Development of a Small-Scale Plant for Electricity and Water Supply in Rural Regions of Côte d'Ivoire as Part of the First Ivorian Dual Study Program with Focus on Renewable Energies

Lukas Saars[1], Charlotte Newiadomsky[1], Ahoutou Paul Kouakou[2], N'guessan Raymond Kre[2] and Arne Graßmann[1]

[1] Hochschule Niederrhein, SWK E² - Institute for Energy Technology and Energy Management, Krefeld (Germany)

[2] Université NANGUI ABROGOUA, Unité de Formation et de Recherche Sciences Fondamentales Appliquées, Abidjan (Côte d'Ivoire)

Abstract

In many African countries, access to electricity and potable water is capable of development, especially in rural areas. Another issue is the lack of practical components in the education system which is one source of the high unemployability rate since it is more theoretically oriented. The project 'Industry Integrated Dual Engineering Studies in a North-South Collaboration (IIDES-NSC)' aims to address the issue of limited access to electricity and water in the West African state of Côte d'Ivoire. To reach these purposes, the first dual study program in Côte d'Ivoire is developed and introduced at the University NANGUI ABROGOUA. It combines theoretical, practice-oriented, and project teaching modules, which enable the students to work on a prototype for a self-sufficient electricity and water supply system to be installed in a model village. To acquire the competencies demanded by the industry, technical, economic, and social modules have been included in the development of the curriculum, together with relevant stakeholders from industry, public institutions, and universities. One of the four semesters of the study program will take place at the Hochschule Niederrhein in Germany, where the Ivorian students will develop and build one out of a total of two prototypes and simultaneously increase their intercultural skills. In the end, the study program can make an important contribution to combating the high unemployment rate among graduates and at the same time accelerate the expansion and security of renewable energies and water supply infrastructure in Côte d'Ivoire.

Keywords: Academic Education, Industry, Dual Study Program, Côte d'Ivoire, Electricity and Water Supply

1. Problem and Motivation

The access to electricity and water in rural areas in Côte d'Ivoire as well as in large parts of Africa is limited. According to Ivorian government sources, the national coverage rate of drinkable water and electricity was on average about 80% in 2020, whereas there are differences between rural and urban regions. The coverages are lower in rural areas that are situated far from the governmental infrastructures. Africa is a priority region in the World Energy Outlook 2019 to provide a robust, evidence-based platform for energy decision-makers (International Energy Agency, 2019). The 'Sustainable Africa Scenario' of the African Energy Outlook 2022 wants to achieve universal access to affordable electricity by 2030, although 43% of the total population in Africa lacks access to electricity at present (International Energy Agency, 2022). As the African population continues to grow, the absolute number of people without access to electricity and water continues to increase. The supply of electricity and clean water is closely intertwined and leads to direct interdependencies and impacts (Newiadomsky and Tietze, 2017).

The safely managed national coverage rate of drinkable water in Côte d'Ivoire in 2020 was 35.20% (14.58% in rural areas and 54.47% in urban areas) (WHO/UNICEF JMP, 2021). In addition, only 69.70% of the Ivorian population had access to electricity in 2020, (94.50% of the urban population and only 43.10% of the rural population) (The World Bank, 2022). The sometimes long and time-consuming supply chain for potable water, which is largely handled by adolescents, especially girls, severely limits the educational and training opportunities of those affected (Mitsubishi UFJ Research and Consulting Co., Ltd., 2013; Noubactep, 2016).

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The poor supply of electricity also hinders education, since there are often no possibilities for students to learn after sunset. It also affects economic power, so only a limited production of goods (e.g. with the help of electrical tools) is possible. Besides, increasing electricity demand is predicted in Côte d’Ivoire due to economic growth (International Energy Agency, 2019). The highest potential for electricity generation in Côte d'Ivoire lies in solar energy, which is why the Ministry of Energy plans to expand the installed capacity of photovoltaic plants by up to 424 MW by 2030 (Seier, 2016). The following figures show that the potential for electricity generation from photovoltaics in Côte d'Ivoire is very large. The figure on the left side (Fig. 1) shows the global horizontal irradiation and the one on the right side (Fig. 2) the photovoltaic power potential in Côte d'Ivoire.

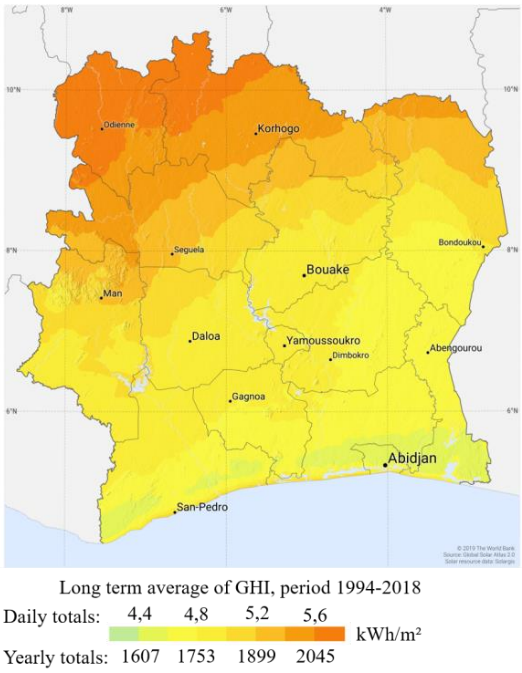

Fig. 1: Global Horizontal Irradiation in Côte d'Ivoire (Solargis, 2022a)

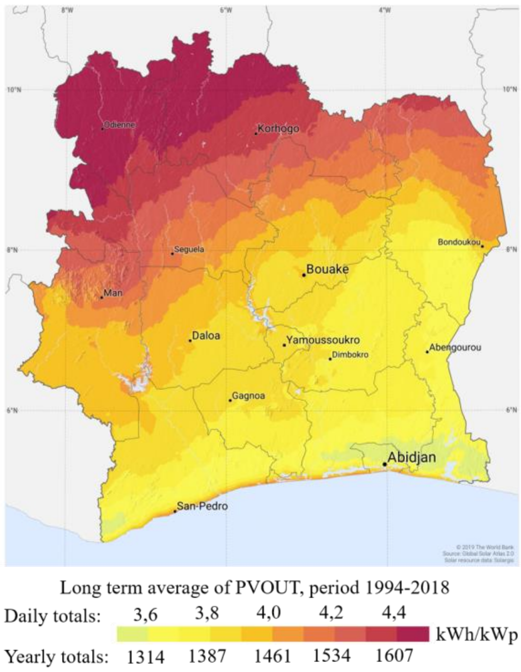

Fig. 2: Photovoltaic Power Potential in Côte d'Ivoire (Solargis, 2022b)

Despite the large photovoltaic power potential, the share of electricity production from renewable energies (excluding hydroelectric) in total electricity production in Côte d'Ivoire is still extremely low with only 1.2% in 2015 (The World Bank, 2022). The Ivorian government's expansion plans are essential to provide decentralized renewable energy to the growing population, especially in rural areas.

This conflict can be complemented by other areas, such as education. In most of the public universities in Côte d'Ivoire, learning is more theoretical than practical. Human resources managers at Ivorian companies often complain that university graduates' knowledge is based on a purely theoretical foundation and their practical experience is still lacking. Therefore, in industrial human resources management it is said that university graduates are not ready to enter the industry. In general, graduates have to start working as a trainee in industrial companies for around two years after graduation, to be considered as potential full employees. As a result, universities and companies in Côte d'Ivoire rarely work together or enter into long-term collaborations. According to Yapo (2018a), the recruitment rate of graduates in Côte d’Ivoire was only 14.43% in 2016, which means that almost 86% of these graduates were unemployed. At the same time, the average overqualification rate in Côte d’Ivoire is 29.69%, from which workers with secondary and higher general education are more affected (38.15% and 30.68%, respectively) and especially women are more exposed than men (30.97% versus 29.25%, respectively). As a result, graduates often start to work in sectors that do not require the special knowledge of their former studies, so a quick adaption to the field of work is necessary.

Introducing a dual study program, where theoretical and practical knowledge are gained simultaneously, is a big step forward to improving the economic power in Côte d’Ivoire and helps students to get in contact with interested companies early, who might be willing to employ them after their graduation. The practical relevance is the biggest advantage of dual study programs. The main goal is to enable students to simultaneously gain theoretical knowledge as well as practical experience from working in a local company in the field of e.g. energy or water supply. Since students who study in dual programs already gain a lot of work experience during their studies, they are better prepared for professional life in terms of working experience. Currently, there are no dual study programs in Côte d'Ivoire, although they have great potential to strengthen cooperation between universities and companies and reduce unemployment rates among graduates. This and the fact that the Ivorian government has issued optimistic targets for the expansion of renewable energies lead to the development of the project idea and concept. The dual study program will contribute to the development of the Ivorian economy by improving electricity and water supply in rural areas, employability of graduates through practice-oriented higher education, cooperation with local institutions and companies as well as enabling the local population to solve electricity and water supply problems independently and sustainably.

2. Application-Oriented Study Program

This paper presents some solutions to tackle the beforementioned problems in Côte d'Ivoire by implementing a dual study program that combines practical and theoretical teaching modules with a focus on renewable energies (specifically solar energy) and water supply. The students will not only learn engineering-specific content but will simultaneously work on a prototype of a small-scale plant to supply electricity and water in a model village in a rural region. This can make an important contribution to combating the high unemployment rate among graduates and simultaneously accelerate the expansion of renewable energies and water supply infrastructure in Côte d'Ivoire.

The first group of students will develop and construct a small-scale electricity and water supply plant within the framework of practice-oriented teaching modules. One of the key objectives of the project is that the developed and implemented dual study program at the University of NANGUI ABROGOUA will remain after the end of the project so that a sustainable expansion of Ivorian academic education and acceleration of renewable energy development can be achieved. The following groups of students will then work on other projects accompanying their studies, which will meet the requirements of the industry. The basic structure of the Ivorian dual study program is shown in the following figure.

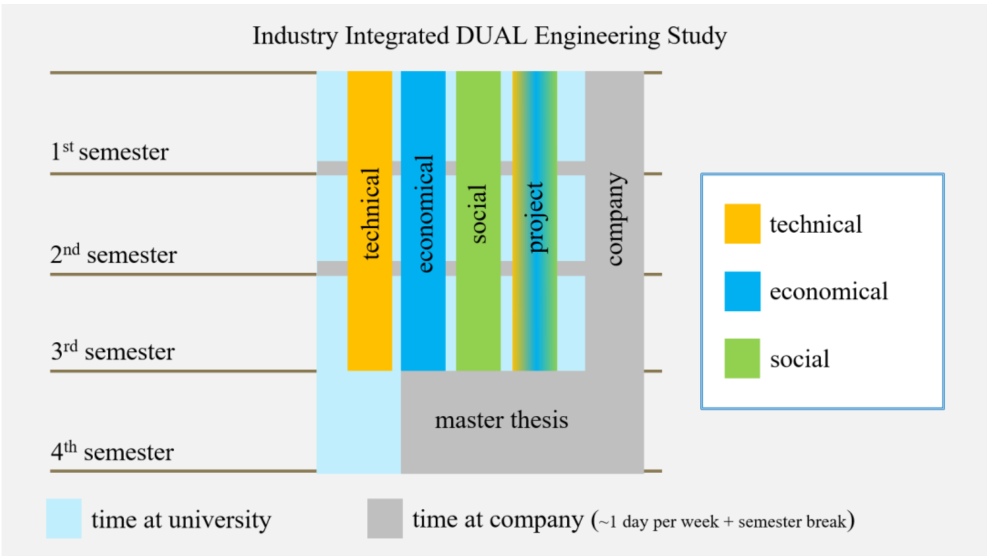

Fig. 3: Basic Structure of the Dual Study Program

As shown in Fig. 3, the Master's program that will take place at the University NANGUI ABROGOUA in Côte d'Ivoire is a four-semester continuing education program. It's composed of technical, economic, social, and project modules, partly to be conducted at the university and partly to be conducted at a company to have competitive training. One semester abroad at the Hochschule Niederrhein is firmly anchored in the curriculum (third semester of the study program). The study in Germany is to be structured with a duration of one semester including the practical part.

The first two practice-oriented project modules of the study program are intended for concept development and detailed planning of a prototype by the Ivorian students. During the third semester, the students travel to the Hochschule Niederrhein in Krefeld (Germany) to build up and operate the first prototype. After finishing the semester abroad, the training material and facilities are to be transferred to the University NANGUI ABROGOUA in Côte d'Ivoire. Subsequently, students from the Hochschule Niederrhein from existing study programs fitting thematically into the topic of the study program in Côte d'Ivoire, will visit the University NANGUI ABROGOUA to work together with the Ivorian students on a second prototype. The mixed student group has to consider its experiences during the build-up of the first prototype as well as local sourcing for components and necessary work to be done.

In the dual study program, the Ivorian and German students will learn how business models are set up and what is important during development, using the prototype as an example. The best business model will be selected in the program of a competition, involving local financiers and industry partners. The first prototype is set up at the campus in Abidjan and put into operation. Afterwards, the procurement of local materials for the second prototype starts and the workspace is prepared.

Further German students (not necessarily from the mentioned group before) travel to Côte d'Ivoire during the fourth semester to write their thesis about the project from technical and economic perspectives. At the same time, the Ivorian students build and implement the second prototype on campus. After the successful installation and operation of the second prototype at the University NANGUI ABROGOUA, it is brought to the selected model village and put into operation. The last practice-oriented task during the study program is the evaluation of the operation experience and an improvement of the planning steps. The existing plans for the first two prototypes should be improved or enhanced in a way to create a basis for a small series. Furthermore, possible additional industry partners will be addressed to develop business models for a small series of the system.

3. System Design of a Small-Scale Plant for Electricity and Water Supply in Côte d'Ivoire

One possible design of a small-scale plant is shown as an Inventor drawing (cp. Fig. 4) and as a Piping and Instrumentation Diagram (P&ID) (cp. Fig. 5).

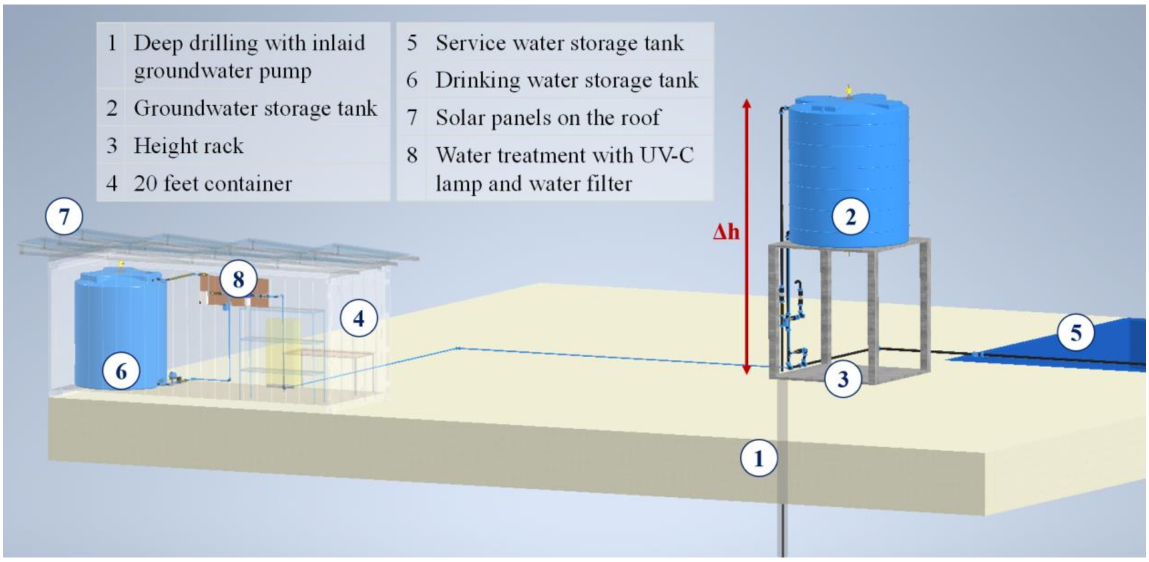

Fig. 4: Inventor drawing of the small-scale water supply powered by a solar energy plant

Fig. 4 shows the overall concept of the small-scale plant for electricity and water supply for rural areas. For water supply, groundwater will be pumped into a so-called groundwater storage tank installed at a certain height. From there, the groundwater is transported either to the water treatment station inside the 20-feet container to be chemically and bacteriologically treated or directly into a service water storage tank to be distributed to the population. The needed electricity for the small-scale plant is provided by several solar panels, which are installed on racks on top of the container. Surplus electricity not used by the water treatment system will be used by the population for other needs. Further usage of surplus electricity still has to be designed according to the local needs of the model village.

The chosen model village is located near the city of Duékoué in western Côte d'Ivoire, 400 km from Abidjan. It is a village of cocoa tree farmers that is not connected to the public electrical and water grid. There are many other villages in the surrounding area, so the developed concept can serve as a flagship for other villages. For the design of the prototype, all basic conditions like the number of villagers, service and drinking water demand of the model village must be recorded and included as parameters in the calculations.

The students of the master's program at University NANGUI ABROGOUA will be enabled to create and communicate visualizations using internationally common tools. To be able to build a small-scale water and electricity plant, it is necessary to develop a P&ID diagram (cp. Fig. 5) in advance. Gaining the skill to do so will be part of the dual study program as the students will have to develop this diagram on their own within group work.

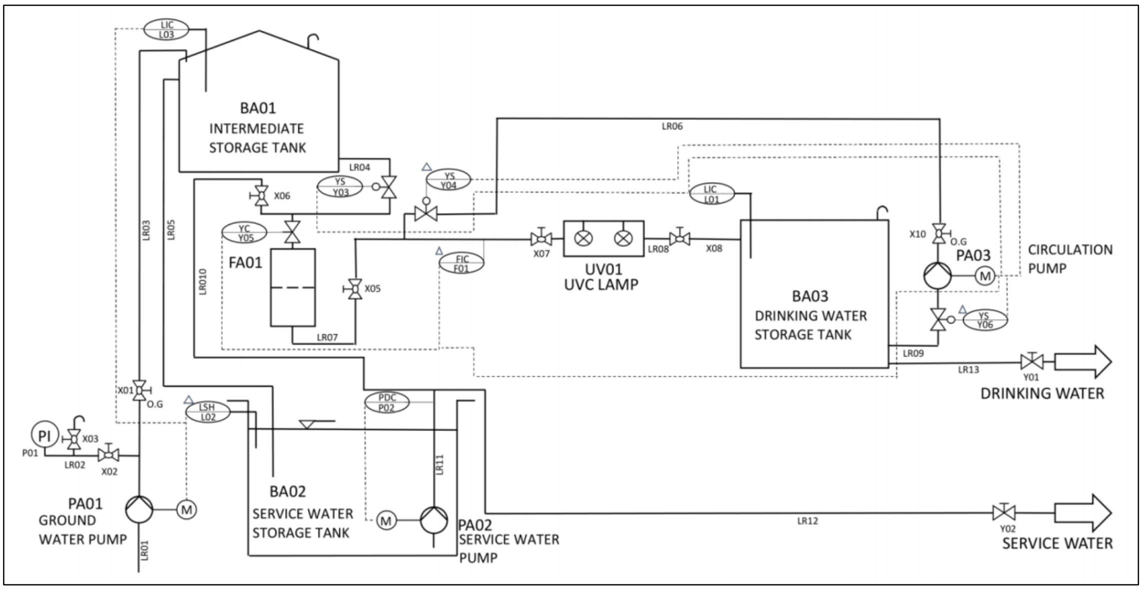

Fig. 5: P&ID diagram of the small-scale water supply and treatment plant

The purpose of P&ID diagrams is to show the plant's components and the associated connecting parts and measuring devices. It is possible to locally purchase each necessary part to build the plant in remote rural areas, which do not have a connection to the national electricity and water grid.

Fig. 5 shows the main parts of the plant, the groundwater pump PA01, the intermediate storage tank BA01, the service water storage tank BA02, the service water pump PA02, the UV-C lamp UV01, and the drinking water storage tank BA03, and the circulation pump PA03. The capacity of the storage tank must at least equal the daily drinking water demand of the model village, where the plant will be operated. From there, the groundwater is either pumped to the water treatment station inside the container or into the service water storage tank BA02, depending on the filling level of the drinking water storage tank BA03 and the overall demand for drinking water. The service water pump PA02 is switched on automatically with a differential pressure switch if water is withdrawn and the pressure in the connected pipelines drops. It is possible to use the service water in emergency operations for drinking water treatment, for example, in the event of a malfunction of the groundwater pump PA01. For this purpose, the service water is led to the drinking water treatment. A consistently high drinking water quality is guaranteed by the circulation of the drinking water through the UV lamp UV01. The circulation is carried out by the circulation pump PA03. Flow sensor F01 controls the circulation pump PA03 and guarantees that the maximum flow rate of the UV-C lamp UV01 is not exceeded even when the drinking water is circulated.

Particularly in the case of decentralized plants for electricity and water supply in rural regions, there are mostly no specialized personnel and materials available on site. The system should therefore be as robust and simple as possible so that errors or malfunctions can be rectified by trained personnel on-site. For the developed concept and the associated business model to be successful on a large scale, the highest possible water quality must be achieved at a low cost. The system should therefore also be designed to be as inexpensive as possible. The plant design in Fig. 5 can be adapted and thus an alternative more robust version can be worked out. The P&ID diagram of a more robust version is shown in the following figure.

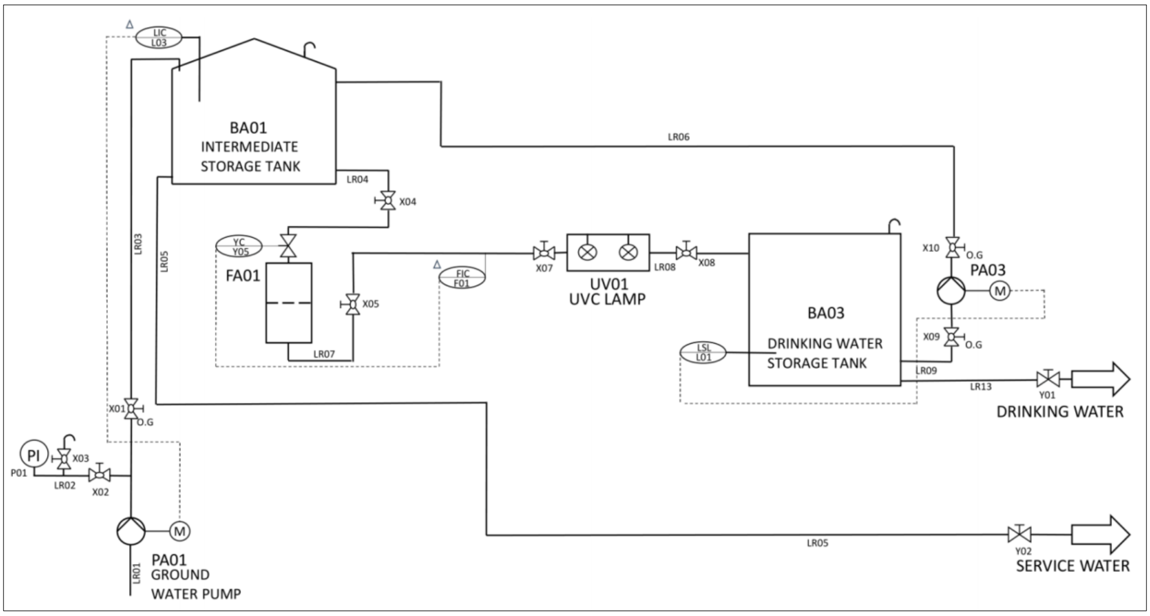

Fig. 6: P&ID diagram of the small-scale plant (optimized for robustness)

This version (Fig. 6) is designed for the case where the villagers have in-house storage tanks. Therefore, in this version there is no need for an automated circulation of drinking water by directing the circulation to the intermediate storage tank BA01 through the pipeline LR06. From the intermediate storage tank, the groundwater as well as the circulating water is directed gravimetrically through the treatment system to the drinking water storage tank BA03, as in the previous version. The flow is controlled manually by an operator via valve Y05 and local flow meter F01. The flow rate must be set by the operator at the maximum level of the intermediate storage tank to the permissible flow rate. Dry running of the circulation pump PA03 is prevented by the digital level sensor L01. The pump is automatically switched off whenever the level of the drinking water storage tank falls below it.

4. Conclusion and Perspectives

The project thus makes a significant contribution to achieving some of the 17 Sustainable Development Goals (SDGs) of the United Nations. The dual study program developed in the project is not only intended to combat unemployment of highly qualified personnel (SDG 8: Decent Work and Economic Growth) but also to improve unrestricted access to water and electricity for the Ivorian population in rural regions (SDG 6: Clean Water and Sanitation; SDG 7: Affordable and Clean Energy). With the implementation of the first dual study program in Côte d'Ivoire, the project contributes to the achievement of SDG 4 (Quality Education). An equal number of female and male students are selected to start the program in a gender-neutral way (SDG 5: Gender Equality). With the practice-oriented teaching content, the link between academic teaching and industry is established so that it is easier for engineers to enter the business world (SDG 9: Industry, Innovation, and Infrastructure).

The goal of the project is to introduce the dual study program by October 2022 and to install the small-scale plant in the model village by the end of 2024. In addition, the study program is to be maintained through long-term cooperation between the participating universities and the integration of new practice-oriented project modules so that the project can have a long-lasting impact.

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