Energy generation is an imperative and essential research field with deep social and cultural relevance. Inexhaustible solar energy provides reliable and affordable energy to expand electricity access and promote global development. The Sun is a source of clean energy and every day it gives off far more energy than we need to power everything on earth. Energy production using sunlight is a big challenge that promises freedom from the sources, which causes global warming and climate change. In a smaller span, the power performance of perovskite solar cell (PSC) has crossed 25% and is competing with existed solar cells based on the Si, GaAs, CIGS. Despite the excellent efficiency of PSC, stability and scaling are the major hurdles that must be addressed for commercialization. Already many efforts have been made in PSCs to design and modifying them to become more efficient and stable.

Till now, the most efficient solar cells use Lead (Pb) based perovskites, though there exist a few concerns like toxicity and water solubility of Pb, responsible for the water pollutions. In general, all solar cell uses visible light, but does not utilise UV and IR light properly from the solar spectrum to produce electricity. Interestingly, IR light strikes more intensely on the Earth surface, which can be utilised to generates electricity, intriguing semi-transparent/transparent solar cell (STPSC). The majority of the existed STPSCs are fabricated on expensive ITO/FTO glass substrates, leading to an increase in their thickness, weight, and cost. Consequently, these substrates are not suitable for the printing technology, which are replacing with the easily recyclable flexible materials to overcome these issues. The solution-processing approach can easily pave the way to employ in any desired flexible form such as on transparent windows, and in space where the ultra-lightweight solar cell is highly anticipated. Device engineering plays a crucial role in the device's performance and stability, which can be tuned by employing different transport layers at heterojunction interfaces. The 2D materials have shown their potential as a charge transport layer in the PSCs. For example, an emerging 2D-materials Mxene has shown great potential as a window/transport layer in STPSCs due to its high transparency, metallic conductivity, etc. Similarly, another 2D material, a transition metal dichalcogenide MoS_2 can tune its work-function by altering a number of layers, elemental doping, etc., and makes it a suitable candidate as a charge transport layer for PVs performance enhancement.

By considering the track record of individual component and their fundamental properties may help to understand obstacles, and overcome the available challenges in STPSCs. Therefore, in this project, we are proposing a thorough investigation of different transparent heterojunction which are utilise in construction of complete solar cell configurations based on a free-standing nanocellulose-based. We will use an ultra-light weight, flexible, and bio-degradable substrate to meet the printing technology standards. As a free-standing conducting electrode, cellulose nanocrystals grafted with semi-metallic polyoxometalate clusters will be developed for STPSCs. In addition, lead-free (non-toxic) perovskite synthesis and further device engineering by utilising novel 2D materials can improve the overall performance, stability, and transparency of the PSCs. These developments require multiple optimization processes at transparent heterojunctions, which can provide an assurance to achieve minimum 30 kW/kg of specific power. In other words, it can produce maximum power from negligible weight substrate. We have prior experience to build different heterojunctions, and analyse their light-matter interactions at the interfaces. Based on our initial results from the fabricated heterostructures, we are proposing a systematic study of polyoxometalate grafted nanocellulose/Mxene, Mxene/Sn-perovskite, Sn-perovskite/MoS_2 heterostructures for a new non-toxic PV technology. Under the light-matter interactions, the photo-dynamics at the novel interfaces will be investigated. These interactions at the novel heterostructure will provide fruitful but elementary information about heterostructures. The other important questions are: how many photons can convert into electrons (electric current)? how much time will be required to separate excitons? what are the factors responsible for the carrier recombination? and many more. The evaluated optoelectronic parameters will help to improve the PVs performance with better stability. Finally, all individual transparent heterostructures performance will be corelated with complete semi-transparent solar cell configurations, that may help to optimise the process parameters to obtained high efficiency and >30 kW/kg of specific power.