UK SCIENCE'S SECRET ADVANTAGE WHICH COSTS LESS THAN A CUP OF COFFEE…

Lorna Campbell, Diamond Light Source

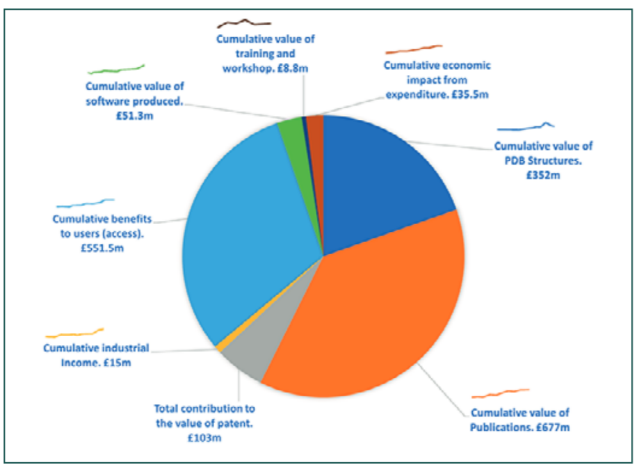
Not everyone knows about the UK 'secret' advantage that's played a key part in many of the major science advances of the last decade. But, that could all be about to change. A new study has revealed that the UK's national synchrotron, Diamond Light Source, has had a socio-economic impact on UK science and the economy of at least £1.8 billion. And as taxpayers we get all of this for less than a cup of coffee at £2.45 per person each year .

Put simply, synchrotrons enable scientists from academia and industry to make the invisible visible. They are used in imaging and non-destructive testing of materials and structures, as well as in drug discovery and development. They harness the power of electrons to produce light 10 billion times brighter than the sun which enables scientists to study a vast range of subjects, from new medicines, viruses and vaccines to innovative engineering, new materials, batteries, and fuels as well as cultural heritage. (At Diamond this includes the conservation of the Mary Rose and the world's oldest hominin Little Foot.)

The study, by research consultancy Technopolis and Diamond, measured the scientific, technological, societal, and economic benefits of the UK's synchrotron and reported on its 'mission' to keep the UK at the forefront of science. The results speak for themselves. Since Diamond started operations in 2007, work conducted there has resulted in:

* **9600+ research articles** calculated to have a cumulative impact to date of £677 million
* **Patents** citing Diamond contributions valued at £10.2 billion* (2018 prices) A conservative estimate suggests that at least 1% of this considerable sum can be 'claimed' as a result of work at Diamond.
* **28 cases of breakthrough science** from the plastic degrading enzyme to the new synthetic vaccine against the Foot-and-Mouth disease virus, as well as academic and industrial innovations
* **Software and applications** worth £51.3 million.
* **Many 'softer' impacts** include training and teaching researchers worth £8.8 million
* **Wider Societal Benefits** - 80,000+ visitors reached through a programme of engagement supporting the UK Skills' agenda in science, technology, engineering, and mathematics (STEM).

Commenting on the report, chief executive of Diamond, Professor Andrew Harrison, OBE said; "The headline figure of £1.8 billion is almost definitely an under-estimate, but it shows what a fantastic return on investment the facility represents. It's very difficult to monetise the value to industry from increased profits because of confidentiality issues but these gains will continue to emerge for many years to come, underlining the brilliant science being achieved by our 14,000-strong user community, who are tackling some of the most challenging scientific questions of the 21st century."



Diamond Socio chart - updated3 - Copyright of Diamond Light Source Ltd 2021

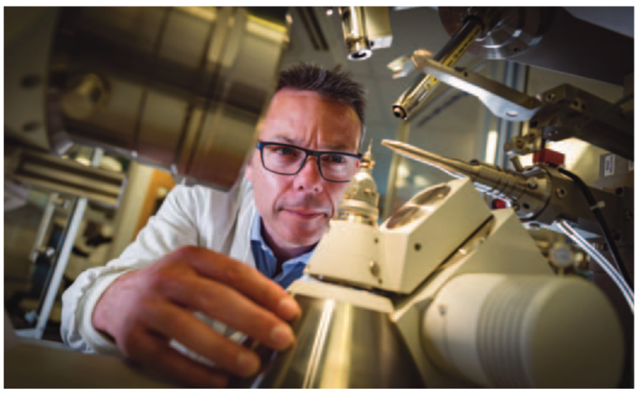
Diamond was set-up in 2002 as an independent not for profit company through a joint venture, between the Government funded - UKRI's Science and Technology Facilities Council (STFC) and one of the world's largest biomedical charities, the Wellcome Trust - each respectively owning 86% and 14% of the facility. Diamond has received £1.2 billion in investment over 14 years.

SIGNIFICANT SCIENCE BREAKTHROUGHS

Plastic digesting enzyme

The 28 science breakthrough case-studies developed for the study include the work of John McGeehan, professor of structural biology and, Director of the Centre for Enzyme Innovation at the University of Portsmouth. His team has used Diamond to study the bacterial enzyme PETase, which digests plastic. "Diamond's I23 [long-wave macromolecular crystallography] beamline is unique in the world. It allowed us to solve the 3D structure of the PET-degrading enzyme, first found in plastic dumps in Japan in 2016. Three years ago, it was the highest resolution image of the enzyme measured and remains so today. Having this information allows us to understand how the enzyme works, and how to make it work faster and better."

As a result, the team has been able to visualise the active site of the enzyme and how it consumes plastic. The researchers discovered that the active site was slightly wider than cutinase, a similar enzyme that bacteria use to break down natural plant polyesters. "The technology leading from this research means plastic waste can be broken down and put back together into bottles (infinite recycling), or can be



Professor John McGeehan 2 - CREDIT Stefan Venter, UPIX Photography - www.upixphotography.com - Copyright University of Portsmouth Centre of Enzyme Innovation

made into higher value products such as resins for wind turbine blades," says McGeehan. Patents are pending.

Important biomedical applications

Manchester University's, Professor Saiani's research

Professor Alberto Saiani

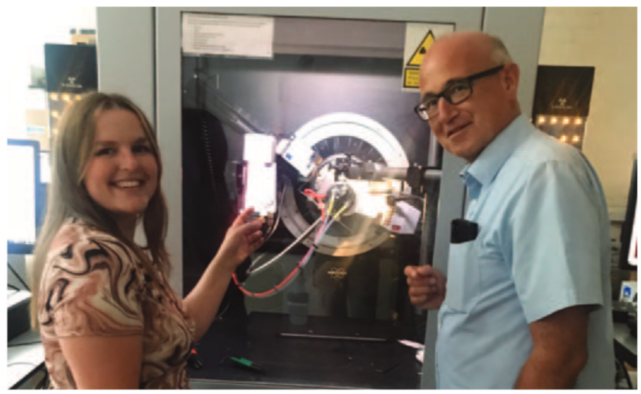
focuses on the characterisation of molecular materials across length scales in particular the correlations between chemical architecture, structure / morphology, and physical properties in complex polymeric systems. Over 15 years ago, he and his colleague Professor Aline Miller, synthesised a family of self-assembling peptides, with interesting gelling properties. They used Diamond to gain a better understanding of how peptide design affects the fibres' structure and how these fibres assemble to form hydrogels.

These hydrogels are commonly used for cell culture and tissue engineering applications, providing structural support and a natural physiological extracellular environment for cells. They also offer additional opportunities, including in the development of more effective drug delivery systems and biosensors. Industry and academic demand for the peptide hydrogels led to the co-founding by Professors Saiani, Miller and Dr. G. Saint-Pierre of Manchester BIOGEL™ in 2014. This start-up licensed the technology from the University of Manchester and now offers a range of self-assembling peptide hydrogel products (PeptiGels®), suited for use in 2D and 3D cell culture, 3D bioprinting (PeptiInks®) and incorporation into medical devices.

The Diamond-based research contributed to the fundamental knowledge of the product and process control required for the design of these hydrogels with precise properties. These off-the-shelf formulations are now sold to a range of clients working in the biomedical field (e.g.: disease modelling, tissue engineering and regeneration, drug delivery).

Phase Change Materials with potential to reduce CO_2 emissions and fuel bills

Forty-two per cent of UK energy consumption is in the form of heat so there is growing interest in finding more efficient heating solutions, especially



Ms Hannah Logan & Professor Colin Pulham, Powder X-ray diffractometer – Copyright of School of Chemistry, University of Edinburgh 2021

through heat-storage systems. Professor Colin Pulham, Professor of High-Pressure Chemistry at the University of Edinburgh, regularly uses Diamond to examine the properties and behaviour of various materials (pharmaceuticals, fuels, energetic materials) under a range of pressure and temperatures. One of his highest profile research areas has been the crystallisation of phase-change materials and their role in heat storage. In collaboration with Sunamp Ltd, a small rapidly growing Scottish company that designs and manufacturers thermal batteries for heat storage, his research has contributed to the development of its "heat batteries" to store thermal energy at higher energy densities than more traditional methods (e.g. hot water tanks).

Professor Pulhams's work at Diamond helped provide evidence to develop a more controllable and commercially viable product, with the potential to reduce CO_2 emissions and domestic fuel bills. Thermal batteries use phase-change materials (PCMs); chemical compounds that can store and release large amounts of energy (heat) through melting and solidification (and importantly much more energy per unit volume than traditional methods of heat storage, such as hot-water tanks). The technology therefore has the potential to reduce CO_2 emissions and domestic fuel bills, contributing to the alleviation of fuel poverty.

Dr David Oliver, then a materials science PhD candidate at Edinburgh and Professor Pulham, used X-rays on the Diamond I11 beamline to examine the crystal structures of PCMs – how the atoms are arranged and how these change during crystallisation – as well as to explore possible degradation pathways.

The high intensity of Diamond's X-rays meant data could be collected in seconds, allowing them to study changes to crystal structures in real time under variable temperature conditions. The research determined the temperature at which one PCM formulation developed by Dr David Oliver would cease to function properly and identified the various crystalline species present during heating and freezing cycles. One 48-hour session of beamline time at Diamond helped confirm the PCM formulation worked as intended and could be commercially viable.

The work at Diamond has had important commercial benefits for Sunamp. Knowing the temperature that PCM formulations begin to degrade enabled them to build in appropriate temperature cut-offs to their batteries. The research also provided clear scientific evidence that the novel PCM formulation works, and the enhanced phase-change materials will continue to function over extended periods of some 40,000 cycles. This helped reassure investors about long-term battery performance and appropriateness for domestic installation. The data helped Sunamp secure a several million-pound investment and it's now valued at tens of millions of pounds with its heat batteries currently in 1,000 UK homes and a memorandum of understanding in place to supply Chinese homes.

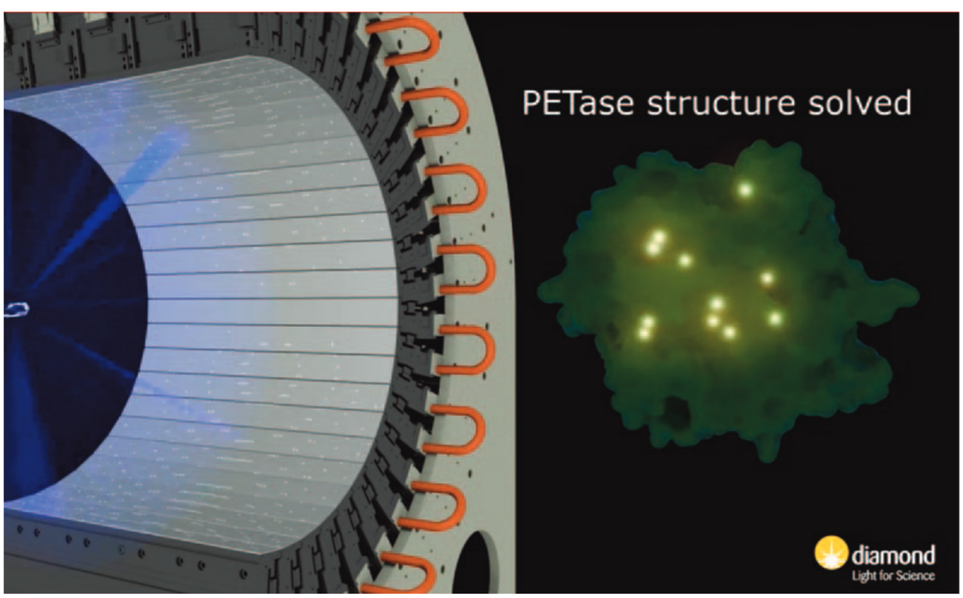
Diamond Light Source Aerial View 3 - Copyright of Diamond Light Source Ltd 2020

DELIVERING AGAINST REAL-WORLD CHALLENGES

Professor Mark Thomson, Executive Chair of STFC, concluded: "With support from STFC, the Diamond research facility continues to deliver both economic growth and research impact on behalf of the UK. It brings together the best of British science, as well as fostering multi-disciplinary research activity with a wide range of global collaborators. It continues to deliver against real-world challenges, with some of their recent successes including enhancing our understanding of the Covid-19 virus."

Tom Collins, Acting Head of Genetics and Molecular Sciences at Wellcome, added: "Diamond has delivered world-leading scientific advances through the innovation and excellence of the people who built and operate the synchrotron, in collaboration with the UK's scientific community. The report highlights the real-world impact of it's research and the continued efforts that it makes to engage the wider public, complementing Wellcome's mission to solve the most urgent health challenges facing everyone."

For a full copy of the report see: https://doi.org/10.5281/zenodo.4769839 □



PETase structure solved at I23 beamline at Diamond Light Source - Copyright of Diamond Light Source Ltd