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3rd Generation Solar PV in the Developing World

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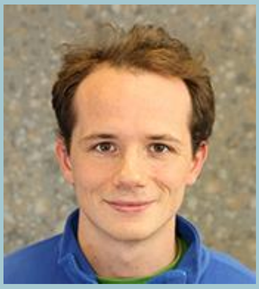

Oliver Rigby

In this article Oliver discusses the importance of understanding local social context for the design of solar cells, speaking to end-users when developing technology and of interdisciplinary work for problem solving.

Oliver is a PhD student with the ReNU CDT and he is working on developing sustainable solar cells out of ferroelectric minerals.

Solar cells, or photovoltaics (PV), offer pathways towards mitigating the effects of the climate crisis by converting light into electricity without emitting greenhouse gases which have an adverse effect on the atmosphere. Globally, 10% of people still do not have access to electricity, many of whom are from low-income countries. This presents a unique possibility for these low-income nations to avoid the “dirty” stages of energy generation which higher income nations have historically favoured and instead create a “clean” energy infrastructure using technologies such as PV. Doing this will require collaboration between people who develop solar cells and those who understand the societies where they can be implemented.

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The recent **"3rd Generation PV in the Developing World"** conference was a rewarding showcase of the challenges and opportunities of combining these physical and social disciplines. From addressing fundamental issues such as a lack of trust in solar cell distribution due to counterfeit products in Kenya, to detailing phase purity problems of earth abundant solar cells, the conference united diverse thinkers and encouraged an interdisciplinary approach to problem solving. To make PV technology accessible and useful to all, it is vital to have "needs-lead" research, where projects developed by researchers are done alongside the communities where they will be used.

This has led to a variety of stimulating opportunities for PV in areas which may not immediately come to mind.

Modern Energy Cooking

Cooking food and making meals is something we all share, yet the fuels we use to do so will differ across the world. In Tanzania, cooking is traditionally done indoors using charcoal or firewood in houses with poor ventilation, which has direct impacts on human health. Household air pollution is estimated to cause an additional 4 million deaths per year globally. Traditional cooking methods in Tanzania impact gender equity too as women of all ages typically must spend a lot of their time collecting firewood and cooking. This contributes to many missing out on attending school, and in 2012 only 8% of women completed a lower secondary school education (compared to 13% of men).

The Modern Energy Cooking Services (MECS) project has identified these problems and engaged in communities with the aim to electrify cooking by considering supply and storage techniques to reduce cooking time and improve health. Hybrid mini-grids, local household PV and centralised battery banks have all helped bring this about for households. An important step forward was communicating with locals to learn more about their typical diets by encouraging food diaries. This brought greater understanding of which devices would be most effective in electrifying cooking. For example, in Kenya many meals consist of energy intensive foods such as cooking beans and so an electric pressure cooker powered by PV was found to be of most use. This helped reduce cooking times by up to 50% as well as reducing energy used and fuel cost by up to 85%. However, innovations are still needed for the best way to finance and deliver eCookers. Many households do not have savings and eCookers are expensive items, putting them out of reach for lower income households. There is hope that pay as you go methods which are already used for household scale PV can also provide a business model for electrified cooking.

Figure 1: People cooking on stoves outside.

Cheap and accessible solar cells - Perovskite

In the future, the hope is for solar cells to become cheap enough to be accessible for all. There are many and varied next generational materials which claim this, and it can be hard for any one technology to stand out. However, one class of materials called “perovskites” have achieved a peak efficiency of an impressive 25.5% over just 7 years of development. Compare this to amorphous silicon (another thin film technology) which has taken 40 years to reach a peak of 14% and the rapid progress perovskites have made is remarkable.
Perovskite solar cells are made with a simple repeating structure of ABX_3, where A and B are cations and X is an anion. This provides a huge range of possible designs but despite the record laboratory efficiencies, many unfortunately still have problems with stability and defects. One example of this is an irreversible decomposition in $MaPbI_3$, (or MAPI), due to exposure to moisture or humidity which causes MAPI to crystallise into a different phase. This leads to a permanent loss in device performance and has inhibited its commercial viability. Dr Pablo Docampo and his group have found they are able to mitigate this probelm by using a "lasagne" approach where they layer other perovskites on top of the MAPI. This innovative thinking has not only improved the stability of MAPI but has also improved the voltage output.

Perovskites have an exciting future as they can be produced at a much lower cost and with much less energy than silicon. Commercial production is already underway for some perovskites, where Oxford PV have sped up the industrialisation by combining them with silicon. They are in the process of building a large-scale production chain which is a significant step in making solar cells and clean energy more accessible globally. There are still challenges to face though, notably around the use of Pb which is toxic.

The next stage is to find non-toxic substitutes and, perhaps even more vitally, to practically design a circular economy for solar cells to limit the future electronic waste problem.

Designing PV systems – vertical arrays in Bangladesh

To best design PV systems for the future, it is important to consider how and where they will be used. Professor Rezwan Khan looks at how the conventional PV we already have can be integrated into Bangladesh. Although Bangladesh receives almost three times the Sun's irradiance as the UK in places, only 1.7% of the installed capacity comes from solar compared to 12% in the UK. One reason is that Bangladesh is an incredibly fertile land and agriculture is the largest employment sector. For large scale PV farms to make an impact, they must compete with the already limited land space as well as the uncertainty of job security.

Figure 2: Solar Powered Irrigation Pump Bangladesh

> *“To make PV technology accessible and useful to all, it is vital to have "needs-led" research, where projects developed by researchers are done alongside the communities where they will be used”*

However, even with this difficult starting position there are many opportunities for PV to adapt. For example, "Vertical" PV arrays, where the panels are oriented perpendicular to the sky, have seen a recent uptake in Bangladesh. Despite reducing the energy production of the solar cells (as less sunlight falls on them), it also minimizes the land taken up by them, meaning they can co-exist alongside farmland.

Having vertical PV arrays also helps a different sort of challenge faced by PV in Bangladesh. Dust, dirt and droppings can collect on the surface of solar cells which seriously inhibits their efficiency by blocking light from entering. Exciting new cleaning techniques such as vibrating panels can help but these solutions are still too costly to implement. By simply orienting the solar panels vertically this reduces the amount of dust and dirt that can accumulate on the surface and helps rain to clean the panels.

On the smaller scale, adoption of PV is increasing but is still limited by the high cost. An insightful idea from Professor Khan came from considering where the high cost came from as well as what the solar panels were being used for. Usually, solar power is converted from DC to AC using an inverter, but in many cases, appliances are insensitive to either an AC or DC load. The inverter has a significant cost and by removing it from the system, this reduces the cost of electricity generated by solar power almost five times, making it a much more attractive source of electricity. There are many other exciting opportunities for PV in Bangladesh which are directly influenced by the local culture. The vast network of canals and rivers are a major means of communication and solar powered boats could be easily retrofitted to the popular diesel ones that are already there.

Next generation PV provides opportunities around the world, with many and varied applications which are not always anticipated by those developing the technology. This variety of solutions is only made possible by talking with the end-users of PV to discover problems that would have remained unconsidered if the technology were developed in isolation. Communication is a simple tool, but one easily forgotten, especially in the virtual world we live in today. Conferences such as this one reminds us that we are better at coming up with ideas when we work together.

Oliver Rigby, April 2021

Find out more

- **The 3rd Generation PV conference** was multidisciplinary conference organised by DEI Fellow Professor Chris Groves (Durham University, Engineering) as part of the North East Centre for Energy Materials (NECEM) and its associated CDT ReNU. Researchers from around the world discussed the latest advances in 3rd Generation PV devices and use of PV systems in the developing world. Find out more at **https://research.ncl.ac.uk/necem/**

- Find out about **Professor Chris Grove's research group** and **Durham University's Solar Energy research expertise** https://www.durham.ac.uk/research/institutes-and-centres/durham-energy-institute/research-profile/research-themes/solar

- **Renewable Energy Northeast Universities Centre for Doctoral Training (ReNU CDT)** is a £5.5m doctoral training programme in Energy Materials funded by EPSRC. The project is a partnership between Northumbria, Newcastle and Durham Universities.

  The training provided goes beyond that provided in a normal PhD to include a mini-MBA, responsible innovation training, researcher skills and specialist modules on energy materials and experimental techniques.

  The scientific focus of ReNU CDT are the materials science issues that underpin future renewable energy technologies in the following areas:
  - Photovoltaics
  - Fuel cells and Hydrogen
  - Wind/marine turbines
  - Smart Grids and Systems
  - Solar and Bio fuels
  - Batteries and Storage

  If you would like to discuss engaging with the ReNU CDT please contact **chris.groves@durham.ac.uk**

  Find out more at: **https://renu.northumbria.ac.uk/**

- **Modern Energy Cooking Services** is a five-year programme funded by UK Aid (FCDO) through our Low Carbon Energy for Development network (LCEDN) led by Loughborough University with Durham as one of the partners. By integrating modern energy cooking services into the planning for electricity access, quality, reliability and sustainability, MECS hopes to leverage investment in renewable energies (both grid and off-grid) to address the clean cooking challenge. MECS is implementing a strategy focused on including the cooking needs of households into the investment and action on 'access to affordable, reliable, sustainable modern energy for all'.

  Find out more at **https://mecs.org.uk/**

- Find out about the work and research of **Professor Rezwan Khan, United International University** http://eee.uiu.ac.bd/profiles/rezwanm/

- Find out about **Dr Pablo Docampo, Glasgow University** https://www.gla.ac.uk/schools/chemistry/staff/pablodocampo/#researchinterests

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