

Institution: University of Surrey		
Unit of Assessment: 9 Physics		
Title of case study: Transforming the UK swimming pool cover industry by deploying innovative optical materials		
Period when the underpinning research was undertaken: 2000 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Stephen Sweeney	Professor	2002 – present
Marian Florescu	Reader	2011 – present
Steven Clowes	Senior Lecturer	2007 – present
Period when the claimed impact occurred: August 2013 – December 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words)		
<p>Research conducted by Surrey's Photonics & Quantum Sciences Group has played a transformative role in establishing UK SME Plastipack as a world leader in innovative swimming pool cover technology. Working in close collaboration with Plastipack, Surrey's research has led to the successful development of mass-producible polymer-based functional materials for increased efficiency in solar heating of swimming pools, while simultaneously preventing the growth of algae. This led to the development of new products for the company resulting in a substantial increase in revenue and an Institute of Physics Business Innovation award in 2018.</p>		
2. Underpinning research (indicative maximum 500 words)		
<p>Surrey's experience in the advanced design and optical and electrical characterisation of photonics and electronic materials underpins the research that led to the innovations and impact as described here. Since its invention of the strained layer quantum well laser, the group has been successful in developing new optical and photonic materials for commercialisation. Some examples of this include local self-uniform materials [R1] and new materials for high efficiency light sources [R2, R3].</p> <p>Owing to the Surrey group's experience in the characterisation of thin films for photonic applications [R2, R3] and track record of engaging with industry [R4], in 2011 Professor Sweeney was approached by Plastipack Ltd to help them to innovate their swimming pool-covers. The research challenge was to create an affordable masterbatch (the blend of additives introduced to the polymer during the extrusion manufacturing of the cover) that would give selective transmission to maximise heating through solar radiation, while inhibiting photosynthesis to prevent algae growth, thus minimising use of chemicals harmful to the environment. This research project, led by Dr Steven Clowes, took the idea through all stages on the technology readiness scale (from TRL1 to TRL9).</p> <p>Achieving the maximum solar heating from a pool cover, while inhibiting algae growth, requires a consideration of several factors. To prevent the algae growth, transmission of wavelengths below 750 nm must be filtered, whereas to heat the underlying water, the transmission of wavelengths around 750 nm must be optimised, while also considering the wavelength-dependent absorption depths of water and the solar irradiance spectra. Existing heat models of swimming pools in the</p>		

literature did not address the wavelength dependence of absorption and reflection in covers that is necessary to understand the heating performance of the selective transmission cover. The Surrey team developed new models for the solar energy balance [R5] and created simulations using finite element analysis. We studied how reflection is affected by the interaction of light with the pigments and the cover layer structure [R6] and explored non-standard pigments [R5] to achieve the desired optical properties. Using the measured optical properties of the cover materials, these models were able to predict absolute solar heating efficiencies of the cover, i.e., the efficiency of converting solar energy into stored thermal energy in the pool's water [R5]. Prior to a full large-scale trial, laboratory-based experiments were undertaken to optimise the composition of the cover material.

Through a Knowledge Transfer Partnership (KTP) with Plastipack, the team designed a full-scale test pool facility based at the company's factory. This purpose-built test facility provides five identical swimming pools with integrated temperature, radiation and weather data acquisition. Using this internationally unique facility, the Surrey team performed a full-scale study to provide key empirical data to quantify the energy efficiencies of various cover materials. Our research showed that the selective-transmission cover (called new EnergyGuard™) had a measurable efficiency of 56±3%, which is 12% higher than a standard opaque blue cover, while also retaining the algae inhibiting properties [R4]. Putting this into context, comparing with solar-cell development, this magnitude of increase in the efficiency would take decades to achieve.

3. References to the research (indicative maximum of six references)

***bold** denotes University of Surrey affiliation.

- [R1] Sellers, S.R., Man, W., Sahba, S., and **Florescu, M.** (2017). 'Local self-uniformity in photonic networks'. *Nature Communications*. **8**, 14439. DOI: [10.1038/ncomms14439](https://doi.org/10.1038/ncomms14439)
- [R2] Sharma, T.K., Hosea, T.J.C., **Sweeney, S.J.** Tang, X. (2008). 'An accurate determination of the electronic transition of InAs/InGaAs/InP quantum dots for mid-infrared lasers using simultaneous complementary spectroscopic techniques'. *Journal of Applied Physics*. **104**(8), 083109. DOI: [10.1063/1.3005903](https://doi.org/10.1063/1.3005903)
- [R3] Blume, G., Hosea, T.J.C., **Sweeney, S.J.** (2005). 'A study of the low-energy interference oscillations in photorefectance of GaAsSb/GaAs quantum well structures'. *Physica Status Solidi (a)*, **202**, 1244-1254. DOI: [10.1002/pssa.200460904](https://doi.org/10.1002/pssa.200460904)
- [R4] **Sweeney, S.** (2009). "Why not do both?", *Physics World*, **22**(12), 44. DOI: [10.1088/2058-7058/22/12/46](https://doi.org/10.1088/2058-7058/22/12/46)
- [R5] Waché, R., Fielder, T., Dickson, W.E.C., Hall, J.L., Adlington, P., **Sweeney, S.J., Clowes, S.K.** (2020). 'Selective light transmission as a leading innovation for solar swimming pool covers'. *Solar Energy*, **207**, 388-397. DOI: [10.1016/j.solener.2020.06.022](https://doi.org/10.1016/j.solener.2020.06.022)
- [R6] Waché, R., **Florescu, M., Sweeney, S.J., Clowes, S.K.** (2015). 'Selectively reflective transparent sheets'. Proc. SPIE 9546, *Active Photonic Materials VII*, 954607. DOI: [10.1117/12.2188622](https://doi.org/10.1117/12.2188622)

Funding:

Clowes, S. & Sweeney, S. Knowledge Transfer Partnership, Innovate UK and Plastipack. [July 2014 – August 2018], KTP9616, £162,267.

4. Details of the impact (indicative maximum 750 words)

Established in 1998, Plastipack is a medium-size UK company supplying a range of pool cover materials that cater for a diverse operating environment. Their business strategy of leading through innovation led them to develop their patented GeoBubble™ cover design prior to their

collaboration with the University of Surrey. Our research has enabled Plastipack to maintain their position as leading innovators and stay ahead of commercial rivals in a very competitive market.

Economic benefits of an internationally leading product

Laboratory based research at Surrey developed a patented [S1] low-density polyethylene (LDPE) formula [R5] which enabled Plastipack's existing opaque cover material (EnergyGuard™) to have wavelength selective transmission. Critical to success of this product was the ability to provide customers (an international network of swimming pool cover suppliers) with empirical evidence of the enhanced performance of the new EnergyGuard™ material [S2]. The creation of the research test facility [S3] and the demonstration of experimental evidence, both led by Surrey, enabled the company to provide scientific data on the benefits of their products. The new EnergyGuard™ product was launched in 2015 and sales of this product saw a more than sixfold increase by 2020 [S4]. Sales of this product continue to grow, with a 41% market share increase in 2020 despite the pandemic and the company has now sold nearly 2 million square metres of the new EnergyGuard™ cover [S4]. This is equivalent to approximately 62,500 covered swimming pools. Owing to our research, it is possible to quantify the economic and environmental impact of this product using the cover efficiencies as measured from the pool test facility based at Plastipack and the analysis [R4]. With the success of the new EnergyGuard™, Plastipack have been able to expand their patented GeoBubble™ materials from 42% in 2015 to 59% in 2020, with their Guard high performance covers now representing between 21-27% of their total production [S4]. Since the KTP project, Plastipack has increased its total number of staff by 18, representing a 156% increase [S4]. In November 2018, the research collaboration between Plastipack and Surrey was recognised with the Institute of Physics Business Innovation Award [S5], cementing Plastipack's standing as the leading innovator in the sector.

Economic impact of environmental efficiency

Key to the success of the EnergyGuard™ cover is its environmental efficiency, which also provides economic benefit to Plastipack's customers [S6]. We showed that the selective transmission cover has a measured heating efficiency of 56%, compared with an opaque cover with an efficiency of 44%. Most of the new cover material is sold to the European market, which is typically used in the spring and autumn months to extend the swimming pool season. For the covers currently in use worldwide, as at 2020, we can show that by reducing the need for electrical pool heating, this corresponds to a CO₂e saving of over 28,800 tonnes per year [S7] when replacing a standard opaque cover with the new EnergyGuard™. This is combined with the prevention of algae blooms which require concentrated chlorine (shock) treatments to remove. These high levels of chlorine can be harmful to the environment and human health.

Economic Benefit of an embedded culture of innovation

Another major impact of this initial research project was that Plastipack were able to embed this knowledge within the company. Using the new research facility and continuing the partnership with Surrey, which included the optical characterisation of new materials and analysis of the energy balance, Plastipack has improved the performance of their other products. This has been achieved in conjunction with our undergraduate professional training year placement programme [S8] from the University of Surrey (five student placements as at 2020). A good example of success is the enhanced performance of their CoolGuard™ cover, now branded Ultra CoolGuard™ [S9] which maximises reflection of solar irradiation to maintain a pool temperature in hot climates. This new product was launched in 2018, and its development would not have been possible without the original research on the EnergyGuard™ product at Surrey. Plastipack has continually innovated their products through Surrey research, and in doing so, they have been able to stay ahead of international competitors. As quoted by Peter Adlington, Managing Director of Plastipack, "If we hadn't have gone down this route, we really wouldn't be here today." [S10].

5. Sources to corroborate the impact (indicative maximum of 10 references)

- [S1] Plastipack Limited (2018) *Sheet Material*. Inventors: Fielder, T.J., Adlington, P.A., Waché, R., Clowes, S.K., and Sweeney, S.J. Appl: 3 June 2016, United States Patent PCT/GB2016/051643
<https://patentimages.storage.googleapis.com/ca/bd/2e/84c14e46aeafa7/US20180195301A1.pdf>
- [S2] New EnergyGuard™ product, Plastipack Ltd Company website
<http://www.plastipack.co.uk/energyguard-st.php>
- [S3] News article of Plastipack test-facility opened by Amber Rudd MP
<https://www.britishplastics.co.uk/plastics-industry-news/plastipack-opens-a-%E2%80%9Cworld-first%E2%80%9D-testing-facility-in-east-su/>
- [S4] The information used in the impact case was provided by Plastipack Ltd. [Available from HEI on request.]
- [S5] IOP Business Innovation Award for Plastipack project <https://physicsworld.com/a/awards-honour-physics-start-ups/>
- [S6] EnergyGuard™ case studies <https://www.geobubble.co.uk/case-studies/?type=energyguard>
- [S7] Calculation of energy saving: For a latitude of 45° (South of France) the typical daily solar irradiation is 8.98 kWh/m² per day in months of April and May and 7.86 kWh/m² per day in August and September when it would be used to extend the swimming pool season. Using a cloud cover factor of 0.65 and assuming that the cover is in use for 5 days out of 7 in the total 120 days, the total solar energy is (8.98 + 7.86) x 0.65 x 60 x (5/7) = 470 kWh/m². For 2,000,000 m² and a 12% enhanced efficiency [R5], the increased energy saving per year is 2.0x10⁶ x 470 x 0.12 = 9x10⁷ kWh. At cost of UK grid electricity (0.256 CO₂e/KWh, UK Government) this corresponds to 28,800 tonnes of CO₂e.
- [S8] University promotional video, Joe Hall's placement at Plastipack
<https://youtu.be/yWGb8noxXvk>
- [S9] Ultra CoolGuard™ case study <https://www.geobubble.co.uk/case-studies/?type=coolguard>
- [S10] University promotional video available at https://youtu.be/D6n06_nIAhc