Q&A: Study finds hybrid solar energy systems could reduce global emissions

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Solar PV-T collector panels on a roof at Imperial College. Credit: Imperial College London

Imperial engineers and a team of global experts have reviewed technological options, innovation and opportunities in the hybrid solar energy industry.

They anticipate that hybrid PV-thermal technologies could produce a further drop in global emissions of about 3% (around 600 megatons of CO_2) by 2030 if the systems mentioned in this study are installed as proposed.

The team, led by Professor Christos Markides, from the Department of Chemical Engineering at Imperial, has compiled a comprehensive guide to a wide range of hybrid photovoltaic-thermal (PV-T) solar technologies and systems capable of harnessing the sun's energy. These can generate electricity and also provide heating and other useful outputs. They have also made recommendations for researchers about promising technology developments, as well as suggestions to help installers and policymakers adopt the most effective and affordable technologies available.

Their findings have now been published in Progress in Energy and Combustion Science.

Corinne Farrell has been speaking to Professor Markides to find out more.

Why did you decide to start this project?

Markides: Solar energy is one of the cleanest forms of energy available to us. Specially designed systems can use solar collectors to capture radiation from the sun and to convert it to electricity, heat and other useful outputs. These systems have enormous potential to meet the growing worldwide demands for energy, but also clean water, while playing a central role in achieving our environmental and carbon mitigation targets. There are several types of hybrid solar systems, and different ways to collect and store energy.

Through a comprehensive study of what is already available, as well as currently under development, we wanted to identify innovative ways to collect solar energy, generate energy in various forms or other useful outputs, as well as opportunities to keep costs down, while improving the performance, effectiveness and reliability of such solar installations. We were also keen to evaluate the global potential of these systems for energy generation and carbon mitigation.

We hope that our work will influence the next generation of technological developments, and increase the uptake of solar energy technologies in installations across the planet.

Are different systems in use across the world?

Markides: PV-T solar systems can be used in a diverse range of applications, including for power generation, heating or cooling provision, drying, desalination, as well as for combined heat and power generation, or combined cooling, heat and power, and even hydrogen production.

The most suitable type of PV-T system in each case depends on local weather conditions and required energy demands. For instance, at lower latitude locations, thermosiphon PV-T water systems can potentially produce enough hot water to cover the entire demand for domestic hot water in most homes. In these systems, the storage tank is located higher than the collection system and takes advantage of convection, where hot water rises and cool water sinks. There is no pump or controller needed, so the system is relatively inexpensive, simple and reliable.

In higher latitude locations, where the outdoor temperatures can drop below the freezing point of water, closed-loop PV-T water systems might be more appropriate. In these systems, the solar collection panels contain a fluid that does not freeze and absorbs heat, which is delivered to the building via a heat exchanger.

Air-based PV-T systems, which utilize air as the heat transfer fluid, are an interesting alternative for space heating provision in applications where water supply is limited.

What did you learn from your review of different collection systems?

Markides: Many solar installations, particularly older ones, use conventional PV panels or solar-thermal (i.e., hot water) collectors to generate electricity. Recently, hybrid photovoltaic-thermal (PV-T) collectors have been gaining attention, as this technology harnesses solar energy to generate both electricity and useful heat simultaneously. They can achieve total solar conversion efficiencies of more than 70%, significantly surpassing the electrical efficiencies of conventional PV panels, which average 10%–25%.

What insights did you gain from looking at new developments?

Markides: There are numerous innovations and state-of-the-art design modifications to the basic PV panel and solar hot-water systems. An important area of research focuses on collector design modifications, such as the improvement of the thermal absorber design, the involvement of thermal-insulation glass glazing or aerogel layers, the use of phase-change materials, all of which improve the thermal performance of PV-T collectors. Another research direction involves next-generation, higher-performance PV cell technologies, aiming at maximizing electrical efficiency. Finally, the use of selective coatings, spectral splitting techniques and nanofluids is gaining significant attention, as these increase both the thermal and electrical efficiencies of

PV-T collectors.

What impact would you expect this work to have on future installations?

Markides: Hybrid PV-T solar technologies are a renewable energy solution with a significant potential to increase the useful energy harvested from the sun. These technologies can lead to a larger renewable energy share, reduced emissions, improved air quality, and decreased reliance on fossil fuels. By consolidating the latest advancements in this field, we aim to stimulate further opportunities for development and adoption.

We hope that our review article will inspire and guide future collaboration, innovation, research and development in the field, as well as the uptake of these promising technologies. There is significant potential to improve the performance, efficiency and scalability of these technologies, as well as to reduce their cost.

Our findings also offer a rich resource to policymakers, energy planners and decision-makers for a renewable and sustainable energy future. We looked at the optimistic emissions curve from IRENA REmap (IRENA: International Renewable Energy Agency; REmap: Renewable energy roadmaps).

We think that the hybrid PV-thermal technologies could over 10 years produce a further drop in global emissions of around 600 megatons of CO_2 (about 3%) by 2030, if the systems mentioned in this study are installed as estimated. Our evaluation of the worldwide carbon mitigation potential of PV-T systems can help inform policy decisions about renewable energy incentives, infrastructure development, and global decarbonization.

What are the next steps for you?

Markides: We have formed a spin-out company Solar Flow to commercialize a particular hybrid PV-T solar collector concept. Funded by the Department for Energy Security and Net Zero, Solar Flow is currently working with the team at Imperial College London that I'm leading, to design and fabricate a high-temperature PV-T collector for industrial decarbonization. We are still in the design phase of the project and aim to perform outdoor tests with this design in early 2024.

More information: María Herrando et al, A review of solar hybrid photovoltaic-thermal (PV-T) collectors and systems, *Progress in Energy and Combustion Science* (2023). DOI: 10.1016/j.pecs.2023.101072

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