2024_04_Data processing and modelling of radiative processes and plant growth for the adaption of photovoltaics for agricultural applications

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(a) Motivation for the project

With global temperatures on track to exceed 1.5 °C of warming, a rapid scale-up of renewable-energy infrastructure is required. In densely populated countries like the UK, expansion in the deployment of photovoltaic (PV) solar panels is seen to compete against agriculture for land use for food production. However, with careful design, the co-location of PV panels with agriculture, known as agrivoltaics, can provide clean energy and improve energy security for farmers while maintaining crop yields. This may involve installing widely spaced PV panels in crop fields or installing PV on greenhouses and polytunnels to provide local power and shade that can benefit plant growth. Curved photovoltaic (PV) modules are a novel way of capturing the Sun's energy during parts of the day (morning and evening) when traditional non-tracking, flat PV panels are less effective. To adapt existing PV technologies and models for non-linear topologies, the observation and modelling of radiation transmitted through semitransparent PV panels atop polytunnels, and its impact on plant development, along with the processing of field data, is needed to enable the wider adoption of agrivoltaics. With proper study, agrivoltaics has the potential to adapt existing PV technologies and farming techniques for novel agricultural integrations.

(b) Context and background

Researchers in Imperial Physics have developed open-source energy-system–modelling software, CLOVER, that can be applied to design solar-energy systems. Agrivoltaic greenhouses and polytunnels would be an ideal application. In the proposed project, we would build a physics-based tool to simulate the performance of curved, potentially semi-transparent, photovoltaic panels, and use it to optimise the maximum power output on curved surfaces. The tool would involve modelling the radiation transmitted through to the plants and would be integrated by adapting CLOVER. Motivation for the project comes partly from an industrial partner (PolySolar) and a research group at the University of Greenwich who have developed a pilot agrivoltaic polytunnel in Kent. Their case-study installation is currently operational and producing data which are available to be analysed. The partners are also keen to install monitoring equipment within to collect additional environmental (humidity, soil quality), irradiance (intensity, fluctuations and diffuse fraction) and crop data (biomass yield and plant morphology) which present a unique opportunity for a student to design devices to collect, and then process and interpret, these data. The crops currently growing within the pilot polytunnels present further opportunity to utilise plants as biological tools, producing indicators for the quality of transmitted light.

(c) Objectives and methodology

The project has the following objectives:

- To develop new modelling techniques in Python to predict the electric output of PV modules adapted for curved topologies, for a general orientation, curvature and location, including the effect of bypass diodes;
- To model the radiation of the transmitted spectrum through the photovoltaic module so that the physiological responses of plants can be assessed;
- To contribute to the design of equipment for data collection, then collect, process, and interpret the environmental data collected, integrating this into the model;
- To integrate the new module into the CLOVER software, adapting the existing modelling framework where appropriate;
- To apply the tool to simulate the output from a polytunnel installation in Kent, compare with experimental data to validate the model, and suggest design improvements that could increase output.

Group members will be available to train the student in the use of object-oriented Python and machine-learning.

The project will involve two site visits to inspect the system and assist with design of monitoring systems to collect this data.

The student will work to determine which data are of interest before utilising these in their model.

Results will be presented to case-study partners and the group's research meetings.

Project length:

8 weeks