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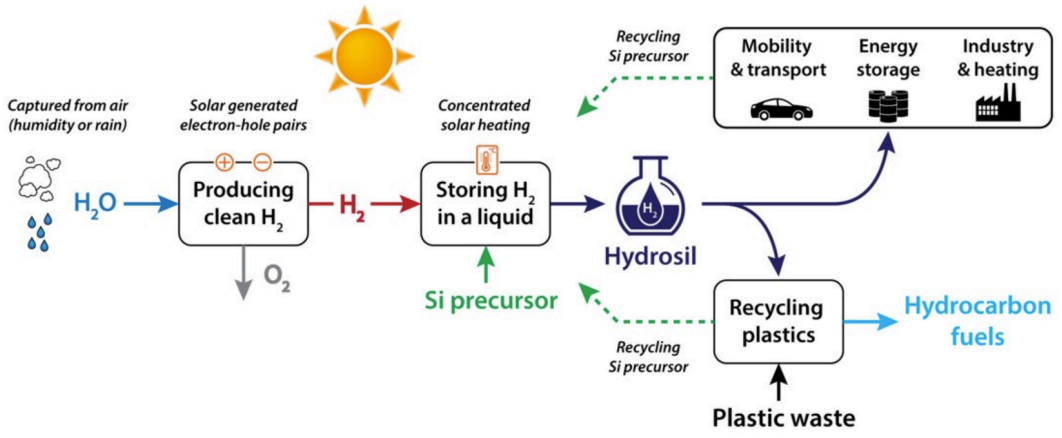
SUN to X
Solar Energy for Carbon-Free Liquid Fuel

PROJECT FINAL NEWSLETTER

During this final newsletter of Sun-To-X, we would like to give an overview of the results obtained and next steps. The project comprised of three main technical ii. Storage of hydrogen in HydroSil – a carbon-free, energy dense, liquid hydrogen carrier and iii. the use of HydroSil for the depolymerisation of waste plastics.

Publications:

- https://www.innovationnewsnetwork.com/sun-to-x-creating-carbon-free-liquid-fuel-energy-storage/29755/
  https://iopscience.iop.org/article/10.1088/1361-6463/ac6f97

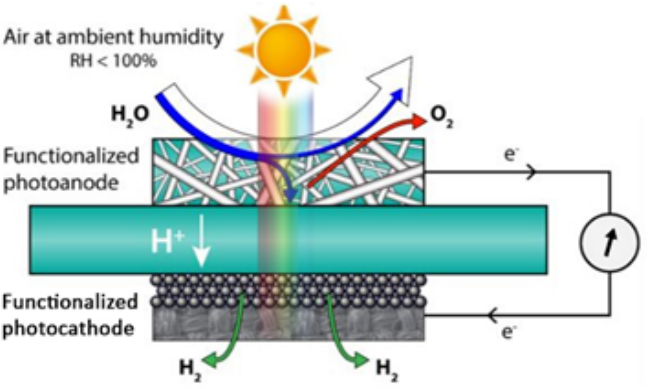


Generation of photoelectrochemical hydrogen – green hydrogen demand is expected to reach 10 million tonnes / year by 2030. Our goal was to produce hydrogen through a vapour-based photoelectrochemical process, using ambient humidity as a water source. To realise this we developed a photoanode and photocathode that could operate in tandem, with the

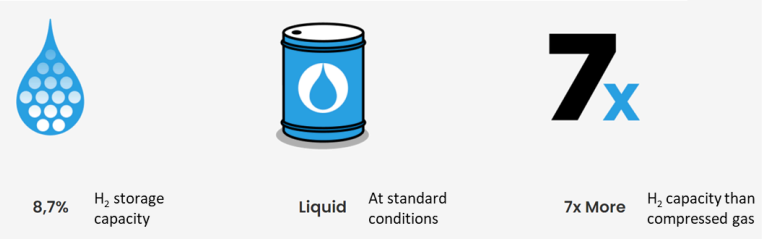
photoanode absorbing blue light (< 520 nm) and being sufficiently transparent to allow red light (< 780 nm) to pass to the photocathode. Since we were operating the cell with ambient humidity, porous photoelectrodes were required and the development of a transparent, conducting, porous support and the growth of charge transport layers, semiconductors, catalysts and proton-conducting, water-absorption layers on the support represented a major challenge in the project. After screening various materials, a combination of $BiVO_4$ photoanode and an organic semiconductor (ITIC: PTB7-Th bipolar heterojunction) photocathode was chosen for use in the final demonstrator, which was prepared on a 900 cm^2 scale (composed of 100 cm^2 modules).

Publications:

- Transparent Porous Conductive Substrates for Gas-Phase Photoelectrochemical Hydrogen Production - Caretti - 2023 - Advanced Materials - Wiley Online Library
- Porous silicon-nanowire-based electrode for the photoelectrocatalytic production of hydrogen - Sustainable Energy & Fuels (RSC Publishing) DOI:10.1039/D3SE00408B
- Transparency and Morphology Control of Cu2O Photocathodes via an in Situ Electroconversion | ACS Energy Letters



Storage of hydrogen in HydroSil – conventional hydrogen storage materials require high temperatures to release hydrogen, limiting their use in decentralised applications. HydroSil is a silicon hydride-based hydrogen storage material that can release hydrogen at room temperature in the presence of water and a catalyst. Unlike other silicon hydrides, it can be recycled – the siloxane base material can be recharged with hydrogen after each use. During Sun-To-X, the recharging process composed of three subsystems was developed for the first time using renewable energy.

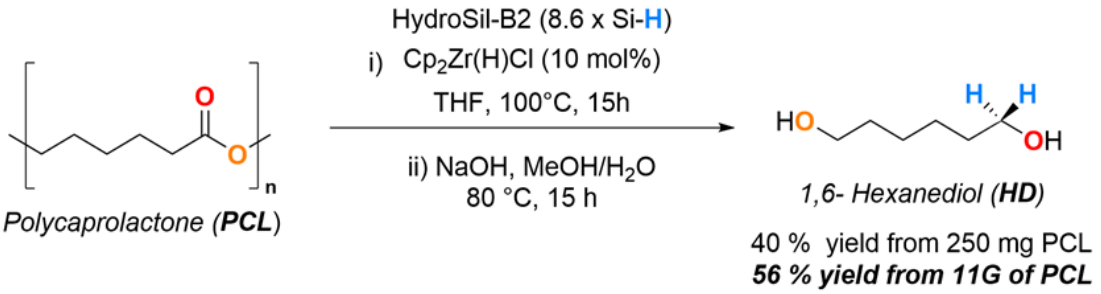


Use of HydroSil in the depolymerisation of waste plastics – conventional plastic recycling is based on milling and re-melting, resulting in recycled plastic being lower quality than the virgin material. Chemical depolymerisation processes can transform plastic back to the monomer state, which can then be re-used in the preparation of high quality plastics, however, the depolymerising agents tend not to be recyclable. HydroSil can depolymerise plastics containing C-O bonds (such as polycaprolactone (PCL)) through its Si-H bonds. During Sun-To-X, selective depolymerisation of waste plastics was demonstrated for the first time. PCL was

depolymerised to form 1,6-hexanediol, which can be re-polymerised to form virgin plastics.

Publications:

- Selective Reduction of Secondary Amides to Imines Catalysed by Schwartz's Reagent** - Donnelly - 2022 - Angewandte Chemie - Wiley Online Library
- Zirconium-catalysed hydrosilylation of esters and depolymerisation of polyester plastic waste - Green Chemistry (RSC Publishing) DOI:10.1039/D2GC02186B



These technical studies were coupled with technoeconomic, lifecycle and social impact assessments, which demonstrated the promise of Sun-To-X technology. Vapour-phase hydrogen production had a lower projected levelised cost compared to the conventional liquid phase due to lower balance of system costs. When this hydrogen is stored in HydroSil, the projected levelized cost is 113 EUR / kg H_2 which compares favourably to compressed gas storage (375 – 500 EUR / kg H_2 depending on the pressure).

Publications:

- Probabilistic Techno-Economic Assessment of Medium-Scale Photoelectrochemical Fuel Generation Plants (acs.org)

Final Webinar

The final webinar was hosted by CINEA - European Climate, Infrastructure and Environment Executive Agency, where we presented groundbreaking advancements in renewable energy to industry stakeholders. Highlights included Sun-To-X innovative approach to hydrogen production using air humidity, and our novel HydroSil storage solution with applications in fuel and

plastic recycling. Our analyses showcased the project's profound impact, paving the way for a cleaner energy future.

Watch the recording here

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The Sun-To-X project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 883264.