

KNUST-TUM PV Knowledge Hub

ProPENS WiSe'24 Ghana

The KNUST-TUM PV Education hub project is one of the first steps from the TUM ENS chair as a long-term vision for strategic and sustainable partnership with KNUST, Ghana. In the shorter-term, we are attempting to cultivate an entrepreneurial mindset among students and enhancing renewable energy skills through block-course format, short education camps.

Overall vision

We focus on knowledge transfer, particularly through "Teach the Teachers" strategy, emphasizing local ownership and teaching capacity building. The daily operation and management of the PV Knowledge hub will remain the sole responsibility of KNUST collaborators, with TUM providing advisory support.

All course content will be open-source, fostering wider accessibility. They should also have interactive lectures with focus on "Active Learning" and "Learning by doing" paradigms, multimedia teaching material for renewable energy systems, experiments with Lego components, 3D printed schematics and circuit layouts for power electronics components and emphasis on reproducibility of teaching material for a variety of countries. Furthermore, video explainers to the teachers, IT tools to create a local encyclopedia of lecture resources for smartphones and computers, group activities with a competitive edge, should also be part of the course development cycle.

ProPENS 2024 Ghana - Overview

Two ProPENS groups are being conceptualised to assist in design and development of the KNUST-TUM PV Education hub. The following are the common expectation from both groups,

Expectations

- The program will be developed for the KNUST-TUM PV Education Hub in Kumasi. A periodic sync and progress update with the end-user is KNUST is to be expected.
- The "DBU Schüler Labor" in ZEI will be used as a local proxy for the end-user. Continuous feedback and surveys should be conducted with the attending teachers and students.
- All major design and development decisions should be made with the end-user in loop.
- Expert sessions with school teachers and renewable energy educators will be organised.
- While being focused on a specific end-user, a business plan to sustain the Renewable Energy Education Program for other countries, customers brackets, through a student-led non-profit format should be explored.
- Deliverables include - Developed material in hard-copy and software format, project report, presentations, business plan (if applicable).
- An outlook for sustainable practices, inclusive classrooms, empathy for other cultures and a desire to democratise renewable energy education should be the guiding principles of the developed products.

Support for the groups

Each group will be supported by the TUM PhD students leading the initiative, whose broader research interests is aligned for education technologies for dissemination of Renewable energy know-how.

The course content and collection of experiments will be provided to the ProPENS cohort. The entire PV-Education hub program will be built by student volunteers, PhD candidates and post-docs at the ENS chair. The tutors for this project are also part of the "Student laboratory for renewable energy systems" project funded by the German Environment Scholarship body. They have also led renewable energy camps in Zimbabwe, Nepal and India.

If needed, professional tools and freelancer services can be availed by the groups for a higher quality finished product.

ProPENS 2024 Ghana - Topics

Group #1 - Pedagogical development of a Renewable Energy Education program

Student and Teacher Handouts

- Create a series of handout for the students based on the lesson plan provided for the experiment series
- Create an equivalent handout for the teacher with time-planning, checkpoints, clear learning outcomes and other best practices.
- Provide figures, tables, photos in an eye-catching fashion for the students.

Developing the experiment kit

- Research all the available resources to produce experiment kits based on the provided lesson plan.
- Analyse the cost efficacy of sourcing components locally without losing significant quality in the learning experience.
- Create CAD, PCB schematics and code repositories wherever required.

Group #2 - Education technology for a Renewable Energy Education program

IT infrastructure

- Create a repository for tutorials, slides, video explainers, experiment plans, which can be hosted both offline and online
- Create an offline version of the repository with an easy update mechanism to host the program at locations without internet connectivity with no change in the learning experience
- Integrate modern classroom features such as - tracking performance, pop-quizzes, homework portal etc.
- Create demo for a professional UI/UX front-end for the IT infrastructure tailored for both mobile and PC users.

Video resources

- Research all available resources - animated format, AI generated, speech-to-video, to make explainer videos as accompaniment for the student and teacher handouts.
- Produce the videos for the provided lesson plan.

References

The course content for the Renewable Energy Education program will be similar to the rubric provided below.

School Program

<div>Day 1</div> <div>Energy basics Kinetic vs Potential Green house effect Why Renewables Current and Voltage Mechanical analogy for V-I Ohm's Law Power and Energy Irradiation and Solar energy Cosine effect</div>	<div>Day 2</div> <div>Solar PV panel demonstration Demonstrate V_{oc} & I_{sc} Effects of shadow, inclination, cloudy conditions Measure energy needed to boil water Measure power of phone charger, hair dryer & toaster Observe change in current with change in load Observe voltage during change in load Concept of energy pooling in grid Mechanical analogy for grid behaviour Need for decentralized energy</div>	<div>Day 3</div> <div>Demonstrate effect of orientation with sun on PV Measure V_{oc} & I_{sc} at different inclination Repeat for both cloudy and bright Measure V & I at different inclination with $R_{load} = 20\ \Omega$ Alternating and direct current Inverters and rectifiers Demonstrate working principle of a battery inverter</div>	<div>Day 4</div> <div>Plot V & I values from previous day Plot V & I curves for bright and cloudy conditions on same graph Plot V & I curves for with and without load on same graph Calculate power for all V & I data series Repeat all plots for Power and observe MPP Compare with ideal curves Series and parallel connections Mechanical analogy for series and parallel Calculate equivalent resistance for any arrangement PV array dimensioning for specific V and I</div>	<div>Required equipment and tools</div> <div>Multimeter 20W Solar PV panel Small Rheostat for Rload DC motor 9V Batteries 9V and AAA Toy drone blades Reusable plug play circuitboard Various coloured LEDs Various resistors Connecting wires Electrical tape Old hair dryer or table fan with variable speed Spreadsheet software on PC (RPI or Linux possible)</div>
<div>Day 5</div> <div>Capacity factor of PV Demand vs Supply Calculate total daily demand for a small home Sizing a battery backup Grid electricity vs diesel generator for typical demand Lifetime cost of a PV system Create daily demand time series for school Calculate Peak and Base demand Decide battery and PV size Plot daily demand and PV capacity factor on same graph Add battery storage into same graph Repeat all steps for a different demand profile</div>	<div>Day 6</div> <div>Mechanical analogy for charge transfer Types of batteries Battery technologies Series and parallel connection of batteries Connect different batteries in series and parallel Measure current and voltage Verify Ohm's law using Rload = 20 Ohm Wind turbines Onshore vs Offshore Tower height and number of blades Factors affecting wind power</div>	<div>Day 7</div> <div>Measure V & I for the wind turbine Measure V & I with different blade length Measure V & I at different wind speeds Observe V & I in turbulence Observe V & I with different direction of wind Create load series of each room in school Estimate the hours of usage and creating a weekly demand profile for school Estimate the number of PV panels Estimate battery size for a 2 day backup Calculate the price of electricity and lifetime cost of system Calculate year of breakeven investment Specify solar array dimension for specific PV inverter Specify location of the solar panels installation in the school compound</div>	<div>Theoretical explanation Demonstration by tutor Experiments by students Data analysis on computers Real world scenario project</div>	

Figure 1: 7-day renewable energy camp in St. Rupert Mayer, Zimbabwe 2017.

University Program (3 Experiments, 3 days)

PV experiment (with tabletop PV kits). 1. Change Inclination and orientation for higher power. Plot this in 2D in excel 2. Issue of dirt on the PV panel. Need Bypass diode. 3. Series parallel combination	H Bridge experiment (from DESL) 1. Explain the concept of P and N type FET. V_{GS} , concept of Q_g 2. Show how to read a datasheet for a MOSFETs 3. Explain a high and low switch	Energy System Modelling 1. Energy system as an optimization problem. Reference energy diagram 2. Concept of sector-coupling (cooling, mobility), demand side management. 3. Unit commitment problem with forecast explanation.
Connect various electrical loads to Solar Panels to explain the need for a charge controller. 1. Difference between a PWM and MPPT controller. 2. Find the power curve using an electronic load. 3. Explain the P&O algorithm using a simulated PV plant.	Basics of switching 1. Pulse width modulation. 2. Gate drivers and TTL switches 3. Designing a H bridge in LTSpice	Generate data sets for ESM 1. How to download generation timeseries? 2. How to collect measurement from domestic loads? 3. Get measurements from local DERs
Connect various electrical loads to Solar Panels to explain the need for a charge controller. 1. shadow effect and bypass diode 3. Inverter + PV 4. Combining PV + BESS	1. Build a H bridge on breadboard 2. Basic Arduino coding to get PWM 3. Comparing output on an oscilloscope	Programming 1. YALMIP (or similar) based simple unit commitment problem. 2. Simple rule based EMS.

Figure 2: Three experiment sessions with theoretical lessons for university students.

A typical lesson-plan for a single topic could like the following,

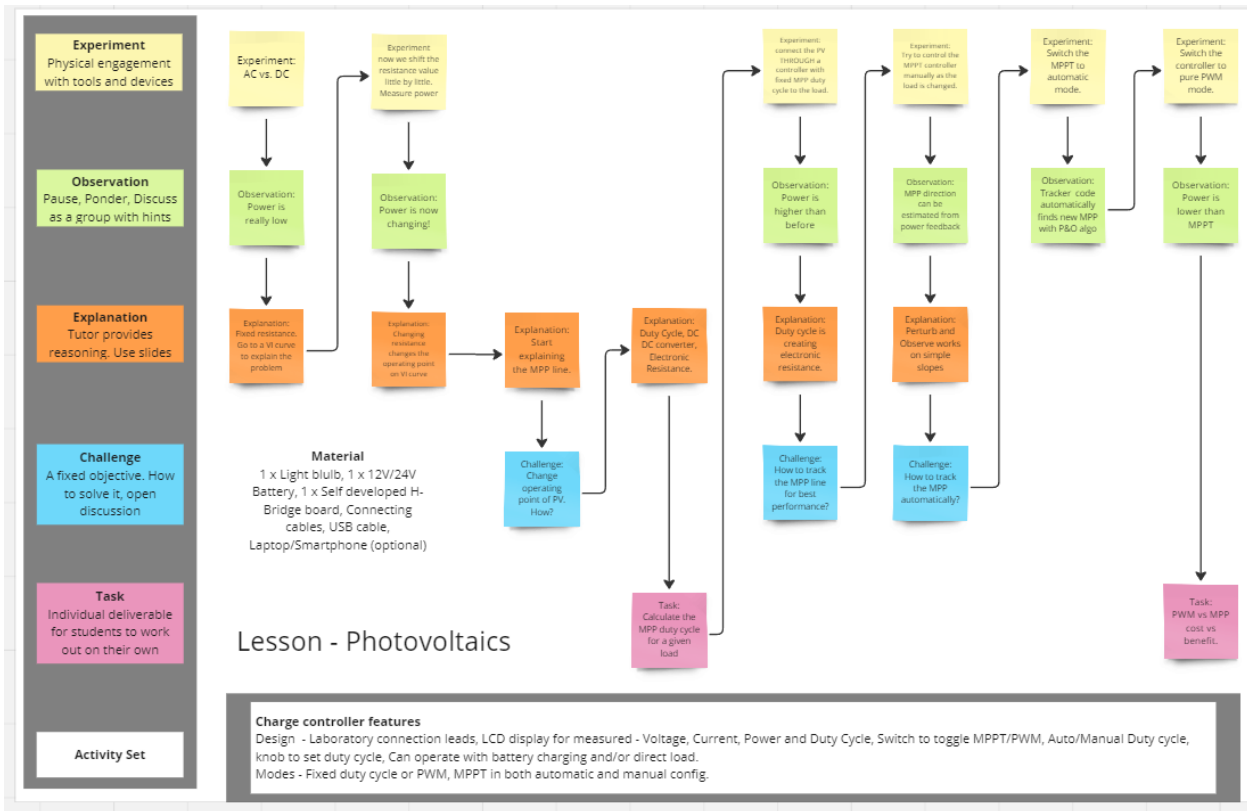


Figure 3: A possible lesson plan to teach PV charging fundamentals.

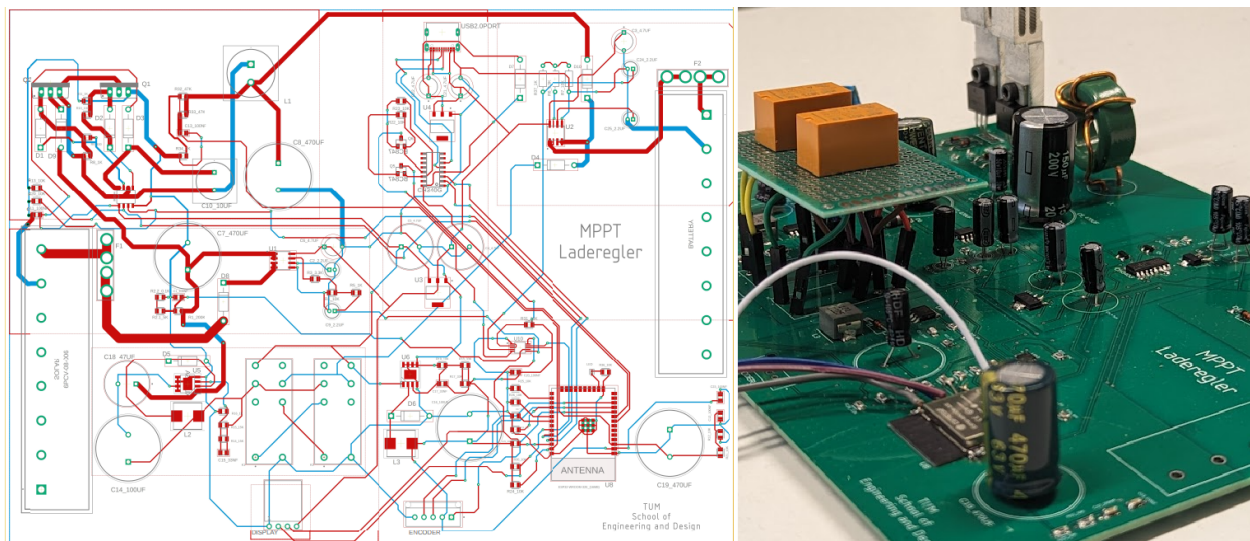
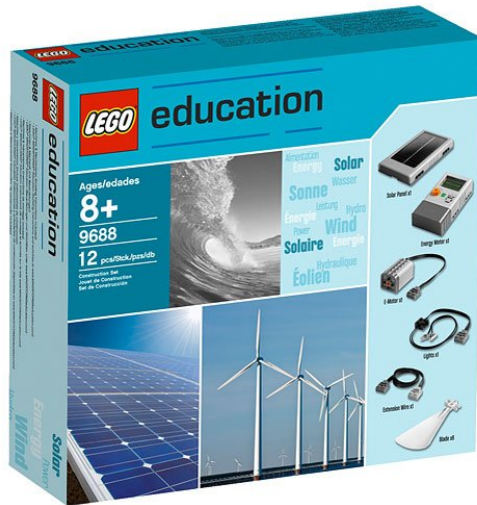


Figure 4: MPPT PV Charge controller prototype with adjustable elements for renewable energy education programs.

Power electronics circuits and PCB prototypes have been developed through other students projects. They can be upgraded and professionally manufactured through freelance development forums.



Construct

Build the Solar Station
(building instructions booklets 2A and 2B, to page 30, step 15)

- Test the model's functionality. Loosening bushings can reduce friction
- Connect the plugs properly by pressing them firmly together
- Make sure to return the joules (J) reading to zero before testing

Test Setting

- Position the solar station at a distance of 15 cm (= 6 in.) from the light source
- A 60W incandescent light bulb, high performance halogen emitters or any other light source that emits a high amount of IR spectra > 800 nm.
- Place the Solar Panel under the center of the light source. Optimally the lamps diameter should cover the LEGO® Solar Panel and have a parabolic reflector
- To help students measure the distance of the bulb in the lamp to the Solar Panel, it is helpful to make a mark on the lamp casing, level with the center of the light bulb

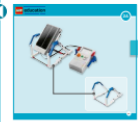
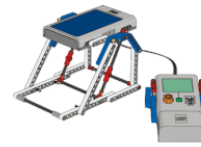


Figure 5: Lego Renewable Energy curriculum pack.

A typical student handout material could be inspired from the Lego Renewable Energy curriculum pack.

The education technology group could be inspired by the KiwiX - Offline Internet and Encyclopedia project and the Google Classroom family of tools with an API access for integration with other tools.

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