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# Singapore team develops new technology that upcycles old, expired solar panels into heat-harvesting electricity materials

**SINGAPORE** – A team of scientists from the Agency for Science, Technology and Research (A*STAR) and Nanyang Technological University, Singapore (NTU Singapore) has developed technology that can turn old solar panels into a new high-performance energy-harvesting thermoelectric material, which harvests heat and converts it into electricity.

The joint study was published in the scientific journal *Advanced Materials* in March 2022.

With the increased use of solar renewable energy over the last few decades, and a limited lifespan of 30 years for solar panels, the global waste generated from silicon in end-of-life solar panels is projected to hit 8 million tonnes by 2030 and 80 million tonnes by 2050[1].

Solar panels are made up of solar cells, which contain a complex mix of various materials such as aluminium, copper, silver, lead, plastic and silicon. Separating such materials and recycling them each in a unique way is a complex and costly process, therefore present recycling approaches mainly recover only the glass and metallic support structures from solar panels.

Silicon, which makes up 90 per cent of solar cells, normally ends up in landfills. It is challenging to upcycle silicon as recycled silicon has impurities and defects, which cannot be used to create functional solar cells, making it difficult to recycle used silicon into solar cells or other silicon-based technologies.

The team turned this limitation into opportunity by developing technology to transform expired solar cells into enhanced thermoelectric material. Compared to solar cells, this technology capitalises on the contrasting properties of thermoelectrics, where the incorporation of impurities and defects serve to enhance rather than diminish their performance.

Scientists from A*STAR's Institute of Materials Research and Engineering (IMRE) and Institute of High Performance Computing (IHPC), led by Dr Ady Suwardi, Deputy Head of the Soft Materials research department at IMRE, contributed their expertise in

[1] G. A. Heath, T. J. Silverman, M. Kempe, M. Deceglie, D. Ravikumar, T. Remo, H. Cui, P. Sinha, C. Libby, S. Shaw, Nat. Energy 2020, 5, 502.

material properties and computational modelling respectively, to determine the optimal composition of materials.

Scientists from NTU's Singapore-CEA Alliance for Research in Circular Economy (SCARCE), led by Associate Professor Nripan Mathews, leveraged their expertise in extracting valuable materials from solar waste to develop the technologies required for recovery of silicon from solar panel waste.

To impart thermoelectric characteristics such as power conversion and cooling efficiency to waste silicon and to enhance the performance of the upcycled silicon-based thermoelectrics, the team first pulverised solar cells into fine powder using ball milling technology. Next, phosphorus and germanium powder were added to alter their original properties before the powder combination was processed under high heat and temperature using spark plasma sintering.

After evaluating the electrical property of various combinations, the team achieved a sample offering the most optimised thermoelectric performance, with a record-high thermoelectric figure of merit (zT) of 0.45 at 873 K — the highest amongst elemental silicon thermoelectrics.

"This study demonstrates that thermoelectrics is a fertile ground for upcycling defect- and impurity-sensitive semiconductors," said Dr Ady Suwardi, team lead from IMRE. "Our goal is to create sustainable materials, extend the life cycle of various products and reduce waste to cultivate a circular economy, and we can only do this through partnership with institutes of higher learning and other collaborators from the local R&D ecosystem," added Dr Jing Wu, scientist from IMRE who was co-corresponding author of the paper together with Dr Suwardi.

"Furthermore, this project demonstrates the concept of phononic engineering, an efficient and useful approach that offers full control of the thermal conductivity of solids", said Dr Gang Zhang, senior scientist from IHPC.

Co-corresponding author NTU Assoc Prof Mathews, who is also the Cluster Director of Renewables & Low-Carbon Generation (Solar) at the Energy Research Institute @NTU (ERI@N), said: "Advanced technologies to tackle the growing solar e-waste problem need to be urgently developed due to the massive scale of solar photovoltaics being installed worldwide. As a part of the SCARCE research centre supported by the National Environmental Agency (NEA), we are working on a variety of innovations that can turn trash to treasure, thus opening new economic growth areas for waste management and recycling.

"Leveraging our resource recovery techniques and in collaboration with A*STAR, we have proven that it can yield valuable materials that are of high-quality and useful in the manufacturing of renewable energy components, which in this case, is the development of a high-performance thermoelectric material that can harvest heat and turn it into electricity."

This effort highlighted the intertwined research by SCARCE whereby silicon recovered from solar panel waste is being upcycled by A*STAR into silicon-based thermoelectrics for harvesting of electricity from heat. The team will also look to pilot the technology for large-scale upcycling of waste silicon, which can be used for high-temperature energy harvesting applications such as converting heat generated from industrial waste processes into electricity.

This research collaboration signifies NTU's commitment to its 2025 Strategic Plan, where sustainability and innovation for a circular economy are key pillars. It also supports the NTU Sustainability Manifesto, which charts the University's course for sustainability, carbon neutrality and societal impact.

This initiative is also in line with A*STAR's efforts to develop sustainable solutions for energy efficiency and waste management.

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**Notes to Editor:**

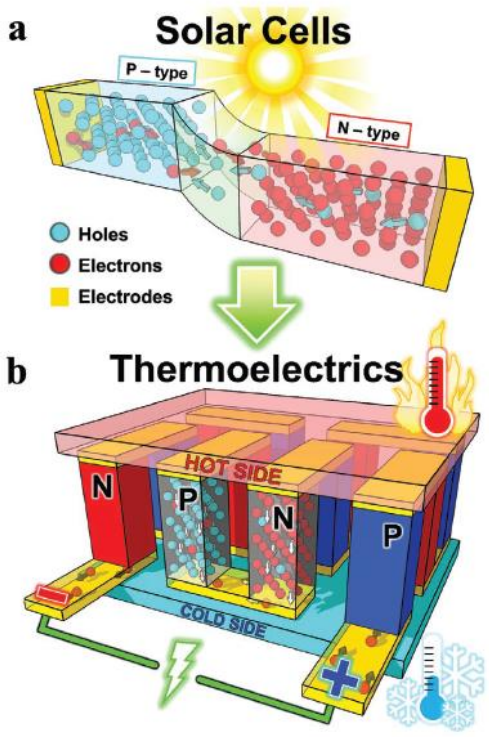


*Figure 1: Illustration showing the minority-carrier nature of solar cells which makes them generally defect sensitive, while the majority-carrier nature of thermoelectrics makes them defect insensitive.*

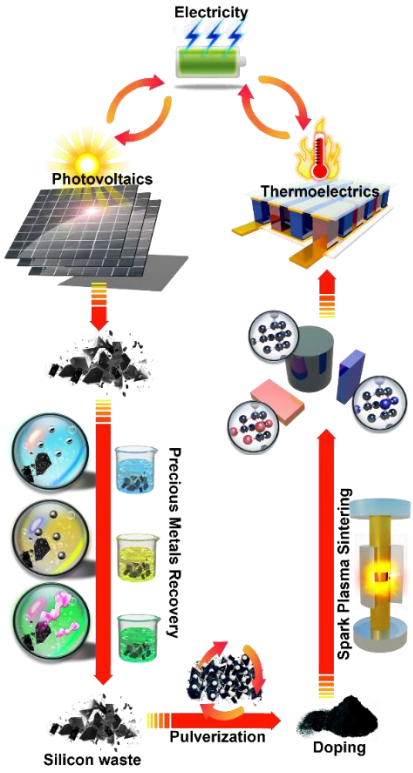


*Figure 2: Illustration showing the process of upcycling solar cells into thermoelectrics*

*Paper titled: "Upcycling Silicon Photovoltaic Waste into Thermoelectrics", published in Advanced Materials, 07 March 2022.*
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***About the Agency for Science, Technology and Research (A*STAR)***

The Agency for Science, Technology and Research (A*STAR) is Singapore's lead public sector R&D agency. Through open innovation, we collaborate with our partners in both the public and private sectors to benefit the economy and society. As a Science and Technology Organisation, A*STAR bridges the gap between academia and industry. Our research creates economic growth and jobs for Singapore, and enhances lives by improving societal outcomes in healthcare, urban living, and sustainability. A*STAR plays a key role in nurturing scientific talent and leaders for the wider research community and industry. A*STAR's R&D activities span biomedical sciences to physical sciences and engineering, with research entities primarily located in Biopolis and Fusionopolis. For ongoing news, visit www.a-star.edu.sg.

***About Nanyang Technological University, Singapore***

A research-intensive public university, Nanyang Technological University, Singapore (NTU Singapore) has 33,000 undergraduate and postgraduate students in the Engineering, Business, Science, Medicine, Humanities, Arts, & Social Sciences, and Graduate colleges.

NTU is also home to world-renowned autonomous institutes – the National Institute of Education, S Rajaratnam School of International Studies, Earth Observatory of Singapore, and Singapore Centre for Environmental Life Sciences Engineering – and various leading research centres such as the Nanyang Environment & Water Research Institute (NEWRI) and Energy Research Institute @ NTU (ERI@N).

Under the NTU Smart Campus vision, the University harnesses the power of digital technology and tech-enabled solutions to support better learning and living experiences, the discovery of new knowledge, and the sustainability of resources.

Ranked amongst the world's top universities, the University's main campus is also frequently listed among the world's most beautiful. Known for its sustainability, over 95% of its building projects are certified Green Mark Platinum. Apart from its main campus, NTU also has a medical campus in Novena, Singapore's healthcare district.

For more information, visit www.ntu.edu.sg