Roofing that generates electricity and heat

A new solar collector system, being developed at the University of Waikato, integrates neatly into standard roofing iron and can generate both electricity and heat.

By Sunil Bura, Mike Duke, Tim Anderson and Mark Lay, Solar Engineering Research Group, Department of Engineering, University of Waikato

Integrating solar energy devices with building products is a rapidly growing market in the building industry. The aim is to make solar devices that integrate into a standard façade, window, roof tile, membrane roof or long run roof. These serve as weatherproofing for a building and also generate electrical and thermal energy.

Integrated photovoltaic thermal roofing

A new range of products that integrate the generation of both electricity and thermal energy or heat (typically warm air or hot water) into roofing products is known as building integrated photovoltaic thermal (BIPVT). There are many BIPVT products under development, but none are yet commercially available.

At the University of Waikato, a new BIPVT solar collector system has been developed using standing seam and trough profile long run roofing systems commonly used in domestic, commercial and industrial buildings. These roofing products have profiles with large flat surfaces suitable for mounting photovoltaic cells.

The BIPVT system consists of a profiled roofing sheet that can be integrated with existing roofs with minimal or no aesthetic disruption. Photovoltaic laminates are bonded into the long run roof trough and act as both an electricity generator and solar thermal collector plate. The long run roofing itself acts as the housing for the BIPVT system and supports the solar thermal collector plate and photovoltaic laminates.

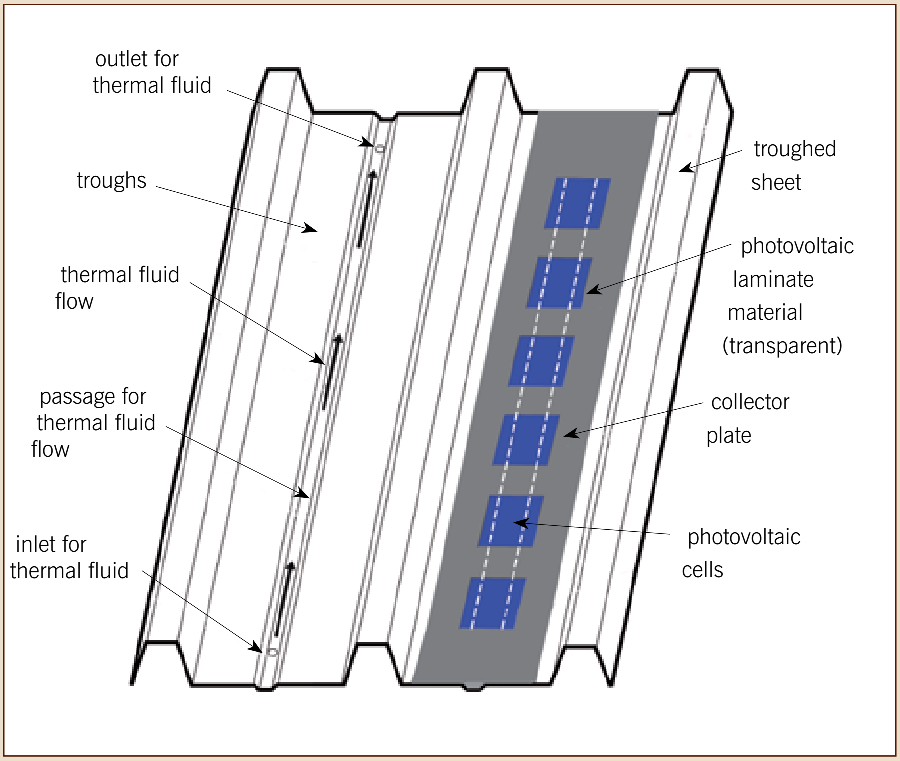

Figure 1: Schematic view of BIPVT product.

The roofing sheet has a central channel in each trough with inlet and outlet points for thermal fluid to flow, as shown in Figure 1. The collector plate is bonded into the trough of the roof sheet and sealed along the edges, creating a confined passage for thermal fluid flow. The collector plate acts as a backing plate (substrate) for the photovoltaic laminates and absorbs heat from the photovoltaic cells and transfers it to the thermal fluid. Inserts seal the central channels' ends, and manifolds mounted underneath the BIPVT are used to supply and collect the thermal fluid.

Production challenges

Commercial fabrication of the BIPVT system would need to consist of several production and quality control processes designed to ensure quick and efficient manufacture.

MAKING ADAPTED PHOTOVOLTAIC CELLS

There are presently no photovoltaic cell manufacturers in New Zealand, so the 'raw' photovoltaic cells have to be imported, typically from China. Photovoltaic cells are extremely fragile and, after being electrically connected into strings, must be protected from physical and environmental damage. The standard protection method is to laminate them into a 'sandwich' of white polyvinylfluoride film, ethyl vinyl acetate (EVA) sheets and low iron glass, producing laminates that are typically four cells wide by nine cells long.

With the BIPVT product, the sandwich is modified by having a sheet metal substrate instead of polyvinylfluoride film and long, thin laminates typically one cell wide by 30 long that fit into the long run roof trough. Specialist photovoltaic laminators heat the 'sandwich' and apply a vacuum. The heat causes the EVA to melt and cure, bonding all the laminate components together. The vacuum removes air so that bubbles do not form when the EVA cures. It is possible to bond the collector plate into the trough and then laminate the photovoltaic on afterwards. Alternatively, the photovoltaic can be laminated on to the collector plate first and then bound into the trough. The advantage of the former is that leak and pressure testing can be undertaken, and if faulty, only the metal is lost. With the latter, irreparable failures will result in wastage of expensive photovoltaic cells.

CREATING THE ROOFING PROFILE

One of the main features of the BIPVT product is the roofing profile, which includes the troughs and central channels required for thermal fluid flow. Roll forming is the most common method of long run roof production but the initial low volumes required for BIPVT prototypes and pilot runs make it uneconomic. For this development work, Dimond Roofing's CNC folding machine was used. This can produce prototypes up to 6 m long in a range of profiles and dimensions in just a few minutes. It is a key factor in the successful development of the BIPVT product.

BONDING THE COLLECTOR PLATE AND TROUGHED SHEET

Once the profiles are produced, the main challenge is how to bond and seal the collector plate with photovoltaic laminates into the trough as well as seal the ends and manifolds for a watertight product. After this, the electrical junction boxes for the photovoltaic laminates need to be fitted, again ensuring no possibility of leakage into the electrical connections.

Quality control steps include checking for fluid leakage from the bonds between the collector plate, manifolds, electrical connections and end seals. This can be achieved using pressurised air, enabling leak and pressure testing.

The key problem identified with the BIPVT product is achieving a leak proof and reliable bond between the collector plate and troughed sheet. After an extensive investigation, three possible methods were considered: adhesives, resistance seam welding and autoclaving.

The crucial advantage of adhesives over resistance seam welding is that Colorsteel roofing can be used. Colorsteel is a tried and tested building product, and its use would reduce risks and product development time. Advances in adhesives have meant that cheap, strong reliable bonds can be achieved, but considerable development is required to establish a reliable production system.

Resistance seam welding is considered the safe option as it is a tried and tested production method for bonding steel sheets. The problem with this is that, after welding, the bonded sheets would have to undergo coating both outside and in the heat transfer channels to prevent corrosion and ensure the required service life. Though possible, this would add extra complexity and product testing above that required of the adhesives method.

The autoclaving system involves the lamination of the photovoltaic cells and bonding of the collector plate into the troughs at the same time. This is an interesting concept, as the production process is far simpler than adhesives and resistance seam welding. Another advantage with autoclaving is that Colorsteel could be used. The disadvantage is that this type of integrated sealing and lamination production method is completely new with many technical hurdles, including the need to develop large scale and expensive autoclaving equipment. For the above reasons, to date, all prototypes have been manufactured using adhesives.

Economic analysis

To investigate the financial feasibility of a BIPVT production system, an economic analysis was undertaken, calculating the payback time and net profit for a company producing the product. The three production methods: adhesives, resistance seam welding and autoclaving were analysed. This took into consideration capital costs (material, labour, machine, energy, operating), process times and production capacity. The payback times were calculated based upon a mark-up of approximately 1.3 times the operating and material cost and a production of more than 6,000 panels per annum.

Interestingly, the payback time was lowest for the autoclaving production system, followed by adhesives and resistance seam welding. Autoclaving, despite having the greater capital investment, had the highest return on investment and the highest net profit. This was because it had the highest production capacity. However, as mentioned earlier, autoclaving has technical challenges that need to be overcome whereas adhesives and resistance seam welding are proven production methods.

Adhesives faired well in the analysis as this method had the lowest capital cost and second highest production capacity. The adhesives method has fewer technical challenges than resistance seam welding and autoclaving and lower capital equipment cost with only a slightly longer payback than autoclaving. For these reasons, the adhesives method has been adopted as the preferred production method for the prototypes and the first pilot runs. At present, adhesives prototypes are being tested, and production planning is under way for a small pilot run later in the year.

This research was funded by Building Research and supported by Dimond Ltd. For more information, contact Dr Mike Duke, dukemd@waikato.ac.nz.