



Background

Across Europe, solar technologies already form a significant part of the renewable energy mix. Going forward, photovoltaic systems can play a major contribution to future energy supplies and help mitigate the impact of carbon dioxide emissions.

Solar PV systems often use cells made from semiconductor materials to directly generate electricity from sunlight that can be used to power a home's demand for products such as domestic appliances. Despite recent cost reductions, in crystalline silicon photovoltaic modules, the silicon solar cells continue to be relatively expensive and contribute to around 80% of the cost of the module. In order to reduce the cost of electricity produced by photovoltaic systems, one way is to reduce the amount of costly solar cells in the system. If the size of the cell is reduced and utilising mirrors and lenses to concentrate the sunlight onto these cells this can significantly reduce the overall cost per Watt Peak of the system. This results in a lower levelised cost of energy (cost per kWh) in areas where direct sunlight can be concentrated onto the cells.

Project Partners

Project Lucent is a joint R&D funded project involving three key partners; Narec, Whitfield Solar Ltd, initially the University of Ulster and then the University of Warwick (DG) connect to the interconnected power system, using a variety of fuel sources such as biomass from rural or brownfield sites, a better understanding of the associated effects is essential.

Partner Expertise

Whitfield Solar Ltd (a spin-out from the University of Reading) - established to commercialise EU and DTI-funded research into concentrating PV systems;
Narec - specialists in the production of crystalline silicon concentrating cells;

The University of Ulster and the University of Warwick - expertise in optical and thermal modelling of solar collectors.

Objectives

The aim of the project was to develop a concentrating photovoltaic collector that significantly reduces the cost of generating electricity directly from the sunlight and develops a greater understanding of system energy capture and thermal behaviour.

Whitfield Solar Ltd

The key objective was to turn its academic research on low-cost concentrating photovoltaic (CPV) systems into an industrially manufactureable design, including the selection of suitable volume production processes.

Narec

The objective was to investigate a range of laser-grooved buried-contact (LGBC) solar cell designs in order to optimise cell efficiency under 50-sun and 100-sun levels of concentration. This investigation covered changes to grid-finger layout, processing options, back surface field enhancement, and choices of silicon wafer type.

The University of Ulster/University of Warwick

The aims were two-fold. One was to take an existing FORTRAN finite-element model of solar collector thermal behaviour and expand it to evaluate cell and component temperatures under realistic operating conditions of the collector designed by Whitfield Solar Ltd.

The second was to develop a model to calculate the annual energy captured by the collector at specific geographical sites as a function of collector field-of-view and row spacing. The work at Ulster transferred during the course of the project to the University of Warwick due to the move of Professor Philip Eames, the academic concerned.

Results

Over 4000 experimental cells were produced by Narec over the course of this project. Allowing a greater understanding of the factors contributing to cell efficiency for the cell dimensions, illumination pattern, and intensity level required by the project's proposed commercial CPV system. Best cell efficiency increased over the project and reached 18.9% and 18.4%, at 50 and 100-suns respectively, for cells made on Czochralski wafers; and 19.2% and 18.7%, respectively, when using more expensive Float-Zone wafers.

Once the annual energy capture model had been created and verified, it was used to carry out predictions for the energy capture of the proposed commercial collector at two likely installation sites in Spain, Madrid and Seville. This showed that commercially-practical values for inter-trough and inter-row spacing yield high percentages of annual energy capture.

The thermal modelling has produced predictions of cell temperature for a range of operating environmental conditions. A detailed validation of the model versus experimental measurements was undertaken.

The project built and tested examples of three prototype collector designs; the majority having optical apertures of 2.4m². One design used a distributed-weight support base allowing it to be deployed on flat roofs in building-integrated mode. Three of the prototype examples were fully instrumented and given long-term testing at the University of Cartagena in Spain. One prototype saw extensive testing and modification in the UK. Over the project period some three 'collector-years' of detailed performance measurements were gathered in total.

Key innovations

Collector design

- One-sun technology LGBC cells were modified for 50-100X concentration to yield a very low cell cost per Wp.
- Optical lenses of relatively small aperture were used to reduce material requirement for cell heat sinking and structural rigidity.
- The development of a low-cost collector housing that combines housing structure with passive heat sinking.
- The development of an intelligent closed-loop sun-tracking sensor and controls, implemented digitally. This combines high-accuracy analogue sun-position sensing with logic functions including a 'seek-and correct' error-correction algorithm.

Cell design

- Extensive use of cell modelling, backed up with a series of experimental cell manufacturing trials, allowing optimisation across the range of process parameters.
- New approaches to the production and control of the back-surface field and the use of different wafer types for this class of cell were investigated.

Thermal modelling

- Update to the existing finite-element code.
- Detailed modelling of specific geometries of collector type to correspond to designs generated by Whitfield Solar Ltd.

Project outcome

The project has seen considerable knowledge-transfer and dissemination activity. It has provided input into several Bachelor, Masters and PhD projects, and interim project results were presented at international conferences.

Collector design for full commercial manufacture is currently going forward. In addition, Whitfield Solar Ltd, a manufacturing business who use Narec's concentration technology cells in the construction of their sun tracking modules has recently announced that the Instituto de Sistemas Fotovoltaicos de Concentración, SA ("ISFOC") has purchased a 2.64 kW Whitfield Solar rooftop installation for its headquarters building in Puertollano, Spain.

The project has helped Whitfield Solar Ltd develop a photovoltaic concentrator platform for solar power generation that optimises the relationship between cost and efficiency.

Dr Roger Bentley, Head of R&D, Whitfield Solar Ltd, said: "Working with this group has given our company access to knowledge and expertise which we could not have provided alone, and has significantly assisted our company's path to product commercialisation".

Project duration

April 2005 – March 2008

Project cost

Total cost - £784,466

DTI/TSB Collaborative R&D initiative contributed - £384,452



Narec's silicon LGBC 50-sun solar cell (1 Euro coin indicates size)