Solar Fuels UK Vision Statement

Global Vision for Solar Fuels:

"Solar fuels is a technology that uses sunlight to make fuels from abundant resources such as water and carbon dioxide."

This would address three key elements of the energy challenge – sustainability, security of supply and cost – as it would be a way to:

- produce renewable fuels for transport
- store solar energy
- help to achieve key sustainable energy technology goals such as carbon dioxide utilisation and renewable hydrogen generation

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Motivation and challenges for solar fuels research and development

There are several routes to developing a scalable, cost-effective and sustainable solar fuels technology. Integrated solar fuels routes, where sunlight is directly employed to drive fuel synthesis, are often referred to as 'artificial photosynthesis'. Such routes are typically based upon inorganic semiconductor photoelectrodes or particle suspensions interfaced with catalysts; some approaches also include molecular light absorbers and/or catalysts. These routes have close parallels and complementarities with alternative routes for solar driven fuel synthesis, including photovoltaics + electrolysis, biological photosynthesis, and thermochemical approaches. It is too soon to say which route or combination of routes will be the most effective as a deployed technology.

Recent scientific advances, particularly in multi-electron catalysis and nanomaterials for light capture and utilisation, are motivating global interest and excitement in research into integrated routes for solar-to-fuel conversion.

Many fundamental science and engineering challenges remain to be overcome on the road to a solar fuels technology. Tackling these challenges will require advances in areas such as materials, catalysis, and device design and system integration.

The development of the science to enable a solar fuels technology has strong complementarities with related energy technology challenges (e.g. electrocatalysis, photovoltaics, etc.). In addition to fuels synthesis, this science could unlock routes to solar-driven synthesis of other useful chemicals, such as ammonia for fertilizers.

The development of renewable fuel synthesis strategies has the potential to utilise the existing fuel distribution and transport infrastructure whilst impacting substantially on CO_2 emissions. This technology for a solar energy conversion and storage strategy is intrinsically scalable from the local to the national level.

The short term target for solar fuels technology is sustainable hydrogen generation. Longer term targets are CO_2 reduction to carbon-based fuels and feedstocks, and N_2 reduction to ammonia. Catalysis development will be critical to achieving all these targets, in particular those that are longer term. The development of an integrated solar to fuels technology for the direct reduction of CO_2 to a carbon-based fuel has the potential to be a game changer in sustainable fuel synthesis.

Currently no artificial photosynthetic technology is ready for competitive commercial deployment. Electrolysis driven by photovoltaics is too expensive, but it does offer a viable short term route to evaluate the potential and impact of solar-to-fuel conversion on energy systems design. Some cost analyses suggest that some integrated solar fuels devices have the potential to be significantly cheaper than other approaches. However, achieving the necessary efficiencies with such low cost devices will require major research advances, particularly in materials for light capture and utilisation, and in catalysis.

Opportunities for solar fuels research in the UK

The UK has substantial research expertise which can be applied to solar fuels research. The UK Solar Fuels research community is growing rapidly (for example, the UK Solar Fuels Network has already attracted 250 members since its formation in 2013). This research field is highly interdisciplinary. There are substantial opportunities for solar fuels research to engage with and connect existing foci of UK strength including the Catalysis Hub and Solar Supergen Hub, as well as the Semiconductor Photochemistry and CO_2Chem Networks, and the Bioenergy and Hydrogen & Fuel Cell Supergen Hubs.

Key research challenges for solar fuels align very well with core UK research strengths and priorities, in particular in catalysis and nanomaterials. Solar fuels research presents an opportunity for these established communities to address key energy, environmental and societal challenges.

Solar fuels is a research area which is highly attractive to young researchers motivated by scientific curiosity combined with a sense of social responsibility. The research skills developed through working on solar fuels research are relevant to many future career pathways.

Priorities for Solar Fuels research and development in the UK

Substantial fundamental science and engineering challenges, particularly in the areas of materials for light capture and utilisation, catalysis, and device design and system integration, remain to be surmounted on the road to a scalable, cost effective and sustainable solar fuels technology ,

In this context, research that builds upon and exploits synergies with existing UK strengths, in particular that which crosses discipline boundaries, should be encouraged. Such boundary crossing can be at the level of different science fields (e.g. interfacing catalysis with semiconductor materials) and between different technology areas (e.g. solar-driven fuel synthesis and CO_2 capture and utilisation).

Increased commercial awareness and engagement should be encouraged. In this regard, an analysis of technology needs and opportunities associated with different potential markets should be undertaken.

Opportunities for international collaborations, particularly with established solar fuels research programmes in Japan, as well as Europe, USA and China, and opportunities to increase training of young researchers in this field, particularly for UK postgraduate students, should be encouraged.

The UK (and international) solar fuels community has grown rapidly in the last five years. Co-ordination and integration of this community is a priority.