
1. wage	CEO	day	34,85 €	30,417	1.060,00 €	0,87 €
2. wage	IT	day	18,74 €	30,417	570,00 €	0,47 €
3. wage	Costumer Support	day	11,67 €	30,417	354,90 €	0,29 €
4. wage	Operations	day	6,05 €	30,417	183,90 €	0,15 €
				Total	2.968,80 €	2,44 €

Table 11:Variable cost per month sharing system (own source)

Variable Cost per Month						
Type of Cost	**Cost description**	**Unit**	**Cost/Unit**	**Quantity**	**Total Cost**	**Cost per day/moped**
E-Moped	Replacement for total demage, theft..	day	8,69 €	30,41666667	264,38 €	0,22 €
					Total	0,22 €

Table 12: Cost per ride sharing system (own source)

Costs per Ride						
Type of Cost	**Cost description**	**Unit**	**Cost/Unit**	**Quantity per month**	**Total cost per month**	**Cost per ride/Moped**
Credit-Card Fee		Ride	0,230 €	304,17	2.798,33 €	0,23 €
Insurance		Ride	0,012 €	304,17	150,00 €	0,01 €
Repair		Ride	0,280 €	304,17	3.406,67 €	0,28 €
Permit-fees		Ride	0,003 €	304,17	38,23 €	0,003 €
				Total	6.393,23 €	0,53 €

Table 12 lists the expected revenue per ride.

Table 13: Revenue per ride sharing system

Revenue per Ride				
Type of revenue	**Unit**	**revenue/unit**	**Quantity**	**Total revenue**
Fee per Ride	Min	0,05 €	8	0,40 €
Fixed Fee per Ride	Ride	0,60 €	1	0,60 €
			Total	1,00 €

It is assumed that an average drive on campus takes eight minutes. The fixed price per ride was determined based on the costs described above. In order to adjust the ride sharing system to the willingness to pay in the further course, 5 cent per minute was set as the fee per ride. This results in a price of 1.00€ for travel time of 8 minutes, which is the average time to drive on the campus.

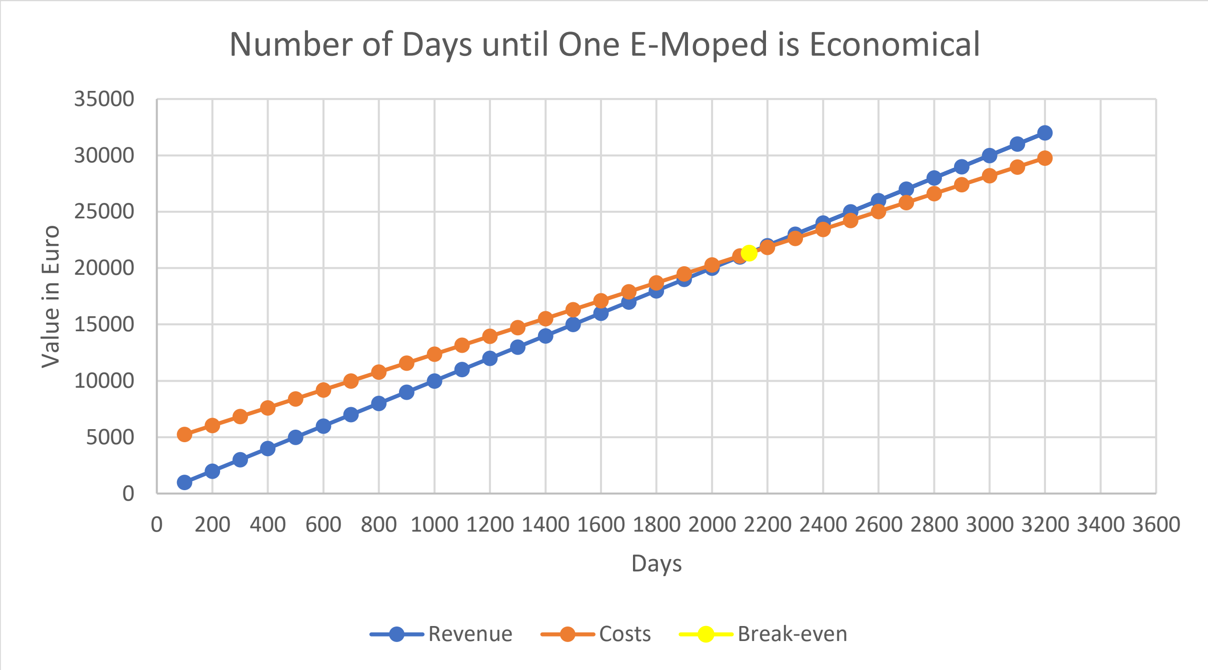


Figure 22: Number of Days until One E-Moped is economical (own source)

In addition to the costs incurred for the sharing system and the price customers should pay for using it, it is also important to know when the business model is profitable. Here it is important to answer the question, after how many days, the use of the e-mopeds will be profitable (see Figure 22). As shown in figure 19, it takes 2,134 days and thus 5.9 years to be profitable with the given assumptions. At this point, it should be noted that the e-mopeds calculated with are models from a local manufacturer (SolarTaxi). Since the exact costs for the software development are currently missing, it can be assumed that the calculation will shift, and that profitability will occur sooner.

In conclusion, there are still research questions for the further course of the project within the sharing system topic that are needed to specify and refine the profitability analysis:

Can our assumptions be confirmed in the field during the pilot phase?

- How often does a moped travel during the day?
- Is the supply of charging stations sufficient?
- How often does a vehicle actually need to be repaired?
- Is the demand as expected? Is scaling possible?
- How much do a development of a suitable software costs in Ghana?

Motorbike Conversion

Another way to promote zero-emission mobility in Ghana is the conversion of fossil fuel-powered motorcycles into electric motorcycles. The concrete demand for e-motorcycles can only be based on estimates at the moment, as there is not yet a market for this type of transport system. However, if you look at the numbers of conventionally registered motorcycles in Ghana, you can see the potential that can be developed in the future in the e-motorcycle market. An estimate of the potential demand for e-motorcycles is done by analyzing the current quantity of conventional motorcycles in whole Ghana (see Figure 22). Eight and a half percent of households reported at the survey that owning between one and four motorcycles which were in good condition for private use. The Upper West region (22.6%) had the highest proportion of households who owned a motorcycle, followed by Northern (19.3%), Upper East (17.9%) and Brong Ahafo (10.7%) regions. The size of the population in Ghana at the time of the survey in 2012 was 25.7 million people (Figure 24). Taking the information of Figure 23 that means that 2.0 million people had one conventional motor bike, 0.15 million people had two conventional motor bikes, 0.03 million people with 4 conventional motor bikes. In total there was a stock of approximately 2.4 million conventional motor bikes in year 2012. With a current estimated population of 30,8 million people (Ghana Statistical Service, 2021) and an assumption of a constant share of conventional motorcycles per person there could be a stock of 2.86 million conventional motor bikes in year 2022. Considering the fact that all countries in the world urgently need to save CO_2 and take measures to reduce this kind of emissions, other transport systems will be required in the future. That means that these 2.86 million conventional motorcycles could be considered as the current potential demand.

	Number of Motorcycles					
Region	0	1	2	3	4	Total
Western	97.4	2.6	0.0	0.0	0.0	100.0
Central	98.4	1.6	0.0	0.0	0.0	100.0
Greater Accra	96.6	3.3	0.1	0.0	0.0	100.0
Volta	91.2	8.8	0.0	0.0	0.0	100.0
Eastern	97.2	2.7	0.0	0.0	0.1	100.0
Ashanti	96.6	3.0	0.0	0.0	0.3	100.0
Brong Ahafo	89.1	10.7	0.2	0.0	0.0	100.0
Northern	77.2	19.3	3.0	0.4	0.1	100.0
Upper East	80.6	17.9	1.4	0.0	0.0	100.0
Upper West	74.8	22.6	2.5	0.0	0.0	100.0
Ghana	**91.5**	**7.8**	**0.6**	**0.0**	**0.1**	**100.0**

Figure 23: Number of motorcycles in good condition for private use (in % of households), Source: Ministry of Roads and Highways, Ministry of Transport & Ghana Statistical Service (2013, p. 67)

	Sex							
	Male				Female			
Region	Urban	Rural	Total		Urban	Rural	Total	
Western	15.7	31.6	1,164,842	47.3	16.9	35.8	1,300,366	52.7
Central	16.1	31.3	1,084,288	47.3	20.3	32.4	1,205,947	52.7
Greater Accra	30.1	18.8	2,019,737	48.9	32.8	18.3	2,110,901	51.1
Volta	9.5	41.1	1,136,444	50.6	9.4	40.0	1,109,581	49.4
Eastern	20.9	28.6	1,374,050	49.4	23.4	27.1	1,405,036	50.6
Ashanti	23.7	22.9	2,328,611	46.6	28.6	24.9	2,671,911	53.4
Brong Ahafo	16.0	32.4	1,186,419	48.3	17.6	34.0	1,268,656	51.7
Northern	13.5	37.2	1,278,217	50.6	13.5	35.9	1,246,455	49.4
Upper East	15.2	34.3	538,735	49.4	15.5	35.1	551,499	50.6
Upper West	17.1	32.1	360,140	49.1	13.9	37.0	373,145	50.9
Ghana	**19.4**	**29.1**	**12,471,484**	**48.5**	**21.7**	**29.8**	**13,243,496**	**51.5**

Figure 24: Distribution of household members by region, sex and locality (in %), Source: Ministry of Roads and Highways, Ministry of Transport & Ghana Statistical Service (2013, p.4)

Since these motorcycles already exist in Ghana, an important strategy in the future will be to convert these conventional motorcycles to the electronic version. How exactly this is done and what requirements and equipment are needed has already been explained in more detail in work package three. At this point, a first profitability analysis is presented and explained and further on a price comparison for the two motorcycle variants will be stated out. At this point, it must be mentioned that the conversion project is still in the pilot phase and therefore the numbers of the profitability calculation are based on this. For this reason, the components for the makerspace are also initial equipment that will be further refined and supplemented in the future.

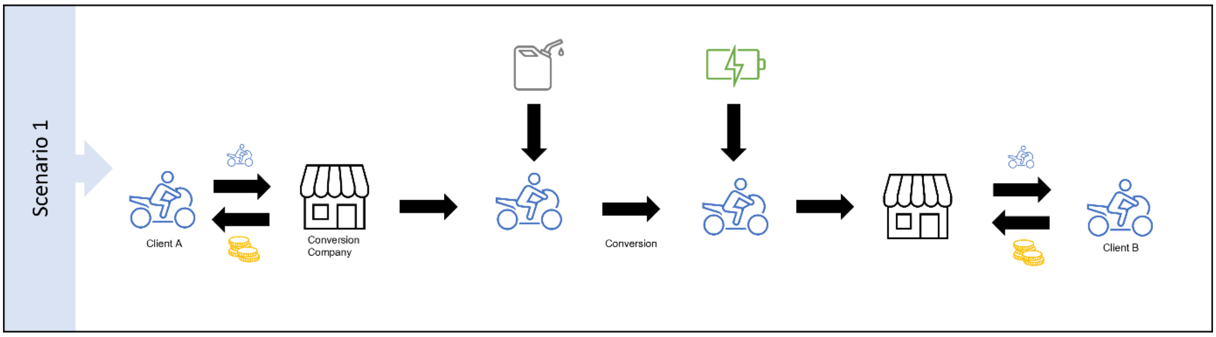


Figure 25: Business Scenario 1 Conversion Motorcycle (Own Source)

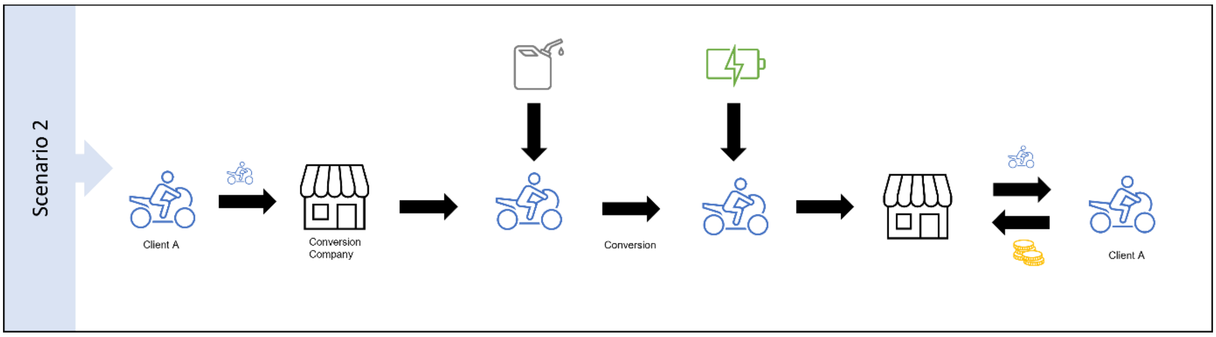


Figure 26: Business Scenario 2 Conversion Motorcycle (Own Source)

There are two different business models when it comes to conventional motorcycle conversion. In scenario number one (see Figure 25), the company buys conventional used motorcycles, converts them into e-motorcycles and sells them to customers who do not yet own a motorcycle. In scenario number two (see Figure 26), the customer brings his own conventional motorcycle to the company and the company converts it into an e-motorcycle. This distinction is important for the consideration of the sales price as well as for the profitability calculation. In cooperation with our local partner SolarTaxi in Ghana, the first conventional motorcycles have already been converted. As described under work package three, a makerspace is needed if you want to establish a business in this kind of area. Table 14 shows a set of tools and equipment that are needed to run a space focused on commercializing converting fuel motorbikes into e-motorcycles within the current pilotphase.

Table 14: Onetime Expenses Equipment Makerspace (Own Table based on SolarTaxi 2021)

Onetime Expenses Equipment Makerspace	
Costs	**EUR**
Welding machine	420,00 €
Electric cutter	112,00 €
Grinder	140,00 €
Spanner set	42,00 €
Wrench set	42,00 €
Rachet set	42,00 €
CNC machine	980,00 €
Spot welder	588,00 €
Multimeter	21,00 €
Soldering station	84,00 €
DC Power supply unit	294,00 €
Oscilloscope	280,00 €
Component storage box	70,00 €
Tool holder	70,00 €
Furniture (tables, chairs, wardrobes, cabinets, etc)	308,00 €
Desktop computer or laptop with dedicated GPU	644,00 €
Personal Protective Equipment (overall, safety boots, gloves, goggles, ear plugs etc)	140,00 €
White marker board	28,00 €
Total	**4.305,00 €**

The first model currently used for the conversion is the Haojin 120-125 model. In Table 15 you can see the current costs for the conversion of this model.

Table 15: Costs E-Motorcycle Conversion (Own Table based on SolarTaxi 2021)

Costs E-Motorcycle Conversion	
Costs	**EUR**
Haojin 125-35	672,00 €
BLDC motor (5kw)	490,00 €
ESC	70,00 €
DC-DC converter	28,00 €
Charger (fast)	56,00 €
Lithium-ion Battery Pack (50Ah)	700,00 €
Fabrication and welding	210,00 €
Import duty	210,00 €
Total	**2.436,00 €**

According to the latest information from SolarTaxi, it currently takes two full working days to convert one motorcycles if one employee is working on it. Therefore, for the following calculations the assumption was made that according to the current status 15 motorcycles can be converted per month. Furthermore, the lifetime of the currently shown equipment of the makerspace was estimated with 10 years. The following tables show the cost structures for the conversion of the motorcycles.

Table 16:Onetime Expenses Makerspace (Own Source based on SolarTaxi 2021)

Onetime Expenses							
Type of Cost	**Cost description**	**Unit**	**Costs/Unit**	**Lifetime (month)**	**Motorcycles produced/Month**	**Costs/Month**	**Cost/Motorcycle**
Equipment Makerspace	Technical Equiptment + Furniture	Workplace	4.305,00 €	120	15	35,88 €	2,39 €

Table 17: Variable Costs Conversion Motorcycle (Own Source based on SolarTaxi 2021)

Variable Costs						
Type of Cost	**Cost description**	**Unit**	**Costs/Unit**	**Quantity**	**Total/Month**	**Cost/Motorcycle**
Converted Motorcycle	Conversion of the Motorcycle	Piece	2.436,00 €	15	36.540,00 €	2.436,00 €

Table 18: Fixed Costs Conversion Motorcycle (Own Source based on SolarTaxi 2021)

Fixed Costs					
Type of Cost	**Cost description**	**Unit**	**Cost/Unit**	**Quantity**	**Cost/Motorcycle**
Rent	all incl. Water, Internet…	Month	790,30 €	15	52,69 €
1. wage	CEO	Month	1.512,00 €	15	100,80 €
2. wage	Machatronic engineer	Month	308,00 €	15	20,53 €
3. wage	Business Administration	Month	421,40 €	15	28,09 €
4. wage	Construction and technical drawing	Month	662,20 €	15	44,15 €
5. wage	Quality Management	Month	280,00 €	15	18,67 €
6. wage	Operations	Month	256,33 €	15	17,09 €
		Total	**4.230,23 €**		**282,02 €**

Taking these costs into account, the following sales prices of the e-motorcycles could be estimated for business scenario one and two, which can be seen in Table 19Table 19.

Table 19: Costs per Converted Motorcycle Scenario 1 & 2 (Own Source based on SolarTaxi 2021)

Costs per Converted Motorcycle Scenario 1	
Describtion	**Costs**
Variable Costs	2.436,00 €
Onetime Expenses	2,39 €
Fixed Costs	282,02 €
Total Expenses	**2.720,41 €**
Margin	5%
Sales Price	**2.856,43 €**

Costs per Converted Motorcycle Scenario 2	
Describtion	**Costs**
Variable Costs	1.764,00 €
Onetime Expenses	2,39 €
Fixed Costs	282,02 €
Total	**2.046,02 €**
Margin	5%
Sales Price	**2.148,32 €**

If you now look at the sales prices for the converted motorcycles, you will immediately notice the significantly higher sales price compared to a conventional motorcycle. The high cost of electric motorcycles is mainly due to the cost of the battery, which accounts for nearly 50-60% of the total costs. However, in comparing the cost of a brand-new electric motorbike to that of a converted electric motorbike of scenario 2, the converted motorbike appears than less than a brand-new electric motorbike (about 18,000 GHS) and it is also robust and has a better performance especially on the Ghanaian roads. In addition, the converted motorcycle also has ecological advantages in that it is not sorted out but subjected to reuse. If you look at the price of the converted motorcycle from scenario one, where a customer did not previously own a motorcycle, the sales price is even higher and exceeds the price of a new e-motorcycle.

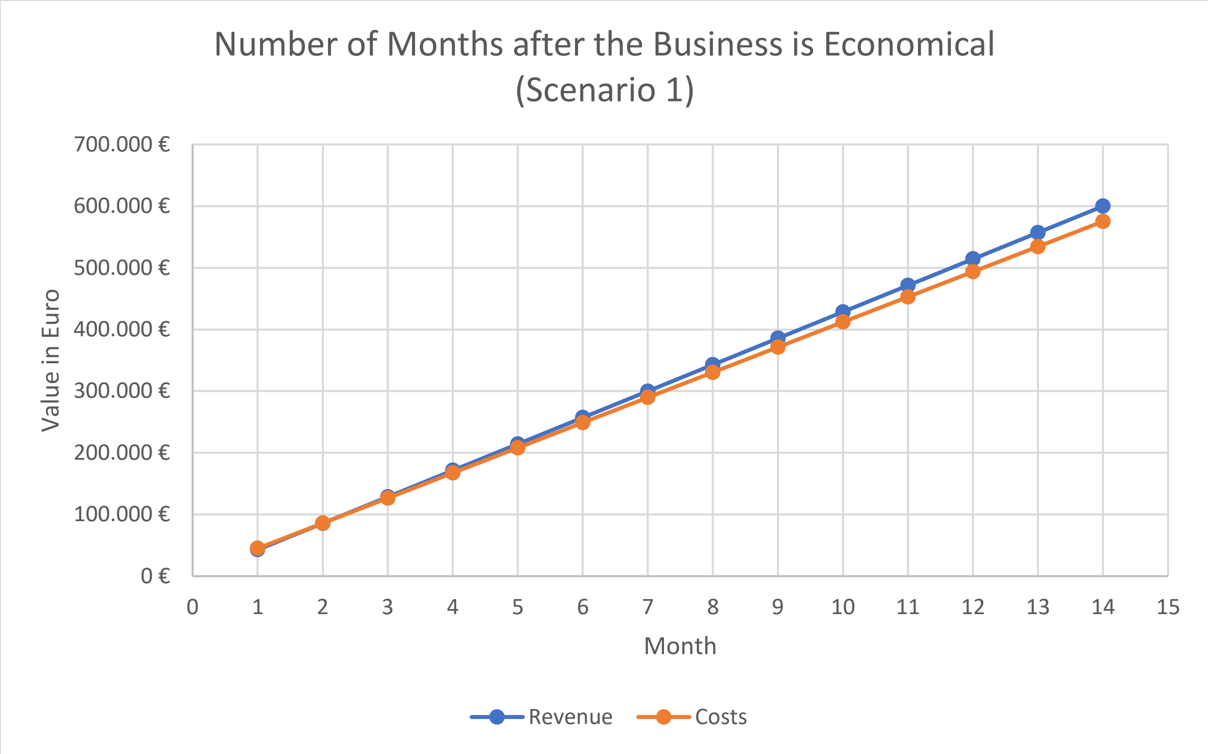


Figure 27: Number of Months after the Business is Economical Scenario 1 (Own Source)

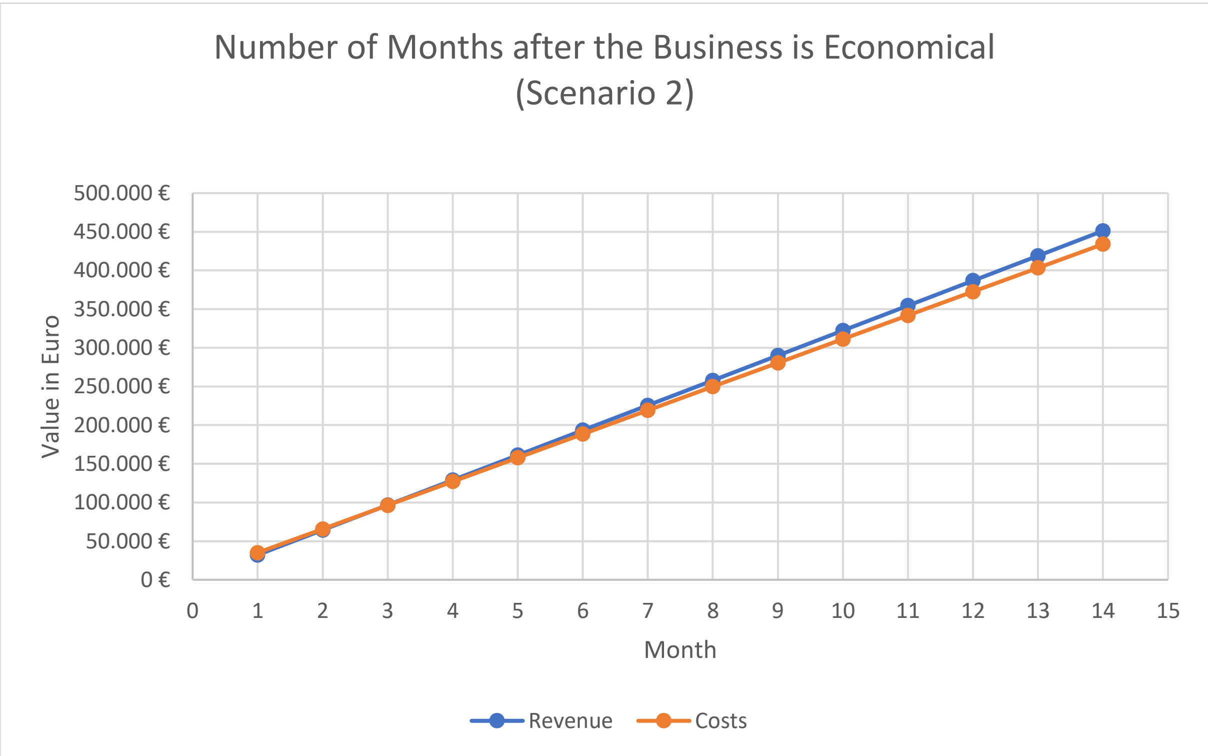


Figure 28: Number of Months after the Business is Economical (Scenario 2) Own Source

Of course, it is important to look at the acquisition costs of the converted motorcycles, as these can be a major barrier to switching to an e-motorcycle. However, it also makes sense to look at the operating costs and compare them between the two variants. Table 20 shows the costs for the fossil fueled variant as well as the costs for the different variants and conversion scenarios of the e-motorcycles.

Table 20: Comparison Operating Costs Fossil Fuel Motorcycle and E-Motorcycle (Own Source based on SolarTaxi 2021)

Fossil Fuel Motorcycles in Ghana							
Name / Brand	**Typical Cubic Capacity**	**Tank Capacity (in Liter)**	**Ø Cruising Range (in km)**	**Ø Used gasoline per 100 km (in Liter)**	**Ø Cost for power per 100 km[4]**	**Ø Cost for maintenance per 100 km**	**Ø Purchase Price (in Cedi)**
Haojin 125-35	125-135	14	500	2,8	2,70 €	4,34 €	672,00 €
E-Motorcycles in Ghana							
Name / Brand	**Power (in kW)**	**Effective Energy (in kWh)**	**Cruising Range (in km)**	**Used Energy per 100 km (kWh)**	**Cost for power per 100 km (in Cedi)[5]**	**Ø Cost for maintenance per 100 km**	**Ø Purchase Price (in Cedi)**
Converted Model (Haojin 125-35) Scenario 1	5	3,6	63	5,71	0,30 €	0,12 €	2.856,43 €
Converted Model (Haojin 125-35) Scenario 2	5	3,6	63	5,71	0,30 €	0,12 €	2.148,32 €
New E-Motorcycle Ghana (SolarTaxi)	Data in progress	Data in progress	Data in progress	Data in progress	Data in progress	0,12 €	2.520,00 €
Brammo Enertia Plus (European market)	12,7	6,2	130	4,60	0,24 €	0,12 €	12.872,58 €

If we now look at the operating costs, it becomes clear that these are significantly lower for an electric motorcycle than for the conventional combustion motorcycle. Furthermore, the long-term goal should be that e-motorcycles are not charged via the national grid, as is currently the case, but by solar charging stations and thus regenerative energy. If you now look at the acquisition costs and the operating costs together, you can find out after how many kilometers, the e-motorcycle are more economical despite the high acquisition costs. Figure 29 and Figure 30 show the difference between scenario one and two. In scenario one, the e-

[4] Gasoline prices in Ghana: 6,9 Cedi/liter = 0,97 €/liter (November 2021)

[5] Ghana power prices households national grid: 0,37 Cedi/kWh = 0,05 €/kWh (November 2021)

motorcycle is more economical than the conventional combustion model after 32.962 km. In scenario two, it is already after 22.277 km.

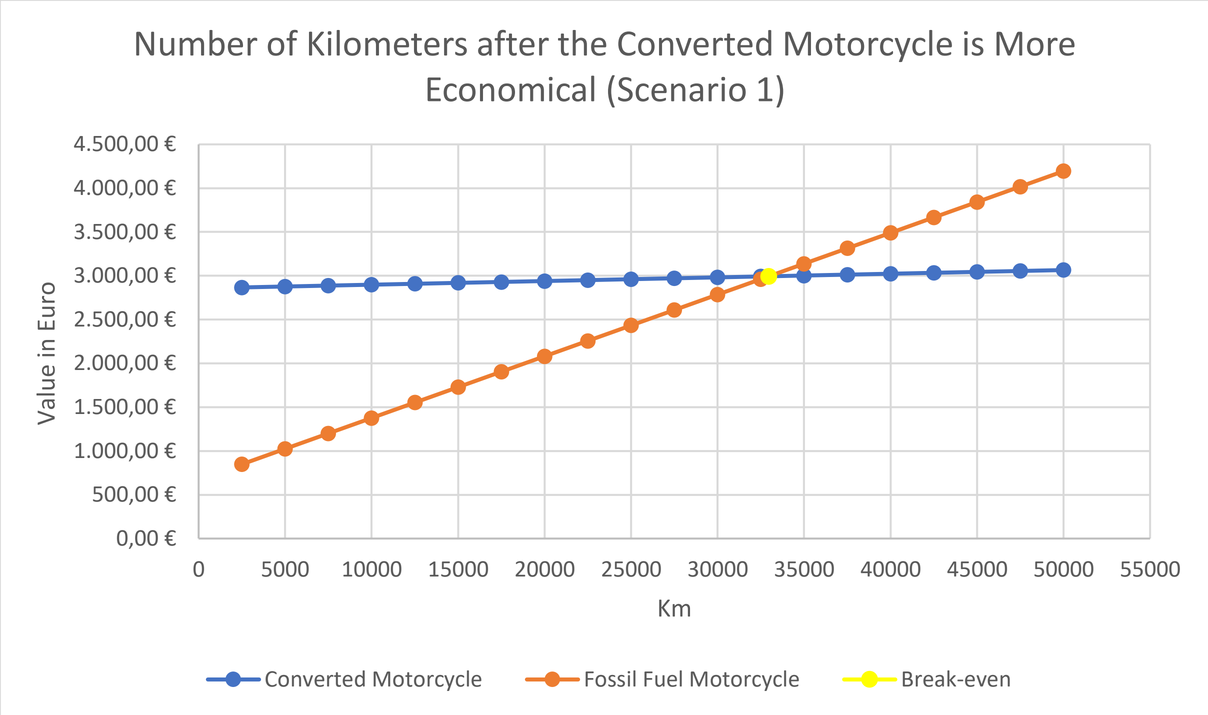


Figure 29: Number of Kilometers after the Converted Motorcycle is More Economical Scenario 1 (Own Source)

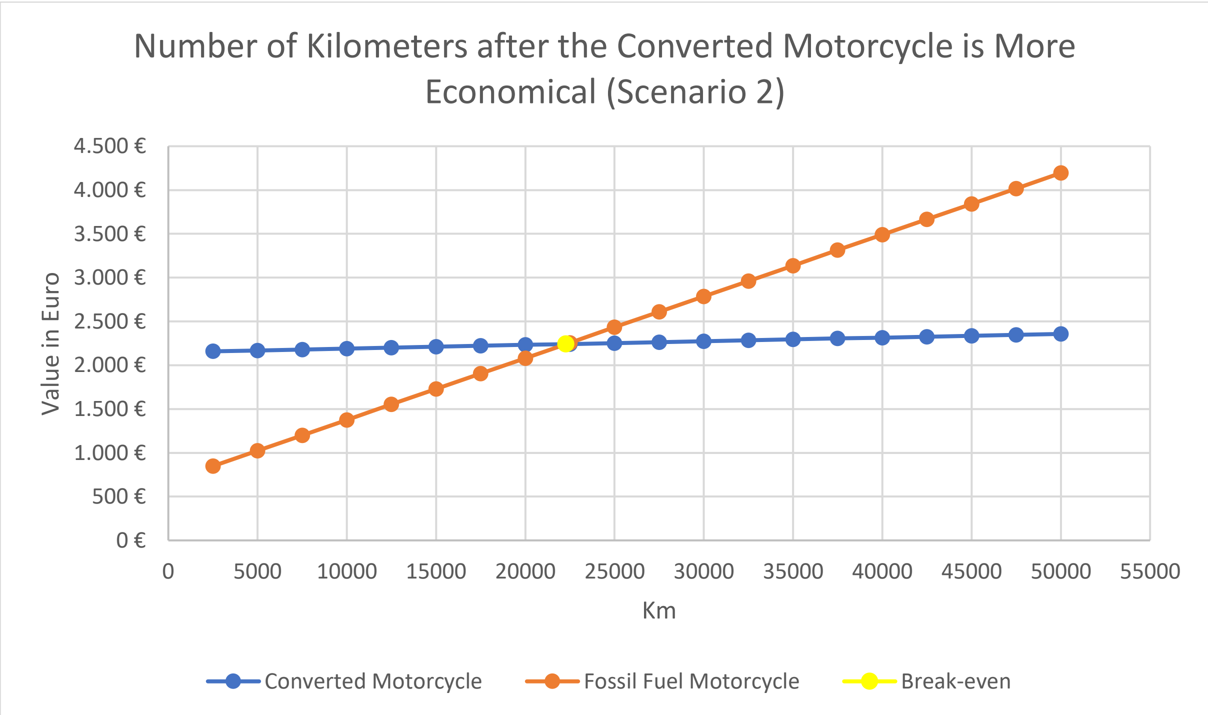


Figure 30: Number of Kilometers after the Converted Motorcycle is More Economical Scenario 2 (Own Source)

In conclusion, it can be said that the profitability analysis was currently still based on prototype construction data. The following research questions need to be explored in further project phases:

- What about the scalability of the company? How does the sales price behave if significantly more motorcycles can be converted?
- What about the automation of the various processes? Are there possibilities to convert more vehicles through automation without further staff expenses?
- Which financing concepts facilitate access to converted motorcycles?
- How does social acceptance behave with regard to converted motorcycles? At this point, another survey makes sense.
- Do incentives, such as free charging at certain charging stations, help stimulate purchases?
- Can the converted e-motorcycles be offered for leasing and thus make them more attractive? Does this lower the inhibition threshold of the large acquisition costs?
- In order to find out how the values from Figure 29 and Figure 30 are to be estimated, the following questions must be clarified in the further course: How many kilometers do private households drive by motorcycle in a year? How many kilometers do companies (e.g., food delivery service) drive by motorcycle per year?
- Are there opportunities for tax incentives or subsidies?

Work Package 5: Communications, Public relations, Publication, Knowledge transfer

Objective	Ensuring scientific and economic exploitation and the transfer of project results in Germany and the target country. Creation of a concept for the transfer of the product system and the qualification concept
5.1	Public concept e.g. project flyer, website, social media
5.2	Publications on the results of the evaluation
5.3	Concept for Student and Faculty Exchanges: • Facilitate and finance at least 4 student exchanges on the thematic areas of sustainability, e-mobility and life cycle assessments between HSBO, UENR and KNUST • Facilitate and finance at least 2 PhD positions on the thematic areas above • Facilitate and finance at least 4 guest lecture sessions on the thematic areas above • Facilitate and finance at least 4 thesis topics on the research areas on the thematic areas above.
5.4	Description of the recoverable product and a concept for its portability, drafting the final report
Result	- texts, website and social media presence - Concept for student and lecture exchanges are established further strengthening the academic bonds between the partner universities. - Description Recoverable product and concept paper for portability - Final Report

Public concept

The communication concept includes both online and offline channels having regard to the different local usage behaviors. For this project to have an impact, it needs to be communicated clearly to campuses and its students that can implement und use this concept, companies that can manufacture technical components for the system, governments that set the legal basis and give financial help, and the interested public that becomes aware of the sustainable innovation which is being realized. Concretely, project flyers and posters have been designed and published (Graphic 1, Annexes), and serve as a visual reminder for the technology on various campuses and student events both in Ghana and in Germany. To address students more specifically, the project has an own Instagram/Facebook channel which informs about all relevant components of the concept and additionally gives more personal insights of the project`s developers and members. To complement the web presence, companies and entrepreneurs that can help to implement and finance the project will be reached through a LinkedIn account, where the communication is less personal but more focused on job opportunities and innovation potential. On all these accounts, a promo video of the project can be shown, explaining the functionality of the sharing system on the KNUST campus. Therefore, students of the campus who already use the technology will present the system. In addition, an own website could help to explain the project and the technologies in more detail and present the journey from the initial idea to the final result to an interested public.

By being a very personal and well visible component, business trips to Ghana conclude the public concept of the project. Recent trips offered the chance to speak to important partners and bring forward new cooperation. Concretely, the team visited their key partner from the private sector, SolarTaxi, at their headquarters to inform itself about their operating business and their vehicles. To explore possible future cooperation, the team met officials from the Siemens Foundation and the Impact Hub, which arose in high interest to work together in several fields of the project. During its visits at two other key partners of the project, the campuses UENR and KNUST, the team made workshops and handed over e-mopeds in front of a broad media audience, which resulted in TV and online clips as well as articles about the events. It can be said that apart from fostering the personal relationship to business partners, these trips also serve the purpose to get mentioned in the local media. With that, the project becomes especially visible to the community that will use the technology in the future and benefit most from it.

Publications

General publications on the project overview and its progress can be seen on a factsheet as well as on the website of Electromobility in Ghana. To reach a scientific audience with the project, contacting online blogs as well as magazines can be a successful option to publish results effectively and spread the word about the concept in industries that might be interesting as potential partners. Moreover, participation at innovative conferences can also serve as an option to share results of the evaluation to an interested audience. In addition, the project team itself uses its chances to speak about the achievements in the project and to network with potential partners in Ghana during their business trips, in order to set up a more personal relationship. Recently, the team updated key partners like SolarTaxi and student campuses as well as an interested public media about their achievements and important next steps personally during their trip to Ghana. The meetings and achievements of this trip have been documented broadly on the project`s LinkedIn channel afterwards. Moreover, the team updated the public about all events in Ghana on the project`s Instagram channel. These posts as well as other impressions of the trip can also be found here.

Concept for exchanges

A key success factor for the project is to strengthen the ability of students at universities in Germany and Ghana to transfer the project results in the future. Students are the innovators of the present and the future and help to continue the development of e-mobility and decentralized energy systems after their education. The scientific as well as the economic development of the project results can occur especially through an active cooperation of the universities. The following concept which shown with Figure 31Figure 31 should ensure that this happens in the right framework and therefore a qualification process takes place, which also ensures the further development of the results after the project work.

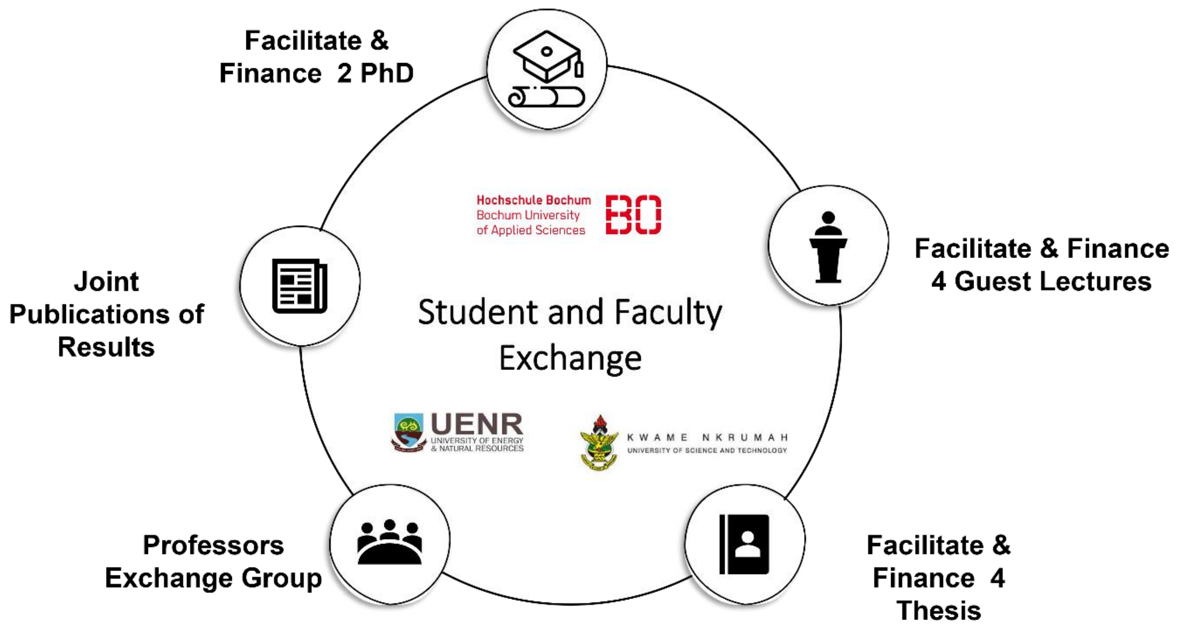


Figure 31: Student and Faculty Exchange Concept (Own source)

The E-Micromobility project in Ghana has the overarching goal of promoting local business models for electromobility and decentralized energy systems. A particular focus is on the population area around the campus of the Kwame Nkrumah University of Science and Technology and the University of Energy and Natural Resources, whereby alternative modes of transport are to be used. That means especially the students of the mentioned universities are the target group. Within at least four guest lectures, the students are supposed to analyze the project results in more detail and develop future scenarios in group work, which advance the topic of electromobility and decentralized energy systems on their campus and in particular which business models are necessary for this. These guest lectures in Ghana will be held by Frederick Adjei, Prof. Dr. Ing. Semih Severengiz and Dr. Sebastian Finke. The main topics on the theoretical level will be the formation of a general understanding of transdisciplinary sustainability research as well as the sustainability assessment of electromobility and decentralized energy system solutions. Guest lectures in Germany will take place within the Project Sustainable Energy Impact, where students work on the topic sustainable e-mobility and decentralized solar energy systems in Ghana. Furthermore, it is planned that there will not only be guest lectures also a mentorship, where the students within the project will receive targeted expertise from the ground.

In order to be able to further develop and transfer the project results, students are needed to deal with the topics in greater depth within their final theses. To make this possible, there should be meetings in cooperation with the professors and interested students of the universities to define topics for this final thesis. The aim here is above all to equip the students with the necessary knowledge for their time after graduation in order to be able to establish their own companies and business models within the subject areas of electromobility and decentralized energy systems. In order to achieve this, a total of four final theses should be announced for the students of KNUST, UENR and HSBO, which will be supervised by the professors in Germany and Ghana.

But not only the transfer of knowledge from professors to students is important, also the exchange between professors in different countries and locations. Here, an exchange group between the professors Dr. Godwin Ayetor (KNUST), Dr. Emmanuel Amankwah (UENR) and Dr. Semih Severengiz (HSBO) is to be initiated, who will exchange information on the research topics and project results on a quarterly basis. This exchange ensures a continuous development of the project topics as well as the initiation of new ones. Furthermore, the differences and progress in the respective countries should be discussed here, so that one can profit from the experiences of the others.

The research results achieved in the project will be made available to the public with the help of publications. These publications should take place in cooperation with our academic partners from KNUST and UENR. The results from the publications can then be presented at appropriate conferences.

Another goal of the concept is to enable and finance two PhD positions. At the moment, it is not yet possible to make any exact plans, as various information are still missing. In order to find out how this can be possible, discussions will be held with the DAAD and the administration of the University of Bochum in the future.

Description of the recoverable product and a concept for its portability

The idea behind the sharing system that is being implemented as part of this project was developed with the intention to improve the transport system and to allow for flexible and independent mobility, while at the same time bringing about an environmental and economical relief. We intended to meet sustainability goals on all three dimensions and created the project idea with this goal in mind.

The sharing system currently consists of two mopeds (Kumpan 1954 Ri); however, we intend to upscale the product system to increase its added value. The goal is to obtain and deploy a total of 40 e-mopeds at KNUST campus. These mopeds are supposed to be powered electrically in order to achieve the aforementioned environmental relief. The electricity required for the charging process will be provided using solar panels. The use of a renewable energy source further supports the core idea of the project. Charging will take place whenever the mopeds are not in use, which we assume to happen mostly at night. For rental and payment processes, a software will be used, which will also allow for later analyses regarding average distances travelled, average time per ride, and more.
As stated out before, we are currently in the pilot phase with the e-moped sharing system. If an institution or company wants to adopt this system, certain decisions will need to be made to implement this pilot project on a larger scale:

- Which model should be used (moped)?
- How many mopeds are needed to obtain added value to mobility in Ghana while being profitable for the company?
- Where should the locations of rental stations be?
- Consideration of local context: a survey or a different form of assessment
- Insurance
- Rentability – economic assessment
- Which partners do they need to implement the sharing-system?

In our pilot phase, the scooters are being tested on various campuses. Of course, a sharing system is suitable beyond the university context. In the further project phase, we will have to find out which locations and customer groups/types are suitable for a sharing system so that it works on a social, ecological and economic level and offers real added value. An upscaling of the sharing system can therefore take place nationwide but should be well thought through. In addition, further regulations and laws are also needed from the government side so that the framework conditions for this mobility service are also defined and companies and institutions have certain certainties as far as their business is concerned.

Annexes

Materials/Assemblies	Quantity	Unit
Acrylonitrile butadiene styrene [ABS]	1.01×10^{1}	kg
Alumnium	1.85×10^{1}	kg
Cast iron	2.30×10^{-2}	kg
Chrome	3.84×10^{-3}	kg
Copper cable 1-wire	9.38×10^{-1}	kg
Copper cable 3-wire	2.12×10^{-1}	kg
Copper cable 5-wire	4.10×10^{-2}	kg
Float flat glass	9.00×10^{-2}	kg
Glass lamp bulbs	2.20×10^{-2}	kg
Knit textile fabric	2.69×10^{-1}	kg
NMC battery Cell	6.44×10^{0}	kg
Polycarbonate	2.10×10^{-1}	kg
Polyethylene foam	8.65×10^{-1}	kg
Polymethylmethacrylate	1.46×10^{-1}	kg
Polypropylene	1.23×10^{1}	kg
Polytetrafluoroethylene	3.19×10^{-1}	kg
Printed wiring board	4.29×10^{-1}	sqm
Styrene-butadiene-rubber	8.95×10^{0}	kg
Stainless steel	1.76×10^{0}	kg
Steel	4.08×10^{1}	kg
Zinc	1.47×10^{-2}	kg

Table 21: List of e-scooter materi

Design and concept development of an E-Mobility Makerspace under the STC model of MESTI in UENR or KNUST

design and concept is developed and written by

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October, 2021

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Abstract - The impact about designing and operating a successful makerspace

A future-oriented Makerspace offers students, founders and companies a place with access to everything they need to invent, build and market innovative hardtech products (Hardtech innovation is technology that has both a hardware and software component). This includes combining a modern work environment like the coworking space with the concept of collaborative work in a micro factory. This combination lowers the barrier to entry and the risk (lowering costs and increasing development speed) to invent new hardtech products and build sustainable economically successful companies. This, in addition to direct employment in the Makerspace, actively promotes businesses that create new jobs, strengthen local businesses through economic growth, and bring together groups of people from different cultural backgrounds to solve the challenges of today's society.

Critical to building and operating a successful makerspace is properly designing the space with workstations and machines (like 3D printing, laser cutting and electronics), educating users through workshops on machine use and entrepreneurial skills, and fostering networking through events and community building. These 3 pillars need to be in perfect balance to create a place with innovation and at the same time economic viability. The success of a makerspace is therefore not measured purely by the economic success of the operation but by how many innovative products, companies and thus jobs are created from the makerspace per year.

The ongoing cost drivers of a makerspace are the rental of space, employment of staff, and the purchase of consumables to operate the machines and coworking space. The financial basis of a Makerspace is secured through the conclusion of monthly membership fees. To supplement this, members can book workshops, book private offices or workshops, and purchase additional coaching and mentoring. The event and meeting spaces can also be booked by external persons, companies and institutions to generate further income. The right balance of coworking & community space, workshop space, event and meeting space, as well as the right content and regularity of training forms is of central importance for economic success.

If a makerspace is successfully operated in a suitable environment, several dozen companies can be spawned per year, patents can be continuously filed, and thousands of people can be actively educated. Through the network and scale effect, the economic structure, the innovative power of a region and the environment can thus be positively shaped in the mid and long term.

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What would an electromobility maker space in KNUST and UENR look like?

The makerspace in KNUST and UENR offers students, startups as well as established companies access to coworking space, workshops with modern machines as well as educational programs and events to build networks. Through networking and economies of scale, access can be offered to everyone at a very low price, which in turn makes it possible to offer all levels of society access to the makerspace and promote exchange and equality regardless of origin.

Central to the makerspace is collaborative working as well as sharing resources such as desks, machines and meeting spaces as well as access to a community with experts from all fields.
Anyone can become a part of the community by signing up for a membership at a fixed monthly price. No further costs are incurred through the use of the workstations or machines. In the following, we therefore always refer to "members".

Coworking spaces
The coworking spaces are ideal for members to work on the computer, create technical drawings or develop new concepts. For this purpose, desks, chairs as well as suitable light and an inspiring environment are available. The principle is similar to a library, where everyone sits down at a table that is currently free. By changing the workplace every day, chance encounters among the members are actively encouraged and new contacts can be established. Important is the possibility of concentrated work, good Internet reception and suitable retreats to perceive video calls or phone calls.

Workshop areas
The workshop areas make a makerspace special and depending on the design of the workshops with machines, different emphases can be placed. For a makerspace on the topic of electromobility, the focus should be on the following workshop areas:

- Electronics Lab
- 3D printing Lab
- Laser cut Lab
- Metal Lab
- Wood Lab

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Each workshop is equipped with suitable machines as well as tools for pre- and post-processing of materials. However, the design of the workshops differs significantly from conventional workshops. This is because all the machines and tools must be positioned in such a way that they allow thousands of different people to work throughout the year. The use of drawers and cabinets that cannot be seen should therefore be actively avoided. At the same time, workshops must be designed to allow for daily training courses to educate members on the machines.

In addition, sufficient space should be planned for the storage of materials as well as for the assembly of products. When designing workshops and offering machines, attention should be paid to occupational health and safety.

Event and meeting areas

The event and meeting areas are ideal for small meetings with 2-3 people to large events with up to several hundred participants. This allows staff to actively promote networking between members but also with regional partners.

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The Makerpsace in KNUST and UENER is a place with a high quality of stay, enabling the development and promotion of talent in the region as well as attracting innovative startups from all over the country. Members like to stay in this place for a long time, as it is where they have their workplace as well as where they make personal contacts. At the same time, the makerspace invites everyone to be inspired and encouraged to take new paths towards a healthy and fair future. The makerspace in KNUST and UENER actively promotes gender and origin equality. Furthermore, it is the central place for companies from all over the world

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when they are looking for access in the field of electromobility in Ghana. While at the same being part of the makerspace makes it easier for all members to expand their business internationally and build up successful partnerships globally.

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What is the space and infrastructure requirement?

Decisive for the success of makerspace is the right balance between community and coworking space as well as office workstations, workshop space and event and meeting space. In order to accommodate these areas in the right proportion and cost-efficiently, a minimum size of approx. 1500 sqm is required. A ground-level hall area that can be divided into different areas is advantageous. In addition, adjacent office space is important to enable founders to grow as a team. Offices in the Makerspace offer startups the opportunity to grow as a team and expand areas such as marketing and sales while being close to product development.

From experience, the following distribution of space has proven to be very good:

Area type	Percentage distribution
Coworking und Community areas	30 %
Workshop areas	30 %
Event- und Meeting areas	10 %
Office and workshop space for startups	30 %

An open and inviting design of the areas for guests is very important. The use of each area should be clearly marked and self-explanatory to allow new members to find their way around immediately. At the same time, all areas should be designed to allow everyone to get started immediately without worrying about doing something wrong.

The location of the makerspace should be as central as possible and easily accessible by all means of transportation. Proximity to universities but also to residential areas has proven to be an advantage. Short distances and good connections make it easy for young people in particular to work frequently in the makerspace and to integrate it into their everyday lives. The proximity to a university also promotes the exchange in various research topics as well as the promotion of talents.
Furthermore, it has turned out to be an additional advantage if there are sufficient possibilities for catering in the surrounding area, such as supermarkets and restaurants.

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What equipment is needed and how much?

The right choice and arrangement of equipment is crucial for the success and intensity of use in all areas. As a basis is the sufficient supply of electricity to enable working around the clock in the coworking area and especially on the machines. Each area requires different equipment, due to the scope we present in the following only the basic equipment features. The number depends on the total size of the space.

Coworking and Common areas

Coworking	Desks
	Chairs
	Lamps
	Couch and armchair
	Multiple junction boxes
	Plants
	Monitors
	Printer
Kitchen & cooking area	Basic kitchen and utensils
	Coffee machine
	Kettle
	Fridge
	Stove
Community Area	Couch
	Armchair

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	Desks
	Chairs

Workshops and Labs

3D Printing	FDM 3D Printer
	SLA 3D Printer
	SLA Cleaning Station
	SLA Heating Station
	SLS 3D Printer
	Workbenches
	Tools for pre- and post-processing
Metal Lab	Metal-Saw
	Bending bench
	Drill Press
	Weld-pak
	Portable Torch Kit with Oxygen and Acetylene Tanks
	Fiberglass drop clothes for welding
	Welding Mask
	Tabletop 3-axis CNC
	Laithe

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	Workbenches
	Electronic tools
Electronics Lab	AC/DC Power Supplies
	Oscilloscopes
	Soldering Iron
	Function Generators
	Helping Arms
	Electronics Kits
	Pick and Place machine
	Spectrum Analyzer
	Breadboards
	Hand tools
	Electronic tools
	Testing Equipment
	Cables and Cords
Laser Cutter Lab	Laser Cutter
	Workbenches
	Hand tools
Wood Lab	Circular Saw

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	Table Saw
	Dust collector
	Drill press
	Scroll saw
	Belt sender

Event- and meeting area

Eventarea	Stage
	Chairs
	Light system
	Projector & video equipment
	Speaker & sound equipment
Meeting area	Desks
	Chairs
	Projector or Screens
	Whiteboards
	Flipcharts

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What does it take to run such facilities? (Personnel, salaries, operations)?

The main cost drivers to run the makerspace are:

- Rent & operating costs (40%*)
- Personnel costs (40%*)
- Consumables (20%*)

*The cost distribution is based on average prices and costs in Central Europe.

In addition, there are the expansion and acquisition costs at the beginning of the Makerspace. Since I have already dealt intensively with the location and the equipment in the previous sections, I will go into detail about the personnel costs and consumables in the following.

Personnel
The company structure can be divided into four basic areas:
1. Management
2. Operations
3. Marketing & Sales
4. Startup Success

For us, the mix of employees from the region as well as employees from other countries is enormously important. We believe this promotes openness and equality within the company and the community. At the same time, employees from the region bring important knowledge about the location as well as regional traditions that create a unique and authentic culture in makerspace. This leads to a high level of recognition and connection between employees and the company as well as the members. Depending on the size of the site, a different number of people are needed in each area, although the number of people does not increase proportionally to the size of the site. In the following, I will discuss the basic activities:

1. Management

The management is responsible for the strategic and financial development of the company. In addition to managing the company, this also includes the strategic involvement of local institutions such as universities, politics and business.

2. Operations

Operational Operations is responsible for the day-to-day execution to provide a good experience for members. This area can in turn be divided into three subcategories:
- Facility Management: maintenance and expansion of the site
- Makerspace Management: Supervision of the workshops as well as maintenance of the machines

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- Community Management: First point of contact for member questions as well as taking care of guests

3. Marketing & Sales

The Marketing and Sales team is responsible for marketing the MotionLab brand in the region. To do this, they use online media as well as local events and the execution and organization of their own events. Furthermore, it is of fundamental importance to understand the local conditions and to know the challenges of the customer persona in order to create, together with the rest of the team, tailor-made offers that correspond to the local conditions.

4. Startup Success

The Startup Success team is responsible for the content-related support and promotion of the members. This includes the development of customized workshops and training measures in the areas of product and company development.
In addition, the integration of local offerings is crucial to effectively utilize existing resources and make knowledge widely available to sustainably promote the local economy.
The personal coaching and mentoring of members identifies individual challenges and makes it possible to develop customized training concepts but also to network with other members to learn together. In addition, the coaches and mentors support business growth and networking with international partners to generate long-term growth.

Consumables

Consumables include everything needed for the daily operation of makerspace. This includes:

- Cleaning materials
- Catering supplies such as coffee, milk, drinks and snacks
- Construction and repair materials for maintenance
- Spare parts for machines and tools
- Consumables for machines and tools
- Training materials

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What is the potential to connect with other such maker spaces globally?

The potential for networking with other makerspaces is enormous, as a global community has developed that actively promotes exchange. The challenge, however, is the large differences in global conditions and the large differences between makerspaces. Therefore, it is very important to have the trust of the community and to know exactly which conditions exist in which regions. For MotionLab, it is crucial to leverage the different locations around the world and make them accessible to members in the ecosystem. Only in this way can young companies grow strategically and make use of the services in each region.

Each location benefits in two ways:

1. Helping their own members establish themselves in new regions and reduce local barriers from the start.
2. Accepting new members from other regions and thus promoting intercultural exchange and knowledge.

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What is the financial requirement to realize this in 2022, and operate in 23 to perhaps 25?

Contrary to the general opinion in the scene, we are firmly convinced that a Makerspace can work economically successfully as an independent company. We are already proving this at our location in Berlin.
From our own experience, it takes an average of three to five years to develop, expand and firmly anchor a location locally. After this time, every location should be economically successful. To what extent and what size, this depends on the local conditions and the size of the area. We recommend at least 1,500sqm but a maximum of 6,000sqm for the operation. Since the costs do not increase proportionally to the area, a larger location can generally operate more successfully economically, always assuming that sufficient demand can be generated. We estimate the profit per site at 5% to 35% after tax per year after three to five years.
Of key importance is sufficient and stable initial funding to expand the makerspace and hire the right staff. An organic growth is important to set up the company in a stable way in the long run, because this way an authentic community with a high degree of identification can be built up.

The exact costs depend on the size, the condition and local cost structures, a concrete naming of numbers without previous location and market analysis is unfortunately not possible.

However, in the following we present a calculation example for a location in Central Europe on 3500 sqm:

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Revenues	**200.000 €**	**600.000 €**	**900.000 €**	**1.200.000 €**	**1.400.000 €**
Rent & operating costs	420.000 €	449.400 €	467.376 €	467.376 €	472.050 €
Personnel costs	200.000 €	280.000 €	360.000 €	440.000 €	520.000 €
Consumables	124.000 €	145.880 €	165.475 €	181.475 €	198.410 €
Upfront Construction & Machinery costs	300.000 €	100.000 €	50.000 €	25.000 €	0 €
Total Expansion	**1.044.005 €**	**975.287 €**	**1.042.860 €**	**1.113.862 €**	**1.190.473 €**
Result	-844.005 €	-375.287 €	-142.860 €	86.138 €	209.527 €
Return on investment	-80,84%	-38,48%	-13,70%	7,73%	17,60%

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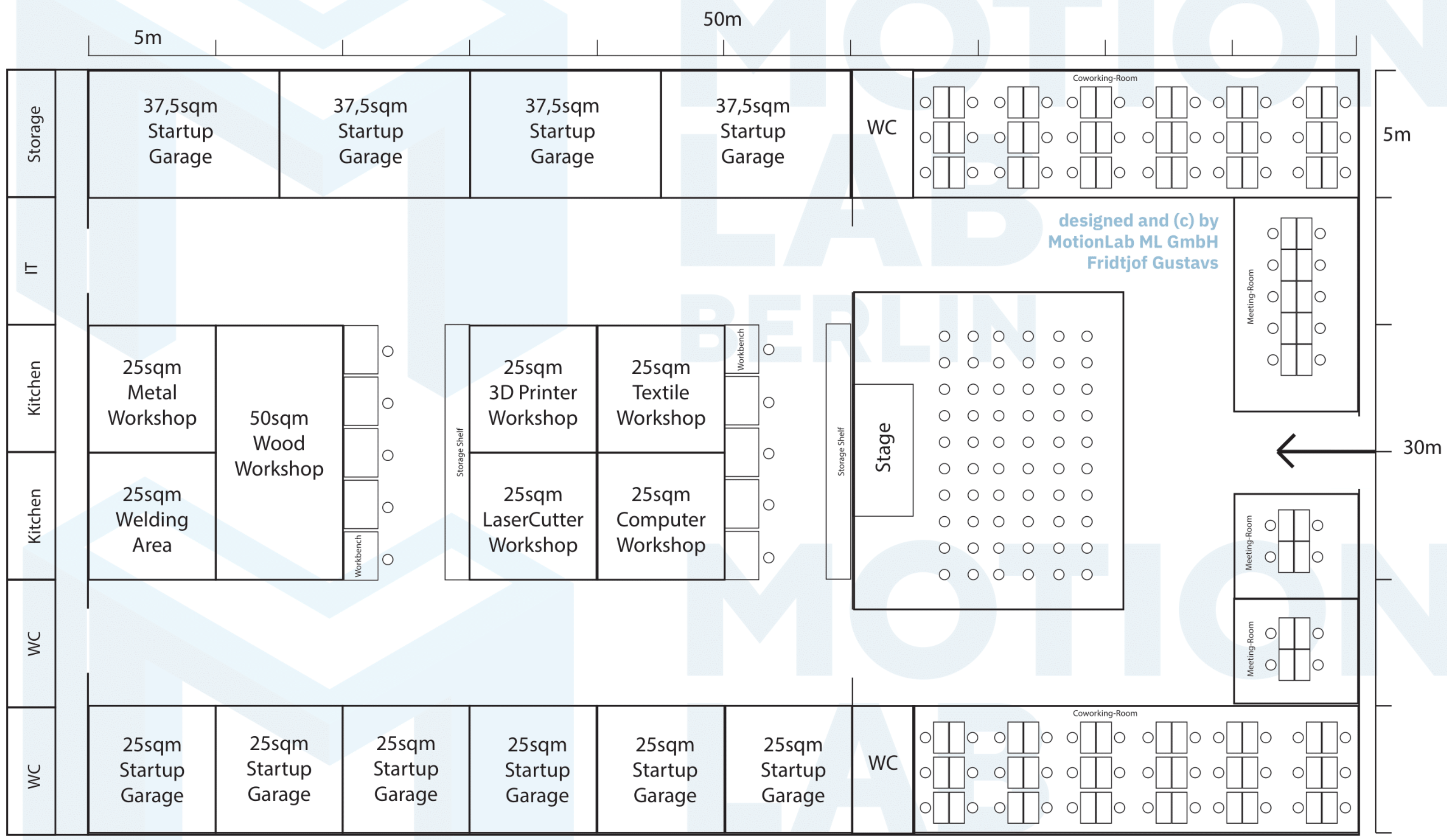


Figure 32: Floorplan of MotionLab

Graphic 1:

E-Micromobility in Ghana (EmmGh)

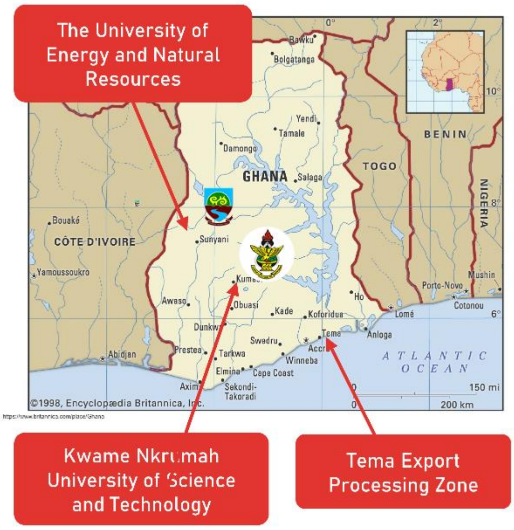
Development and Implementation of a sustainable mobility offer in Sub-Saharan Africa for sustaianable development

Initial Situation

The population and wealth of the Republic of Ghana is growing. With the economic development, the demand for mobility services is increasing, which exists mainly for cars. These vehicles cause and add to high environmental pollution, which creates opportunities for more sustainable mode of transportation. At the same time, these environmentally friendly alternatives provide opportunities for local job creation and economic value to local supply chains .

Objectives

The E-micromobility in Ghana project aims at finding solutions to growing mobility demands and environmental stress by deploying solar charging stations to power Light Electric Vehicles (LEVs) on the project site Kwame Nkrumah University of Science and Technology-Kumasi and the University of Energy and Natural Resources. Additionally, makerspaces dedicated to the research and application of electromobility topics will be established on both campuses. A further objective of the project is the deployment of LEVs on the Tema Industrial Processing Zone for which feasibility studies are currently underway.



Approach

As a starting point for up-scaling, the project would be first implemented on the campuses of the partnering universities (KNUST and UENR). Here the universities would provide the e-mobility offer to students, staff and visitors, making it possible to develop a suitable business model and to create the necessary job positions for administering and managing the product system. Alongside the implementation of the shared LEVs; sustainable mobility workshops, student exchanges, thesis research, guest lecturing will also take place between the three partner universities to ensure knowledge exchange and transfer. Construction of makerspaces on electromobility research will bring together academia, private sector and government to create the environment to foster the growth of business models and value chains in the e-mobility sector. In the Tema Industrial Processing Zone, the first steps would be to assess the feasibility of replacing energy sources for offices and facilities with solar mini grids that can be used by all represented companies on the park. Feasibility studies on the use of LEVs and E-busses with off-grid solar charging stations to foster sustainable mobility of staff and industrial materials will also be conducted.

The project is supported by the Special Initiative on Training and Job Creation of the German Federal Ministry for Economic Cooperation and Development (BMZ), which operates under the brand Invest for Jobs and is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH among others.

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Supported by
Invest for Jobs
Opportunities for Growth in Africa

Duration 07.2021 – 12.2021 (Pilot Phase)

Hochschule Bochum
Bochum University of Applied Sciences

Sustainable Technologies Laboratory

Annex 2

RESEARCH REPORT ON USER EXPERIENCE WITH ELECTRIC MOTORBIKES AND A SHARING SYSTEM ON KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY **(KNUST)** CAMPUS GHANA

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1.0 Introduction

Transportation contributes immensely to the development of every country. It entails the movement of both goods and services and people from one location to another. The diversification in energy usage by various transportation modes has come to pass, through thorough research and investment. A lot of research has been conducted to find a cheaper and environmentally friendly energy source to power different means of transportation. The usage of fossil fuels has its own detrimental impact to the environment and is more and more being advocated to be reduced in order to safeguard the environment. The promotion and the usage of clean energy sources such as the production of electricity from renewable sources such as solar, wind and hydro are currently on the rise due to environmental issues from continues usage of fossil fuels. Climate change has now become a global pandemic, affecting all nations negatively. Mitigations actions are the only surest means to counter impacts of climate change and safeguard the planet for the next generations.

The promotion and usage of e-mobility devices come at a time where emissions have to be reduced as well as having clean air becomes more important in most of the cities around the world. This research aims at reducing the usage of internal combustion engine devices on the University campus of KNUST in Ghana. Also, the goal is to provide an alternative mobility option for smooth and safe movement of the entire university community from one location to the other by using a sharing system.

1.1 Research objective

The objective of the research is aimed at successfully deploying and integrating e-bikes and solar charging station at KNUST campus. The aim will be addressed using the following specific objectives;

1 To analyse the local conditions on KNUST Campus, to allow for a tailored mobility offer
2 To determine the user requirements for mobility devices and power requirement in the study area
3 To explore user experiences with the sharing system

The survey was conducted on 8th and 9th December 2021 through phone calls. At the time of the survey students were on holidays leaving only the workers and some graduate students who were attending to the completion of their thesis or dissertations. Most Respondents used for the research are workers at the university. The study employs a random sampling method in selecting 51 respondents to respond to semi-structured questionnaires.

2.0 Analysing local conditions to the usage of an electric motorbike on KNUST campus

To analyse the local conditions for the usage of e-bikes at KNUST campus, socio-demographic characteristics of respondence, as well as the local conditions of the university campus, were recorded. The results are presented in Table 2.1.

2.1 Gender distribution of respondents

Respondents used for this study were 51 in general. This comprises 9 females and 42 males representing 17.6 per cent and 82.4 per cent respectively.

2.2 Age distribution of respondents

The majority of the respondents (74.5%) are within the age bracket of 20-29, followed by 15.69 per cent within the 30-39 age bracket. However, 3.9 and 5.9 per cent represent age bracket of 40-49 and less than 19 years respectively.

2.3 Mode of transport and reason for choosing such mode to the University

The majority of the respondents rely on the usage of cars (trotro, taxi or personal cars) as a mean of transportation to the university each day. This majority correspond to 62.8 per cent of the respondents interviewed while 23.5 per cent also walk to the university campus. Additionally, 13.7 per cent of the respondents use the university shuttle bus each day.

In finding out the reason for the choice of transportation to the university, the majority of the respondents (54.9%) said they don't have any other choice of transport, while 25.5 per cent said it is the cheapest mode of transport (mostly those that used commercial vehicles (trotro and taxi). Another 13.7 per cent said it is the most comfortable option while 2 per cent said it is the fastest option (mostly those who use shuttle buses). Two respondents, representing 3.9 per cent, choose to walk to work since they live at the university and also consider walking as a form of exercise and beneficial to their health.

2.4 Mode of transport within the University campus

From the survey, majority of the respondents (51%) choose walking as a means moving round the university campus. This is followed by 17.6 per cent of respondents who use the shuttle bus to their preferred location within the campus to transact businesses. Furthermore, 9.8 per cent and 21.6 per cent rely on KNUST taxi and cars (personal or trotro) to move within the university.

2.5 Cost of transportation to the university campus

Respondents were asked how much money they currently spend on transportation per ride to the university each day. Out of the total number of respondents interviewed, 17 participants, representing 33.3 per cent, spend nothing at all, these people either walk or get a free ride to the university campus. However, 35.3 per cent spend up to 5 cedis on transportation daily followed by 19.6 per cent who spend up to 10 cedis daily. Additionally, 9.8 and 2.0 per cent spend up to 2 and 30 cedis daily. The amount of money spent on transportation per ride each day is largely dependent on how far respondent home is from the university campus.

Table 2. 1: Socio-demographic characteristics of respondents

Variable	Frequency	Per centage
Gender		
Male	42	82.4
Female	9	17.6
Age bracket		
< 19	3	5.9
20-29	38	74.5
30-39	8	15.7
40-49	2	3.9
>50	0	0.0
Mode of transport to university campus		
Walking	12	23.5
Car	32	62.8
KNUST shuttle bus	7	13.7
Motorbike	0	0
Bicycle	0	0
Reason for choosing a mode of transport to work		
Comfortability	7	13.7
Less costly	13	25.5
Fastest option	1	2.0
No other available option	28	54.9
other	2	3.9
Mode of transport within the university		
Walking	26	51,0
Car	11	21.6
KNUST Shuttle Bus	9	17.6
KNUST taxi	5	9.8
Bicycle	0	0
Cost of transportation to the university		
Nothing	17	33.3
up to 2 GHS	5	9.8
up to 5 GHS	18	35.3
up to 10 GHS	10	19.6
up to 20 GHS	0	0
up to 30 GHS	1	2.0
up to 40 GHS and more	0	0
Total	**51**	**100**

Source: Author's computation from field survey data, December 2021

2.6 How far do respondents live from KNUST

To determine how far respondents live from the university campus, respondents were asked to tell us the distant from their home to the university campus. About 13 respondents, representing 25.5 per cent, live on the university campus and also more than 30 kilometres from the campus. However, 8 respondents representing 15.7 per cent live 5 kilometres or less whiles 4 respondents representing 7.8 per cent live 11-15 and 16 -20 kilometres away from the university campus. Additionally, 6 and 3 respondents representing 11.8 and 5.9 per cent also live 21-30 km and 6-10 km away from KNUST campus.

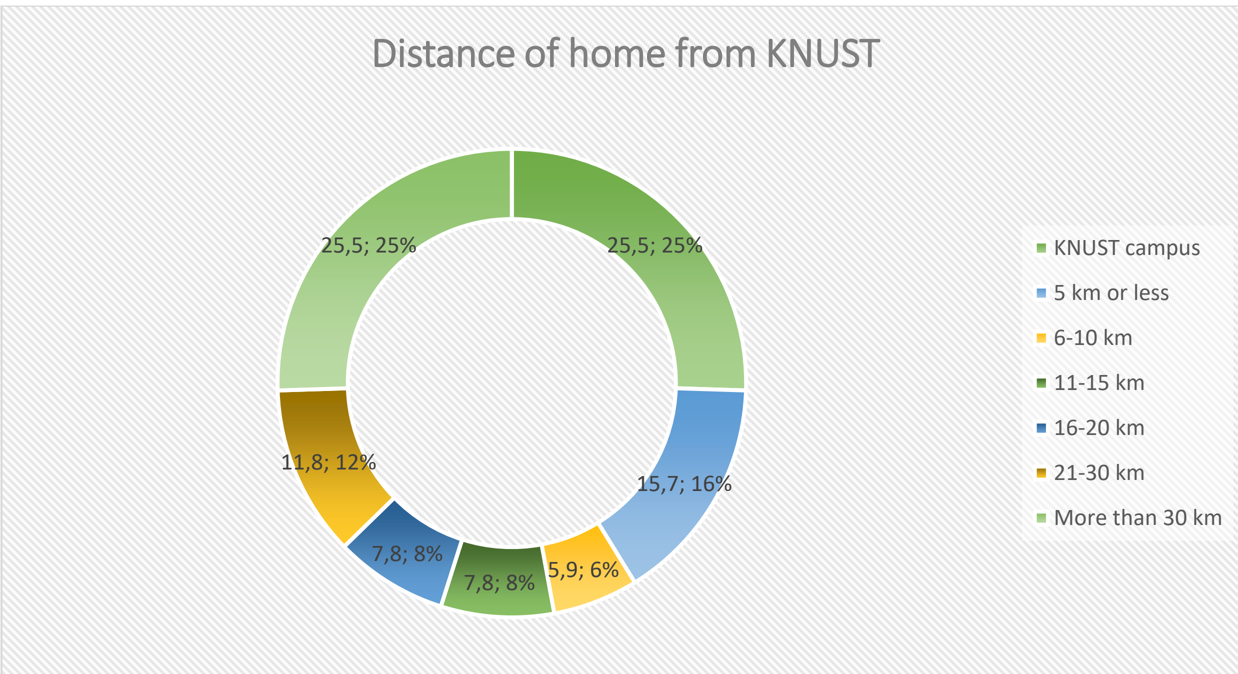

Figure 2. 1: Respondent's home distance from KNUST

2.7 Monthly income or stipends

The majority of the respondents were students of varying degrees from undergraduate to postgraduate with most of them depending on their guardians. 62.7 per cent of the respondents received a monthly stipend of between GH₵ 500 – 1000. 17.6 per cent of the respondent also received a stipend of GH₵ 1001 – 1500. In addition, 9.8 per cent of the respondents indicate they get a stipend of GH₵ 500 or less. However, 7.8 per cent and 2 per cent of the respondents earn between GH₵ 1501 – 2000 and 3000 and above respectively.

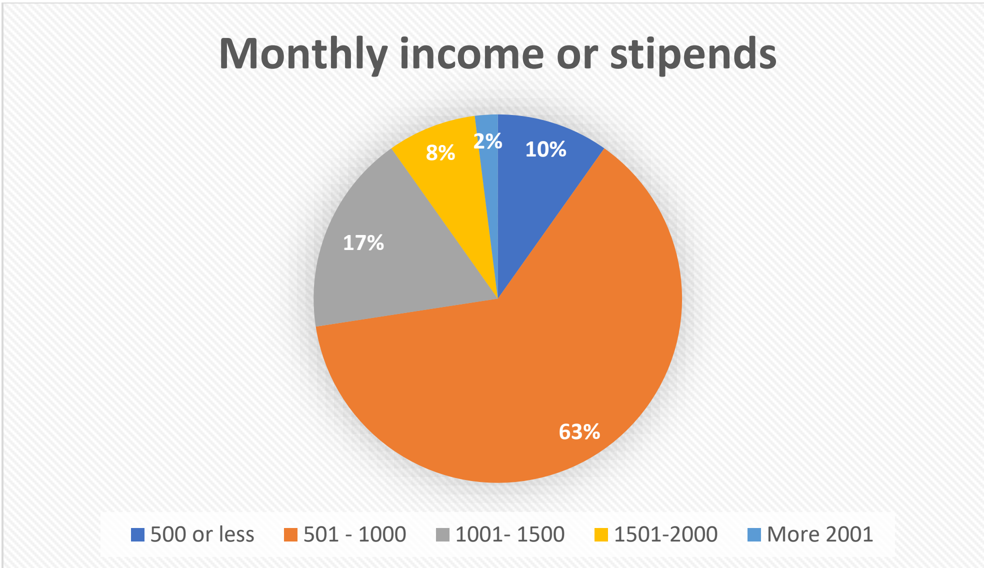

Figure 2. 2: Respondent's monthly income or stipends

3.0 Determining user requirements for mobility devices and power in the study area

3.1 Number of times per day transportation is required by respondents

On average 80.4 per cent of the respondent required transportation to campus 1 to 2 times per day, while 19.6 per cent seeking transportation 3 to 4 times per day.

3.2 Availability of transportation options and reasons

On the issue of alternatives regarding transportation, it was overwhelmingly agreed by 98 per cent of the respondent of this survey that the university campus would require a lot more transportation options while an insignificant number of 2 per cent had a contrary view of not needing transportation options. Some of the reasons espoused by the respondents were: the growing number of students population on campus; with other transport options, it will bring down the cost of transport on campus generally; It will help get transportation closer to where students are clustered, moving to campus easily.

3.3 Interest in Electronic Vehicles repair and maintenance

When the respondents were asked about their interest in learning repairs and maintenance of electronic vehicles, 33.3 per cent indicated that they are interested, with 5.9 per cent of the respondents indicating they are a little interested in learning. However, a whopping 60.8 per cent of the respondents indicated that they are not interested in learning and will not patronize any learning workshop provided on the campus. However, 9.8 per cent of the respondents revealed that they would visit any learning workshop if there were any on campus. Additionally, 19.6 per cent and 9.8 per cent indicated they would sometimes and in rare occasions visit any learning space provided on campus.

3.4 Driver's License and Usage of a motorbike

According to the survey, the percentage of respondents who had acquired a driver's license stood at 33.3 per cent with the remaining 66.7 per cent not having a driver's license. Additionally, the survey revealed that 23.5 per cent of the respondents own or regularly use a motorbike, or have ever used a motorbike at some point in their lives, with the remaining 76.5 per cent not having any experience with motorbikes. Some of the reasons espoused by the respondents for not using motorbikes were mostly because motorbikes were not safe for them (50%), closely followed by some respondents claiming that they never had any opportunity to learn riding a motorbike (44.7%). However, few other respondents indicated motorbikes were too expensive for them to procure (5.3%).

Table 3 1: Respondents requirements for an electric motorbike

Variable	Frequency	Per centage
Number of times transportation is required per day		
1-2	41	80.4
3-4	10	19.6
9-6	0	0
More than 6	0	0
More transportation options on campus		
Yes	50	98.0
No	1	2
Not sure	0	0
Interest in learning repair and maintenance of electric vehicles		
Yes	17	33.3
No	31	60.8
A little	3	5.9
Ownership of drivers License		
Yes	17	33.3
No	34	66.7
Ownership or usage of a motorbike		
Yes	12	23.5
No	39	76.5
Total	**61**	**100**

Source: Author's computation from field survey data, December 2021

4.0 Exploring user experience with the sharing system

4.1 likeness of the experience with the sharing system and suggestion for improvement

Respondents indicated what they liked about their experience with the sharing system, which includes the fact that the engines of the solar bike do not make as much noise as the regular motorbike. This makes them more environmentally friendly, with no emission of carbon dioxide into the atmosphere. Also, respondents like how the riders treated and spoke to them and in some instances offered them helmets and rode them very carefully to their destinations. However, some respondents suggested that helmets giving to passengers when they board the motorbike should be kept clean since is going to be used by different people. Additionally, some respondents suggested to use an app where students can request a bike to pick them up wherever they are on campus. Some also suggested that the current number of bikes on campus should increase when school reopens to meet the transport demand of students. Finally, the respondents suggested that the fares should be made more affordable since is going to be patronized by students.

4.2 Usage of Software or App

When respondents were asked about the possible usage of a software or an App for renting and operating the motorbikes, an overwhelming number of 94.1 per cent indicated their interest and willingness to use an App to rent the motorbikes. However, 5.9 per cent of the respondents did not indicate their unwillingness to use the App, but were uncertain about whether they would use it.

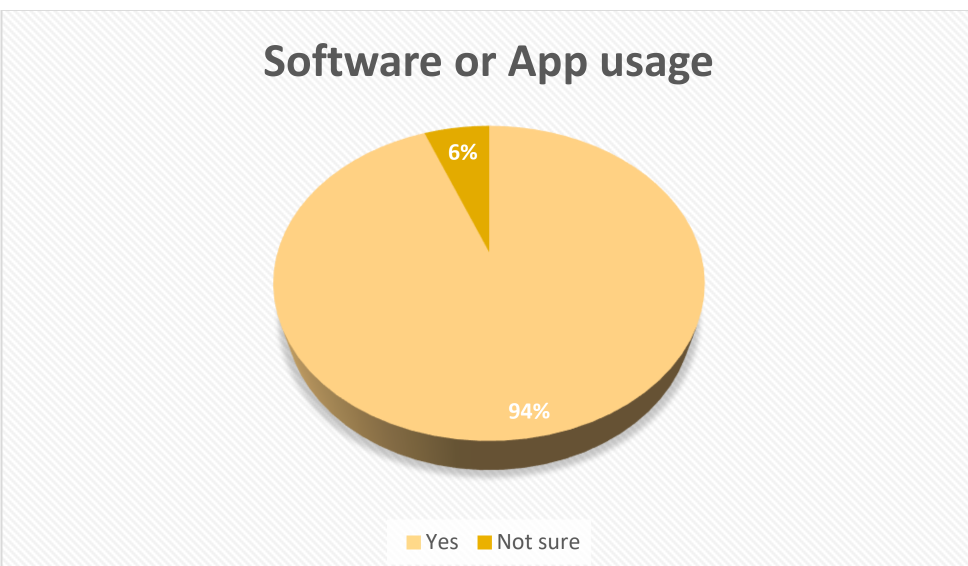

Figure 4. 1: Respondent's usage of *software or app*

4.3 Thoughts and overall experience with the motorbike

Respondents when asked if they think the sharing system on the campus could improve their daily transport experience: 92.2 per cent of the respondent indicated it would improve their transport experience with 7.8 per cent of the respondents who were not sure whether it will improve their transport experience. In addition, all the respondents had no difficulty with their experience in riding on the motorbike. The majority of the respondents (54.9%) indicated that they were satisfied with their overall experience with the motorbikes with 41.2 per cent being very satisfied with their overall experience with the motorbike. However, 3.9 per cent of the respondents were indifferent with their overall motorbike experience. Respondents were further asked if they think the sharing system is overall convenient. 88.2 per cent indicated they do with 7.8 per cent of the respondents also indicating that they sometimes do. However, 3.9 per cent of the respondent did feel the sharing system was not overall convenient, due to the shared helmets they had to put on, especially during the covid-19 pandemic period.

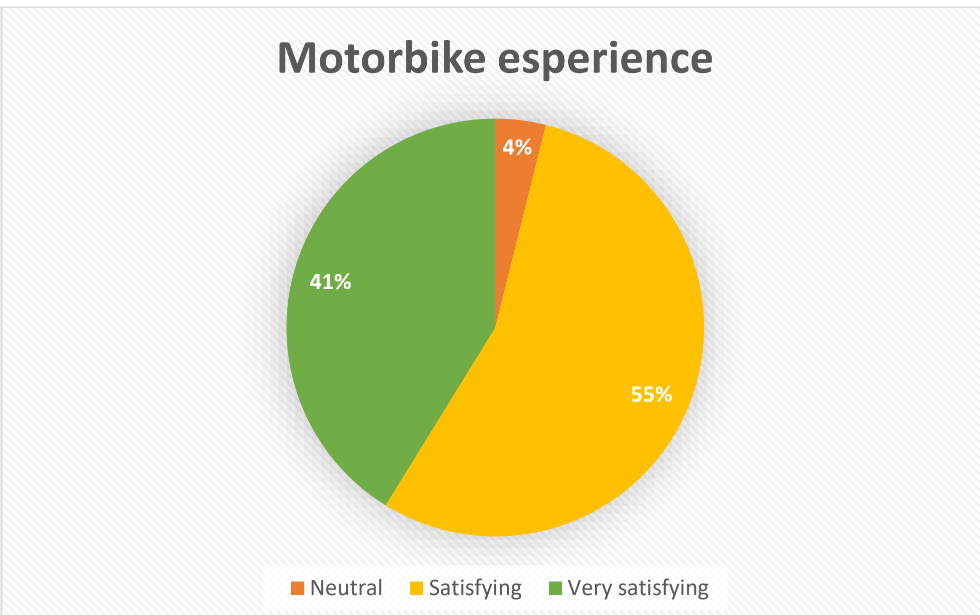

Figure 4. 2: Respondent's experience with the motorbike

4.4 Rating of experience on the motorbike

Respondents were asked to rate their experience on the motorbike regarding these factors that were made available to them.

On their *posture on the motorbike*, 54.9 per cent indicated it was good while 27.45 per cent said it was very good with 17.65 per cent saying it was okay been at the back of the motorbike. On the *sense of safety*, 54.90 per cent said is good while 45.10 per cent indicated it was very good. Additionally on *suspension and turning manoeuvres*, 52.94 per cent said it was good while 43.14 and 47.06 per cent said it was very good respectively. However, on *acceleration, braking, and agility* of the bike, 50.98 per cent indicated it was very good while 49.02 per cent said it was good but vice versa on *comfortability*.

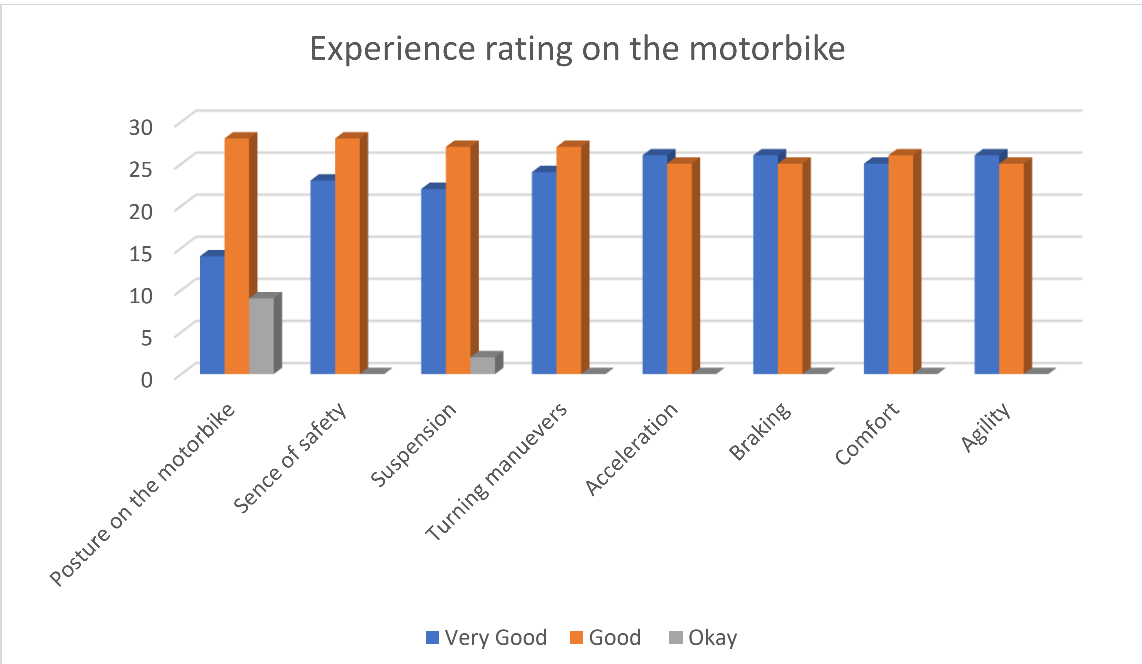

Figure 4. 3: Respondents experience rating on the motorbike

4.5 Willingness to pay

In assessing how students and other patrons of the sharing system are willing to pay at the charging stations on the campus, the majority (58.8%) of the respondents expressed their willingness to pay GH₵ 1 per trip while 13.7 per cent of the respondents were willing to pay GH₵ 2. This was followed by 11.8 per cent, 9.8 per cent and 5.9 per cent of the respondents who were willing to pay GH₵ 5, GH₵ 3 and GH₵ 4 per trip respectively.

4.6 How far you are willing to walk to rental station

According to the survey, 62.7 per cent of the respondents were willing to walk two to five minutes to the rental station, while 33.3 per cent of the respondents are willing to take less than 2 minutes to walk to the rental station. However, 3.9 per cent of the respondents are willing to take a six to ten minutes' walk to the rental station.

Table 4. 1: Respondents experience with the sharing system

Variable	Frequency	Per centage
Frequency of use of sharing system		
Never	1	1.96
Less than once a month	2	3.92
Once or twice a month	1	1.96
Once or twice a week	6	11.76
Almost daily	31	60.78
Daily	10	19.61
Walking time to the rental station		
Less than 2 minutes	17	33.33
Between 2-5 minutes	32	62.75
Between 6-10 minutes	2	3.92
More than 10 minutes	0	0.00
Willingness to pay		
Up to 1 GHS	30	58.82
Up to 2 GHS	7	13.73
Up to 3 GHS	5	9.80
Up to 4 GHS	3	5.88
Up to 5 GHS	6	11.76
More than 5 GHS	0	0.00
Total	**51**	**100**

Source: Author's computation from field survey data, December 2021

4.7 Frequency of use of the sharing system

The Majority (60.79%) showed their willingness to use the sharing system almost daily, followed by 19.61 per cent also indicating they will use it daily. Additionally, 11.76 per cent indicated they will use the sharing system once or twice a week with 3.92 indicating less than a month usage of the sharing system. However, 1.96 per cent of the respondents indicated to use it once or twice a month or to never use the sharing system.

4.8 Ranking of statements on the usage of electric motorbike by respondents

Kendall's Coefficient was also used in analysing respondents' agreement on the following statement. Kendall's Coefficient was found to be 0.416 and significant at the 1% level. The null hypothesis (i.e., Ho: No agreement among respondents ranking) was rejected in favour of the alternate hypothesis (i.e., Ha: There is agreement among respondents ranking) in the statements considered important to the usage of an electric motorbike on the campus of KNUST. Kendall's 'W' of 0.291 implies that there was 29.1% agreement between the respondent in the ranking of statements considered important to the usage of electric motorbike at the university campus.

The three most important statements ranked by respondents regarding the usage of an electric motorbike are accessibility to motor-bike due to the sharing system, an improvement on their flexibility and lastly a positive impact on their economic situations. These factors are very important to the usage of electric motor-bikes on KNUST campus, while also keeping in mind other factors.

Table 4. 2: Ranking of statements to the usage of electric motorbike

Statements	Mean Score	Ranks
I have better access to motor-bikes thanks to the sharing system	2.36	1st
A sharing system can improve my flexibility	2.49	2nd
A sharing system can affect my economic situation in a positive way	2.60	3rd
A sharing system leads to a better access to public services	3.58	4th
A sharing system would have a positive influence on my life in general	3.97	5th
Diagnostics		
Number of observations	51	
Kendall's W	0.416	
Degree of Freedom	4	
Chi-square	84.853	
Asymptotic significant	0.000	

Source: Author's computation from field survey data, December 2021

4.9 Factors regarded by respondents to the usage of an electric motorbike on KNUST campus

Factors that are considered very important by respondents for the use of an electric motorbike on KNUST campus are presented in Table 4.1. These factors were ranked by respondents on a Likert scale from 1-5 (1= absolutely important, 2= important, 3= somehow important, 4= not too important, and 5= not important at all). To find which of these factors is considered important by the respondents, Kendall's Coefficient of Concordance was used to rank the factors. The Kendall's Coefficient of Concordance used in the analysis has a test statistics Kendall's 'W' which measures the agreement between respondents ranking.

Kendall's Coefficient was found to be 0.533 and significant at a 1% level. The 1% significance level implies that the model is 99.99% correct and not mis-specified. The null hypothesis (i.e., Ho: No agreement among respondents ranking) was rejected in favour of the alternate hypothesis (i.e., Ha: There is agreement among respondents ranking) in the factors considered important to the usage of an electric motorbike at KNUST campus. The Kendall's 'W' of 0.533 implies that there was 53% agreement between the respondent in the ranking of factors considered important to the usage of an electric motorbike at the Campus of KNUST.

The four most important factors ranked by respondents are safety, environmental sustainability, comfort, and quality of the motorbike. These factors are very important to the usage of the motorbike on the campus of Kwame Nkrumah University of Science and Technology (KNUST, while keeping in mind other factors as well.

Table 4. 3: Ranking of factors that influence the usage of electric motorbike

Factors	Mean Score	Ranks
Safety	1.9	1st
Environmental Sustainability	3.28	2nd
Comfort	3.53	3rd
Quality	4.37	4th
Design	4.91	5th
Load Capacity	5.81	6th
Range	6.07	7th
Power	6.12	8th
Diagnostics		
Number of observations	51	
Kendall's W	0.533	
Degree of Freedom	7	
Chi-square	190.238	
Asymptotic significant	0.000	

Source: Author's computation from field survey data, December 2021

4.10 Ranking of factors important to the usage of a sharing system by respondents

Kendall's Coefficient was again used in analysing respondents' agreement on the following factors. Kendall's Coefficient was found to be 0.051 and significant at the 10% level. The null hypothesis (i.e., Ho: No agreement among respondents ranking) was rejected in favour of the alternate hypothesis (i.e., Ha: There is agreement among respondents ranking) in the factors considered important to the usage of electric motorbike on KNUST campus. Kendall's 'W' of 0.051 implies that there was 51% agreement between the respondents in the ranking of factors considered important to the usage of electric motorbike at the university campus.

The three most important factors ranked by respondents regarding the usage of an electric motorbike are reliability, price and lastly easily usage. These factors are very important to the usage of electric motorbikes on KNUST campus, while not forgetting the other factors.

Table 4. 4: Ranking of factors important to the usage of the sharing system

Factors	Mean Score	Ranks
Reliability	2.39	1^{st}
Price	2.44	2^{nd}
Easy usage	2.55	3^{rd}
Location of the rental station	2.62	4^{th}
Diagnostics		
Number of observations	51	
Kendall's W	0.051	
Degree of Freedom	3	
Chi-square	7.762	
Asymptotic significant	0.051	

Source: Author's computation from field survey data, December 2021

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