HOW THE UK CAN LEAD THE 'THIRD AVIATION REVOLUTION'

Professor Pericles Pilidis
Professor Gas Turbine Performance
Centre for Propulsion and Thermal
Power Engineering,
Cranfield University

In the 1940s, the UK made large, speculative investments into a new technology: the jet engine. This led to the 'second aviation revolution', transforming the nature and commercial potential of a global aviation industry. The UK's sudden leap forward, made possible through a combination of bold funding and engineering expertise, created a commercial and technological leadership internationally which continues to endure, 80 years on.

The 'third aviation revolution' — the development of a sustainable aviation infrastructure that protects both the environment and economic growth — is an essential and urgent ambition. The UK's net-zero aviation emissions by 2050 target is getting closer.

Again, the UK has the chance to be the prime mover of transformation by taking a global lead in green aviation with hydrogen and electric propulsion as a practical and long-term solution for delivering on all criteria: protecting the environment through zero or ultra low carbon and other greenhouse gas emissions, while also ensuring economic viability. That will mean UK leadership across decades, new market and investment opportunities internationally, employment and upskilling opportunities, and a means of inspiring and engaging generations of young people with careers in STEM and what is explicitly a world-changing technology.

Cranfield has been at the forefront of innovation in aviation for decades

HYDROGEN: FROM 'CRAZY' TO CANDIDATE

Cranfield has been working on delivering hydrogen-powered aviation since the early 1990s. Then, it was considered to be a 'crazy', niche option for the future. Within the last decade, as the limitations of electric and other fuel sources became apparent (the problems around the weight of electric batteries in particular), hydrogen has become a real candidate. Now it's very fashionable – and the large challenges involved in transforming the industry infrastructure into hydrogen-based rather than a kerosene are looking increasingly worth taking on – because the benefits for the long-term are so clear.

Courtesy of EU H2020 project ENABLEH2. The ENABLEH2 project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 769241.

The change has come about largely due to the European Horizon 2020-funded project ENABLEH2 (ENABLing CryogEnic Hydrogen-Based CO_2-free Air Transport), which has provided hard evidence for the case for hydrogen. Findings and the roadmap forward, including the need for the makings of a new regulatory framework, have gained EU approval. Cranfield played a leading role in ENABLEH2, alongside Chalmers University, London South Bank University, Heathrow Airport, GKN Aerospace Safran, the European Hydrogen Association and Arttic. Industry involvement included support from Airbus, IATA, ICAO, International Airlines Group, Mitsubishi Power Systems, Rolls-Royce, Siemens and Total. Cranfield's contribution to the UK's Fly Zero programe provided further impetus.

In essence, the research confirmed the qualities of liquid hydrogen as a zero-carbon emissions fuel, one that would also remove sulphur oxide and soot from the aviation emissions profile. Hydrogen brings a promise of much leaner combustion than any hydrocarbon fuel (fossil, bio or synthetic) delivering ultra-low nitrogen oxide emissions (nitrogen oxides contribute to acid rain and the 'ozone hole').

Cranfield researchers continue to work on each aspect of technologies needed to make the shift to a hydrogen-aviation infrastructure, from hydrogen production, storage and transportation, to airport fuelling processes and safety. A key challenge and focus of large R&D investments is the development of certification processes and rules to ensure that the introduction of hydrogen will continue to deliver the safety standards of today, or better.

NEW PRODUCTION TECHNOLOGY HOLDS GREAT PROMISE

A new generation plant for testing production of 'blue' hydrogen has been installed on the University campus. The Bulk Hydrogen Production by Sorbent Enhanced Steam Reforming (HyPER) project (funded through the Department for Business, Energy and Industrial Strategy and its Energy Innovation Programme) has led to a 1.5 megawatt-hour pilot plant. Partners include the US-based Gas Technology Institute (GTI) and British energy company Doosan Babcock.

The plant is based on a compact technology that captures carbon dioxide during the hydrogen-production process and shifts the chemical reactions to favour the production of more hydrogen. HyPER has the potential to produce high purity hydrogen at up to 30% lower cost than conventional steam methane reforming methods that require CO_2 capture as an additional and expensive step in the process. HyPER also captures carbon in solid form, much more convenient to sequestrate and store.

Cranfield's HyPER project demonstrates an effective way to produce hydrogen

The process is scalable for use in much larger hydrogen production plants and leads to the production of both high-purity hydrogen and carbon, which can be stored, sold and transported to where it is needed. Once scaled up, the process is predicted to have the potential to produce a significant proportion of the UK's hydrogen needs by 2050.

The H2 production facility based on sorption enhanced reforming, demonstrated in HyPER, is cheaper to build than a conventional hydrogen production facilities (50% less) and leads to hydrogen production at a 20-30% lower levelised cost. Carbon emissions are cut by 97%. Building on this work, Bio-HyPER research is testing the feasibility of using biogas feedstocks (supplied from anaerobic digestion plants processing food, plant and animal waste around the UK) for the HyPER pilot plant.

RESEARCHING THE HYDROGEN ECOSYSTEM

Other research is exploring how hydrogen production processes can be made more efficient and cost effective; storage vessels for compressed and liquefied hydrogen; the use of ammonia for carbon-capture hydrogen storage and waste-to-fuel processes; and the value of hydrogen aviation for reducing 'contrail' effects, the vapour trails from aircraft that can produce cirrus clouds with potential implications for climate change.

The Centre for Air Transport Management at Cranfield is investigating the practicalities of implementing hydrogen refuelling across airports using compressed gas and/or liquid hydrogen. This has included a study alongside Heathrow Airport.

The University is building up direct experience of production and refuelling via its own solar-powered electrolyser, producing up to 40kg of 'green' hydrogen per day (meaning hydrogen produced using a renewable source of energy). An electric refuelling truck supplies research projects working on hydrogen fuel-cell aircraft.

The networks of activity are growing. As a result of its history of research, expertise and facilities around hydrogen, the UK-Aerospace Research Consortium (an aerospace consortium of 11 universities) has appointed Cranfield as its hydrogen theme lead. In 2023 Cranfield hosted a Hydrogen and Fuel Cell Showcase event with 250 delegates from more than 100 industries, including leaders from Airbus, Barclays, Heathrow Airport, Rolls-Royce, Siemens, BP and Reaction Engines; alongside academics from Bristol, Southampton, Coventry, Wolverhampton and Aston universities.

A LEAP TOWARDS RESILIENCE AND ENVIRONMENTAL SECURITY

The building blocks of technology and evidence for their practical implementation for a genuine future of sustainable aviation — one with UK technologies, universities and business as leading players — are all falling into place. But moving to a new infrastructure of hydrogen generation and supplies remains a huge leap in terms of the need for investment into emerging technologies alongside substantial energy and water demands to make large-scale hydrogen energy use viable. A huge leap, though, that will mean a sustainable, de-carbonised UK: long-term resilience and environmental security for the foreseeable future.

Cranfield's big picture-modelling of hydrogen needs in the UK suggests around 25,000 tonnes would need to be produced each day (for total fuel needs, not just for aviation, around 10,000 tonnes of the total would be necessary as liquid hydrogen for aircraft use). To put this into context, global production of liquid hydrogen currently stands at under 100,000 tonnes a year.

Green hydrogen production is crucially dependent on electricity for electrolysis. To meet hydrogen demand, the UK would need an estimated fourfold increase in electricity supplies. This is not as unrealistic as it might appear: the UK power generation system achieved fourfold increases due to changes in the nature of population and industry demands in both the 1920s and 1940s. Hydrogen would be another major driver for the shift to renewable energy provision.

Electrolysis also depends on large volumes of water: 25,000 tonnes a day production would require 250,000 tonnes of water. Compared with the rest of the world, the UK has a major advantage in being able to access supplies of freshwater rather than seawater which is both more expensive and leads to serious problems with corrosion of hydrogen production plant facilities. Only a few countries such as Canada and Russia have ample freshwater supplies.

Visionary changes depend on large-scale investment and levels of commitment. With this in mind, the recent news that the UK is re-joining the Horizon Europe research programme could be crucial: here is the opportunity for sharing investment development with the EU. The UK can develop a global lead with vast returns. ■