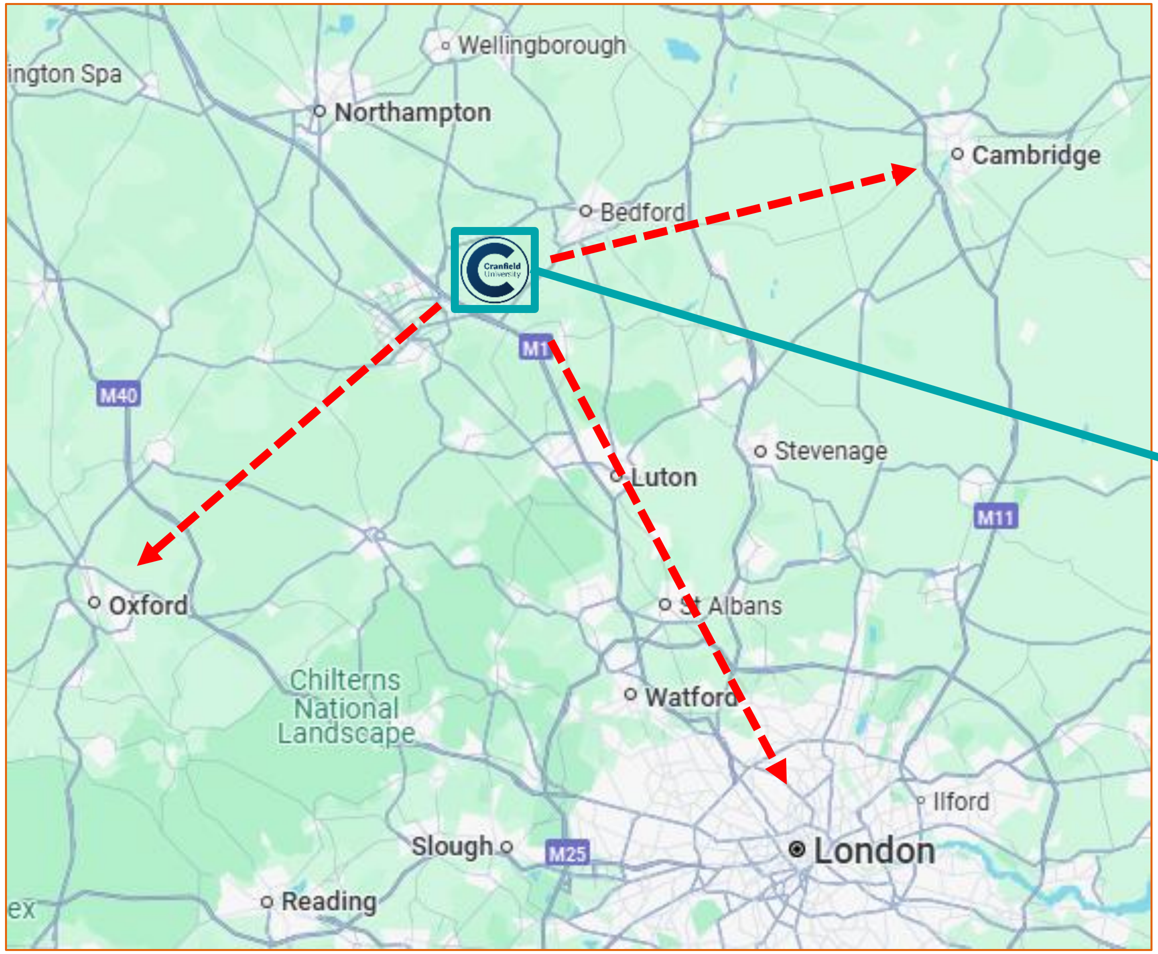
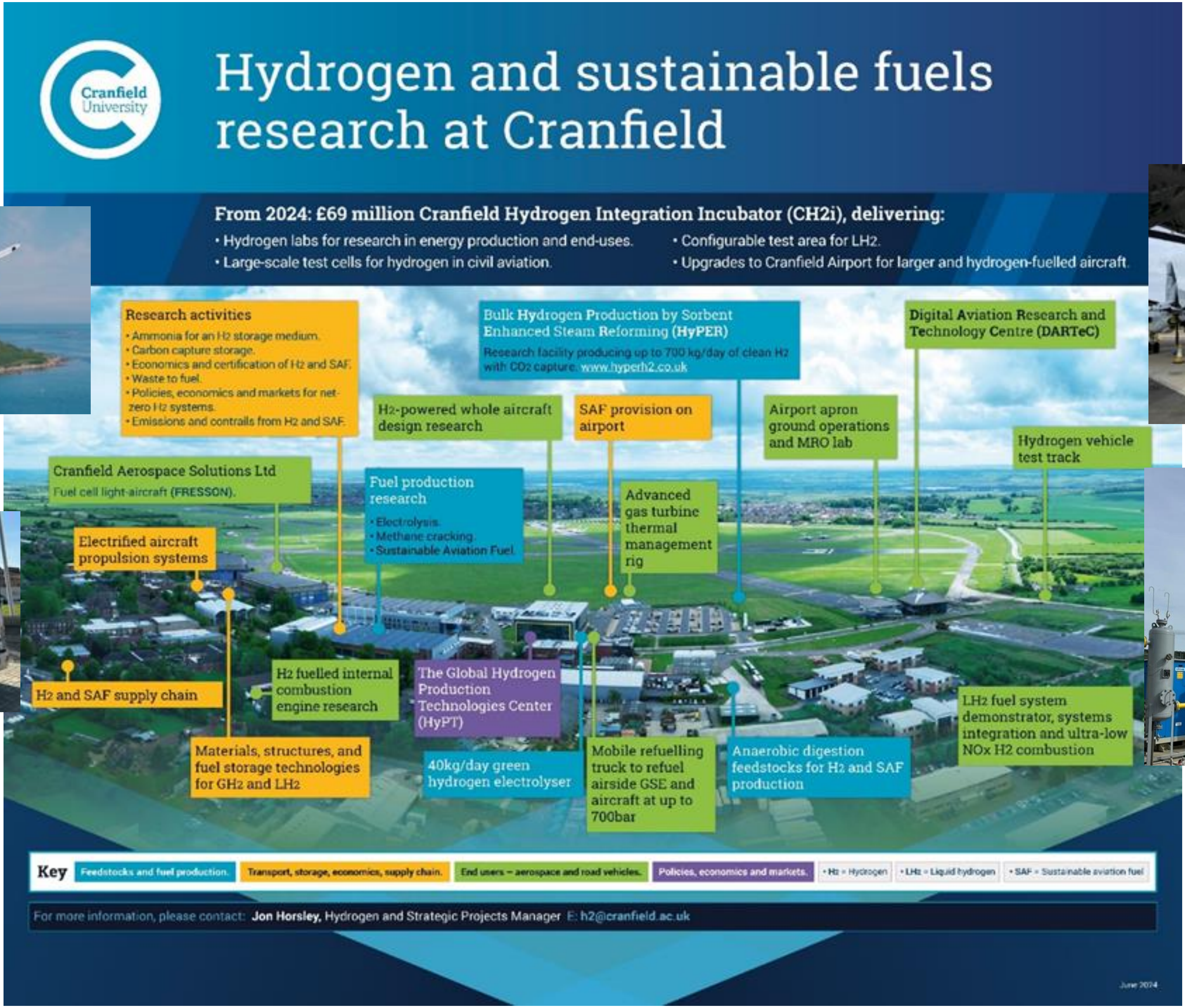
ePAD Research Group at Cranfield University UK

Overview of Cranfield University



- Chosen as UK's post-war Jet Propulsion Lab (ex-RAF Cranfield) as being central to Ox/Camb/London research community
- Europe's only university with its own commercially operational airport (and unique globally for having own aircraft, airline, and D-ATC)
- Postgraduate only, research agenda driven strongly by industry partners



Cranfield University
Hydrogen and sustainable fuels research at Cranfield
From 2024: £69 million Cranfield Hydrogen Integration Incubator (CH2i), delivering:
• Hydrogen labs for research in energy production and end-uses.
• Large-scale test cells for hydrogen in civil aviation.
• Configurable test area for LH2.
• Upgrades to Cranfield Airport for larger and hydrogen-fuelled aircraft.
Research activities
• Ammonia for an H2 storage medium.
• Carbon capture storage.
• Economics and certification of H2 and SAF.
• Waste to fuel.
• Policies, economics and markets for net-zero H2 systems.
• Emissions and contrails from H2 and SAF.
Bulk Hydrogen Production by Sorbent Enhanced Steam Reforming (HyPER)
Research facility producing up to 700 kg/day of clean H2 with CO2 capture. www.hyperh2.co.uk
Digital Aviation Research and Technology Centre (DARTeC)
H2-powered whole aircraft design research
SAF provision on airport
Airport apron ground operations and MRO lab
Hydrogen vehicle test track
Cranfield Aerospace Solutions Ltd
Fuel cell light-aircraft (FRESSON).
Fuel production research
• Electrolysis.
• Methane cracking.
• Sustainable Aviation Fuel.
Advanced gas turbine thermal management rig
Electrified aircraft propulsion systems
H2 fuelled internal combustion engine research
The Global Hydrogen Production Technologies Center (HyPT)
H2 and SAF supply chain
LH2 fuel system demonstrator, systems integration and ultra-low NOx H2 combustion
Materials, structures, and fuel storage technologies for GH2 and LH2
40kg/day green hydrogen electrolyser
Mobile refuelling truck to refuel airside GSE and aircraft at up to 700bar
Anaerobic digestion feedstocks for H2 and SAF production
Key
Feedstocks and fuel production.
Transport, storage, economics, supply chain.
End users – aerospace and road vehicles.
Policies, economics and markets.
• H2 = Hydrogen
• LH2 = Liquid hydrogen
• SAF = Sustainable aviation fuel
For more information, please contact: Jon Horsley, Hydrogen and Strategic Projects Manager E: h2@cranfield.ac.uk
June 2024

Our ePAD group

Our research group members

Dr Jerry Luo https://orcid.org/0000-0003-0766-6174

Prof Patrick Luk https://orcid.org/0000-0002-0459-7081

Dr Fergus Crawley, Dr Qing Qin, Khalifa Ibrahim, Abdullah Alrwili, Ahmed Aldubayyan, Venkat Lakshminarayanan

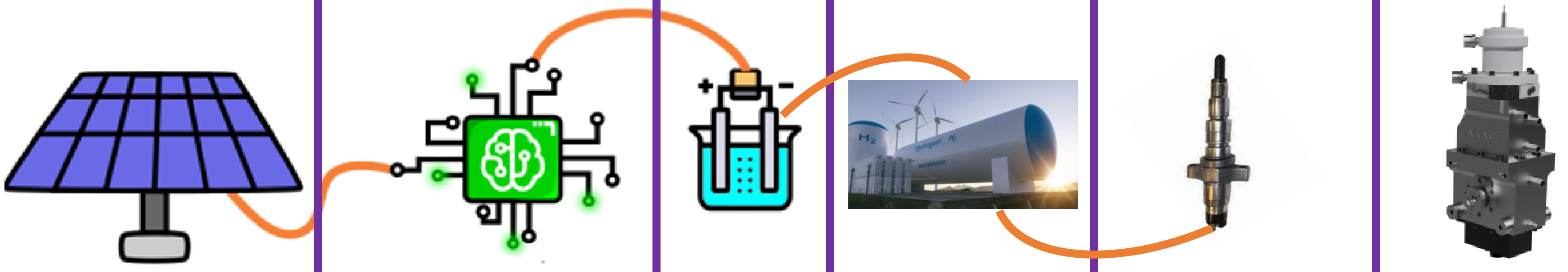
Our research areas

1. Renewable Energy
2. Green Hydrogen
3. Thermal management systems
4. Advanced power electronics
5. Energy harvesting

Green Hydrogen Research

CMDC project (Clean Maritime Demonstration)

This project is to develop & run a zero-carbon, single-cylinder 50 kW Carnot engine operating on hydrogen produced and stored at optimal efficiency and minimal carbon intensity for cold ironing a vessel in harbour. Optimised lifecycle and ideal system architecture for hydrogen use in maritime.



~10kW solar PV system

DC-DC & Power electronics

~5kW Electrolyser (~1 kg/day)

2 stage H2 storage:
- Low pressure bulk
- Higher pressure MOF
- Compressor

HPDI H2 injector

25kW Hydrogen Engine with 7C rated battery

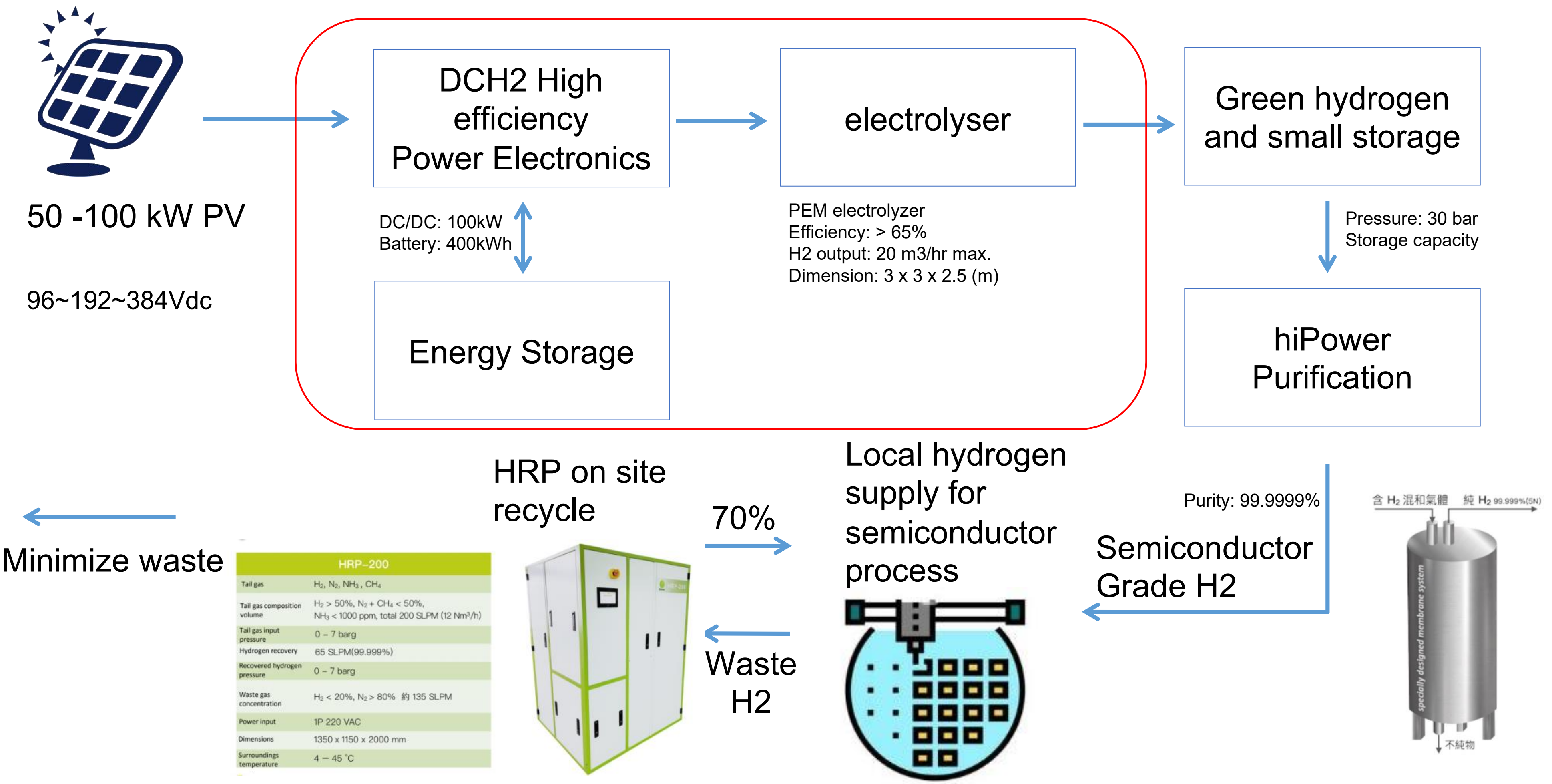
EMS – Holistic system optimisation (with Brunel)

End-user engagement – ports & port authorities

End-user engagement – ports & port authorities and perspective of the vehicle/fleet owner

HySEM project – Green Hydrogen to decarbonise Semiconductor Industry

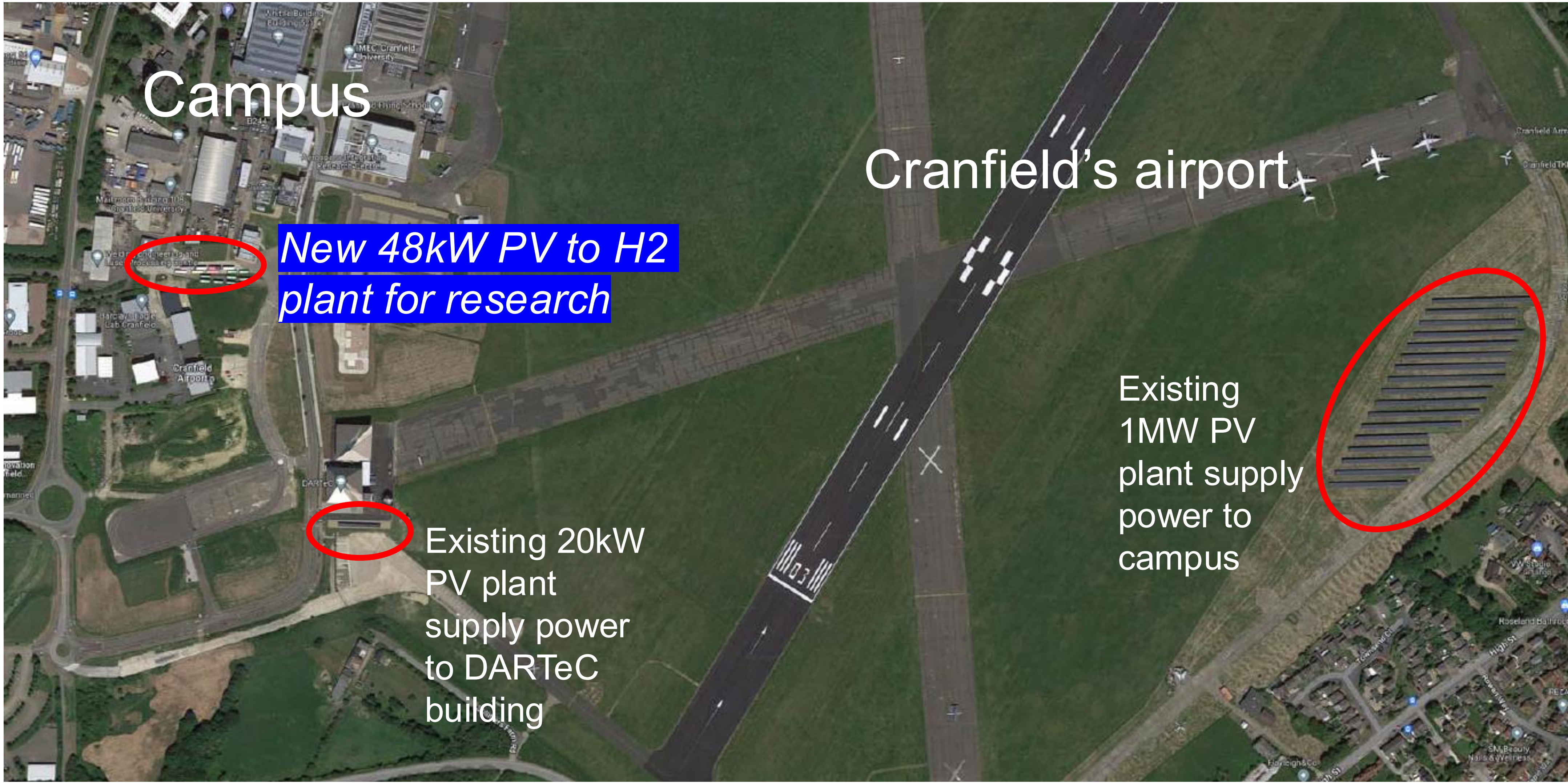
This project is to develop a modularised renewable-to-hydrogen system to produce high purity green hydrogen for use in semiconductor manufacturing process (e.g., plasma cleaning, etching, doping etc.). A typical medium-size seminconductor manufacturer consumes 400 to 500 kg of high purity hydrogen per day.



HRP–200	
Tail gas	H_2, N_2, NH_3, CH_4
Tail gas composition volume	H_2 > 50%, $N_2 + CH_4$ < 50%, NH_3 < 1000 ppm, total 200 SLPM (12 Nm^3/h)
Tail gas input pressure	0 – 7 barg
Hydrogen recovery	65 SLPM(99.999%)
Recovered hydrogen pressure	0 – 7 barg
Waste gas concentration	H_2 < 20%, N_2 > 80% 約 135 SLPM
Power input	1P 220 VAC
Dimensions	1350 x 1150 x 2000 mm
Surroundings temperature	4 – 45 °C

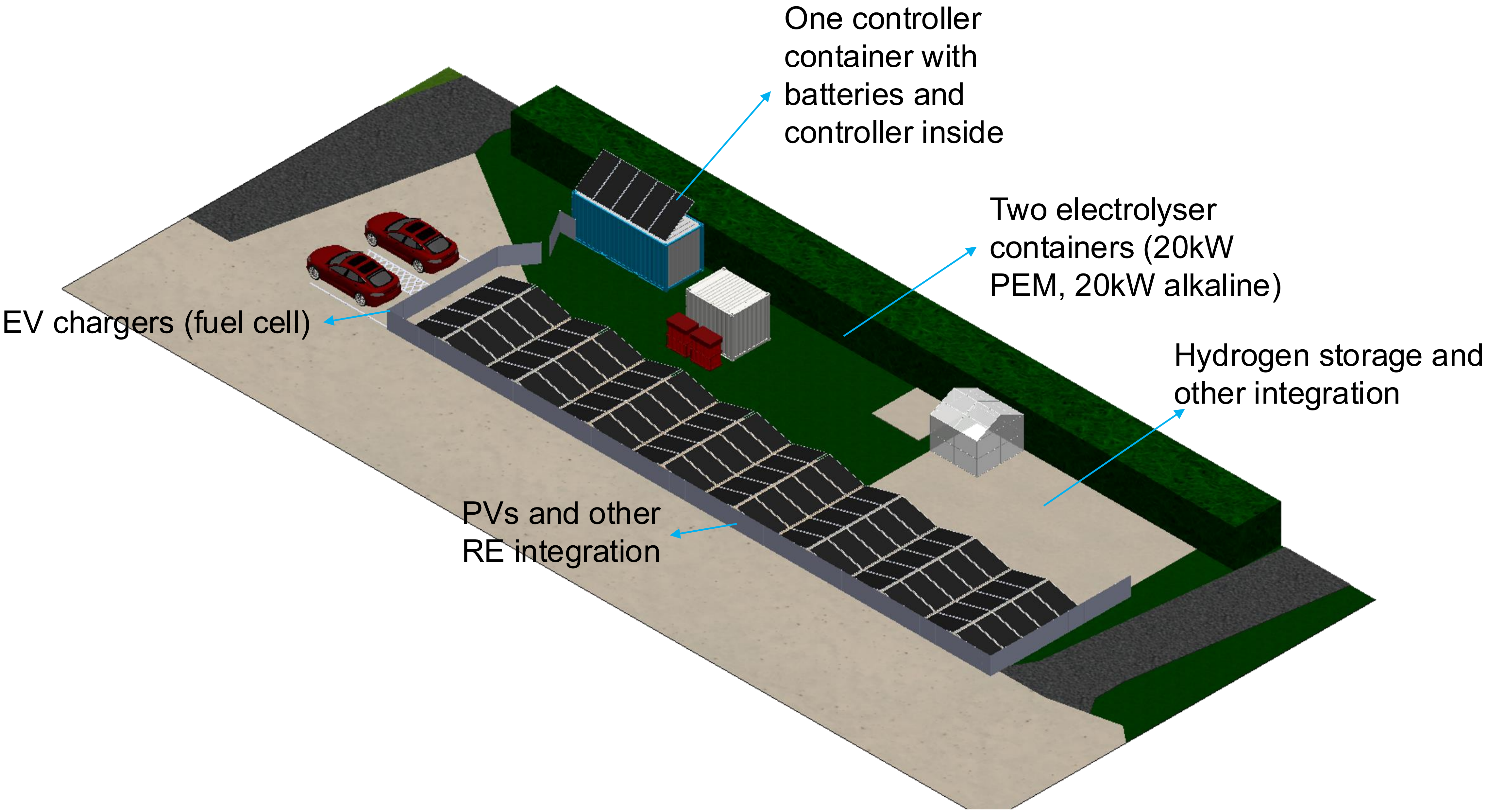
Pilot 48kW PV to H2 plant for research

Existing PV plants and the newPV-to-H2 plant



Deployment of modularized PV panels

Our pilot solar-to-electrolysis research facility



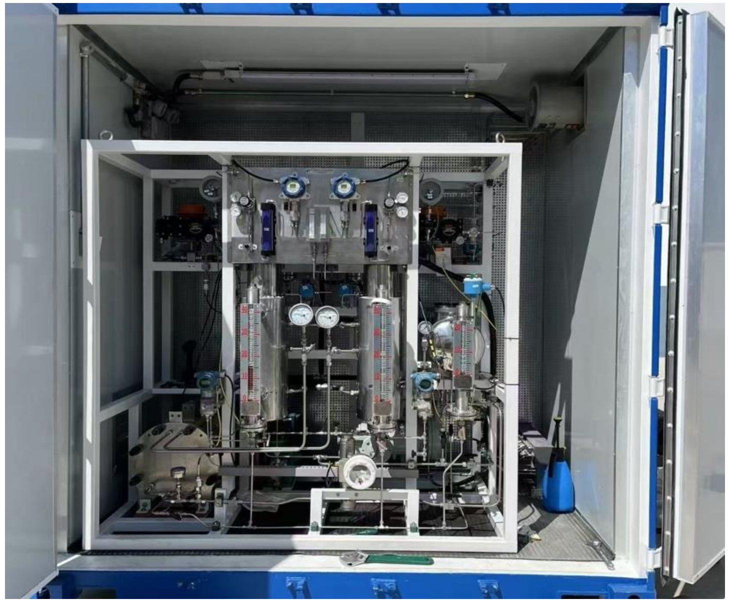
Current facilities

48kW PVs

battery storage

20kW PEM with A/B testing

20kW Alkaline

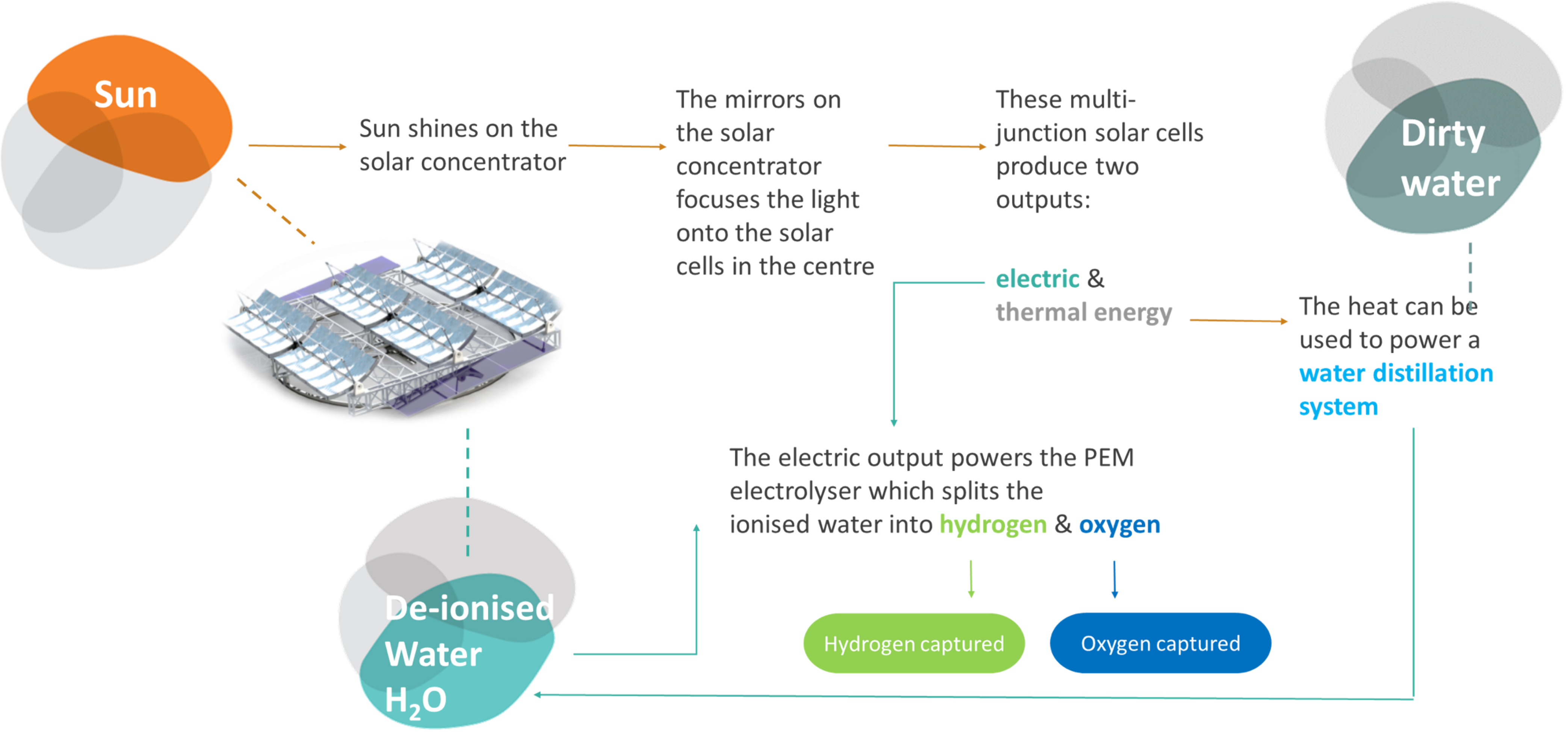


Birdview of the site

Concentrated PV (CPV) Research

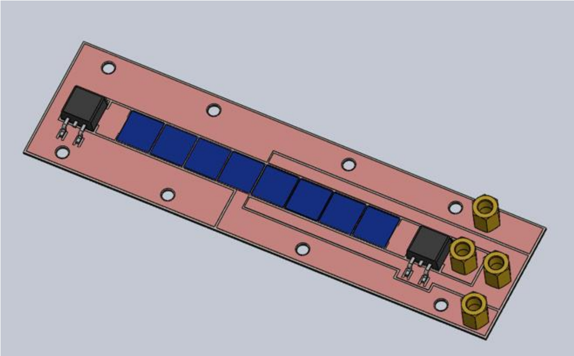
HH-Gen project: High performance green hydrogen generation from solar energy

Overall concept

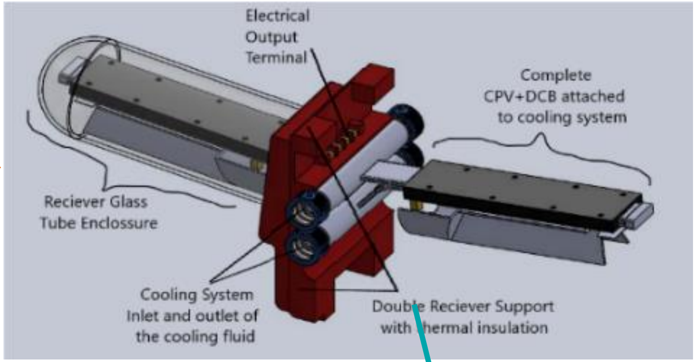


HH-Gen project: High performance green hydrogen generation from solar energy

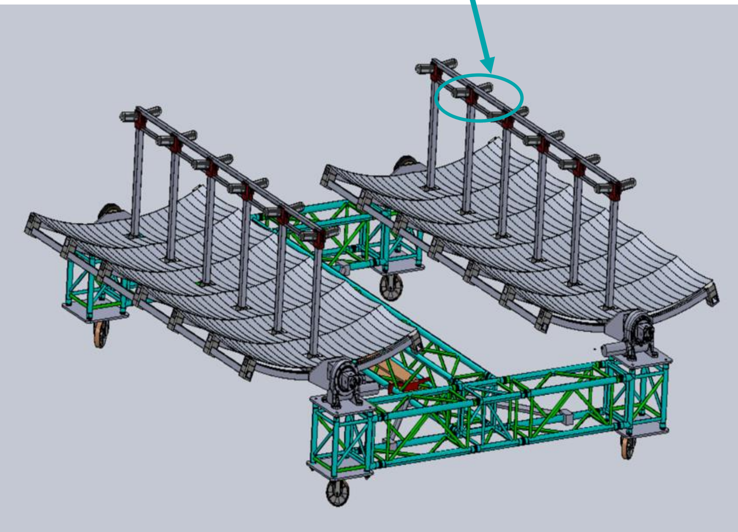
Advanced 5-junction solar cells



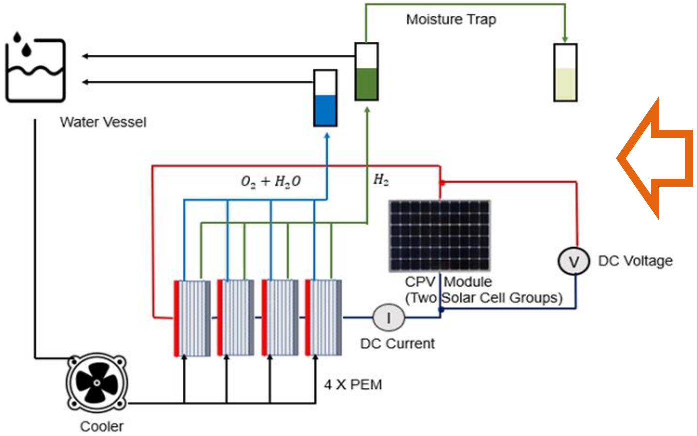
CPV module design



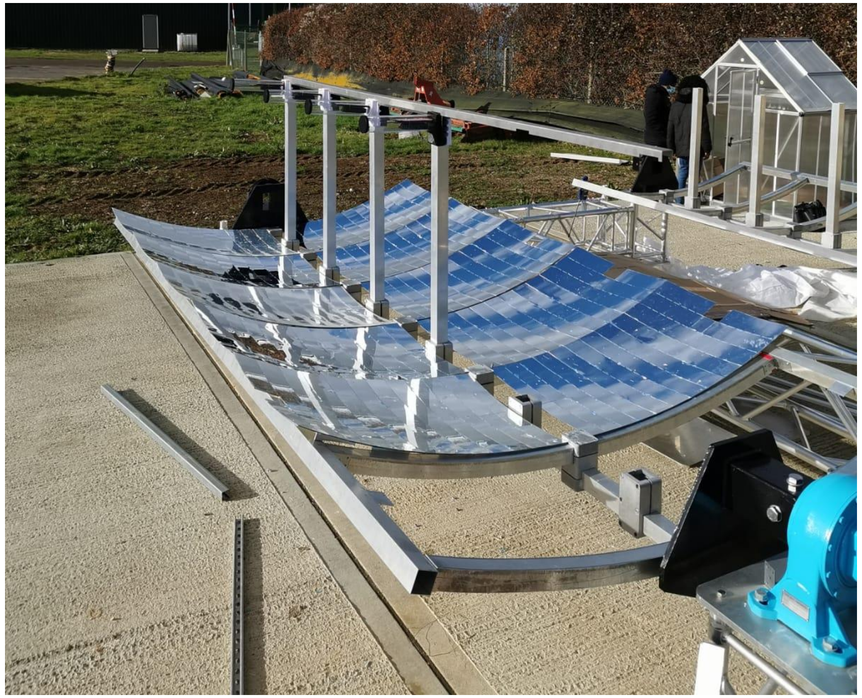
Demonstrator design



Direct coupling with electrolyser to produce H_2

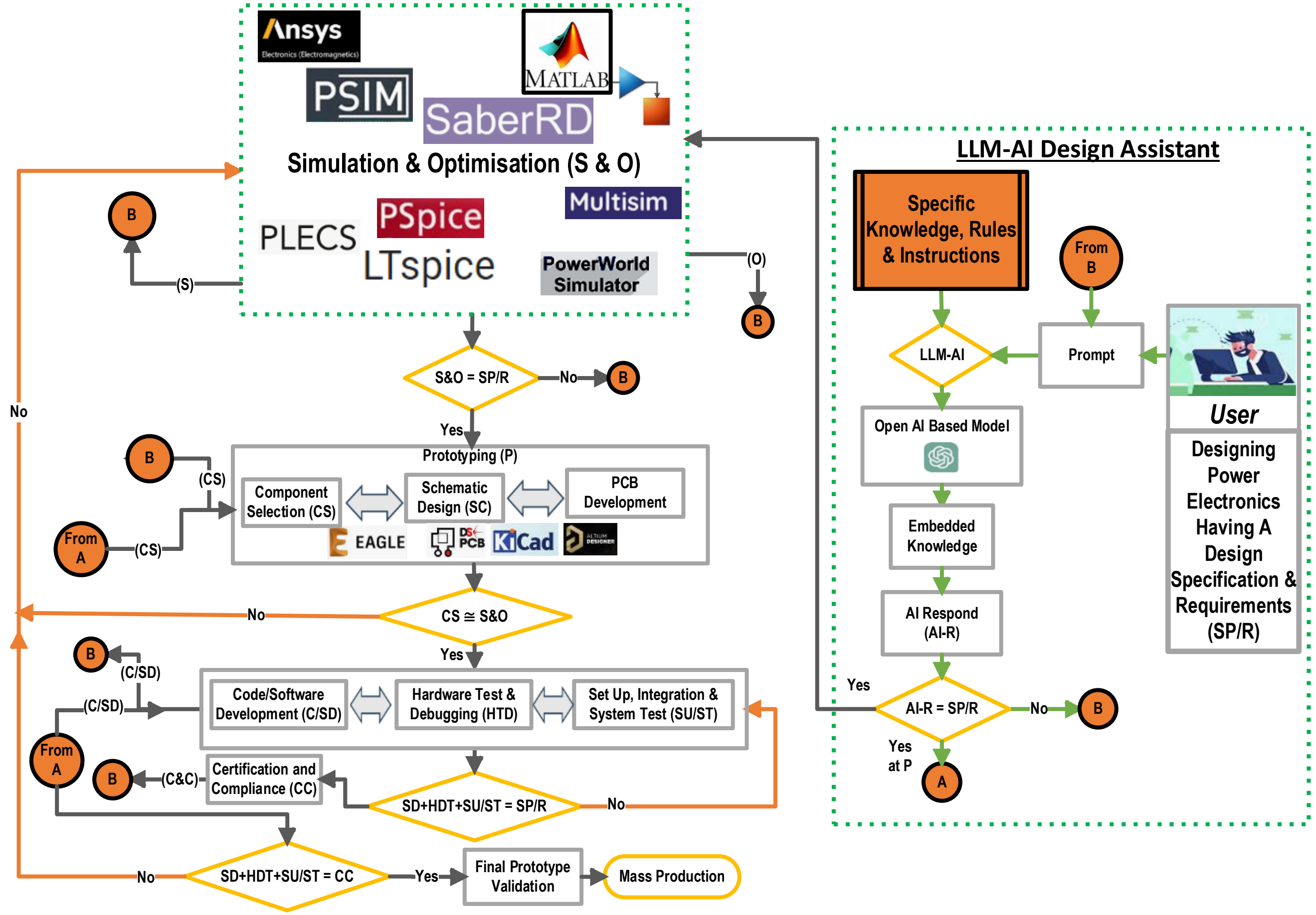


Demonstrator being built at Cranfield

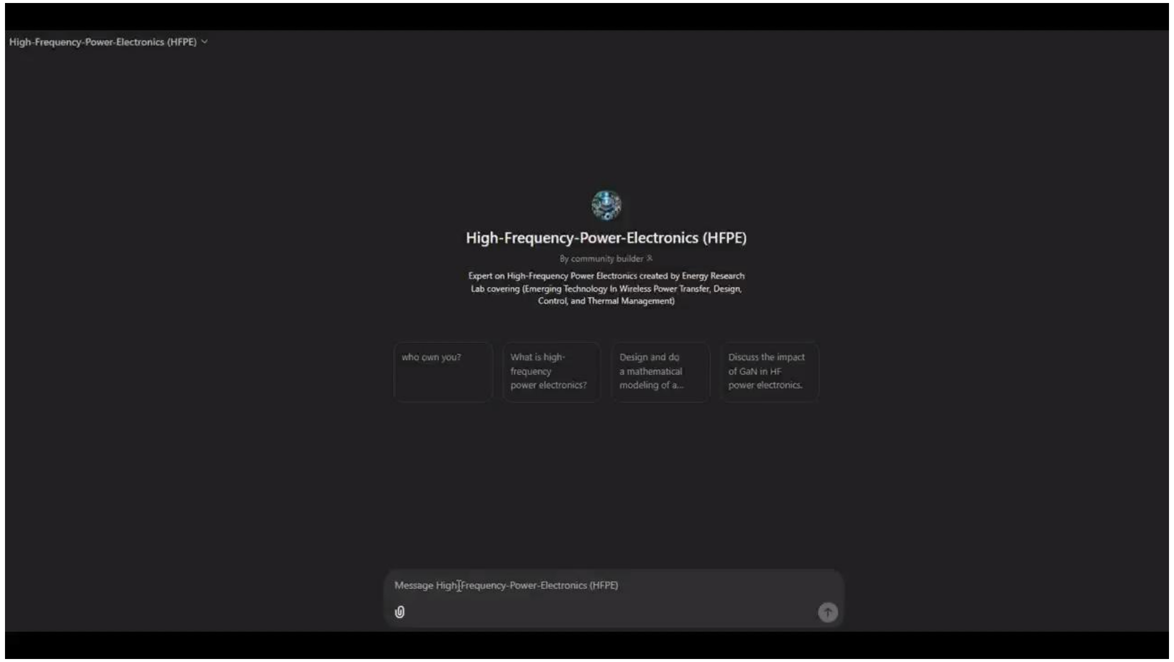


Our other research

Recent research highlights – AI driven power-electronics design



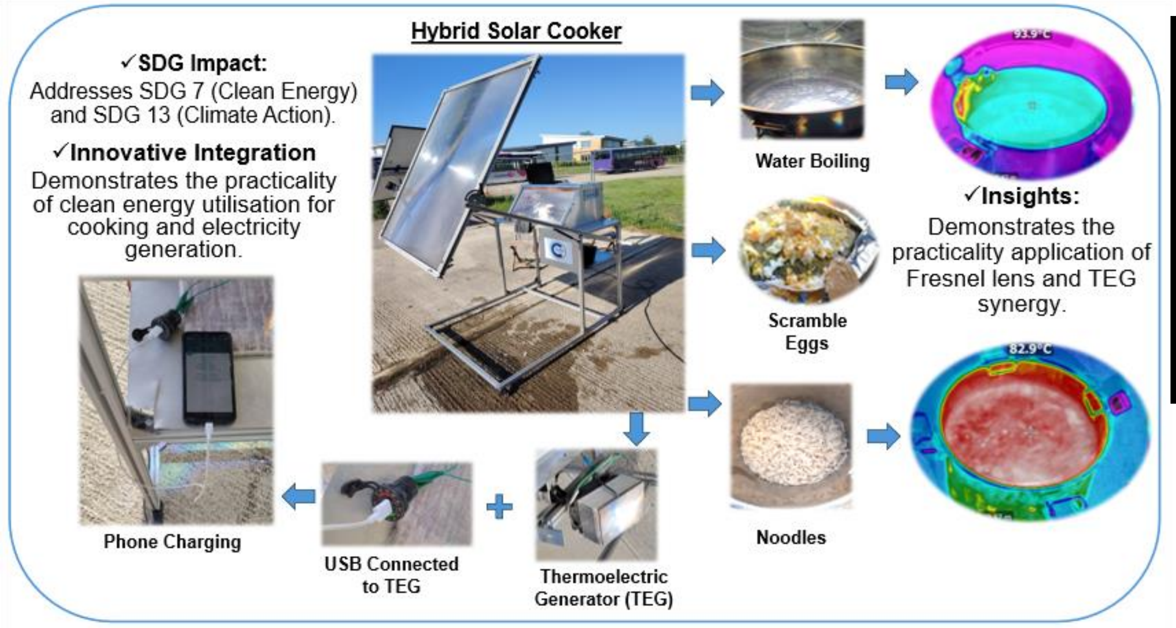
3.1 LLM-AI power electronic design automation framework



3.2 Investigated LLM-AI power electronic design automation

- Traditional PE design is time-intensive, resource-heavy, and prone to human error
- Previous AI improves efficiency but remains limited, LLMs enable faster, smarter and simplifying design
- Up to 50 to 70% time reduction in design complexity and higher accuracy

Recent research highlights – Low-cost hybrid solar cooker for off-grid communities in northern Nigeria



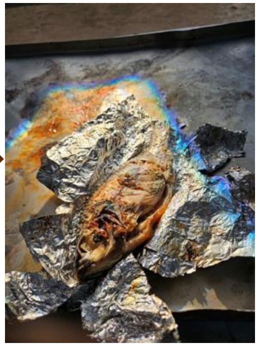
4.1 Solar hybrid cooker

4.2 Boiling water testing

4.3 Boiling water testing

4.4 Sausage grilled

Demonstration in Nigeria & Ghana



4.6 Fish grilled

4.5 fried yam & boiled egg cooked

- Hybrid solar cooker with Fresnel lens + TEG
- Cooks food & generates electricity
- Reached 280°C cooking temperature
- 44% combined efficiency, better than conventional cookers
- Modular, ideal for off-grid use
- Sustainable cooking solution remote areas

Recent research highlights – Metamaterial greenhouse glazing -

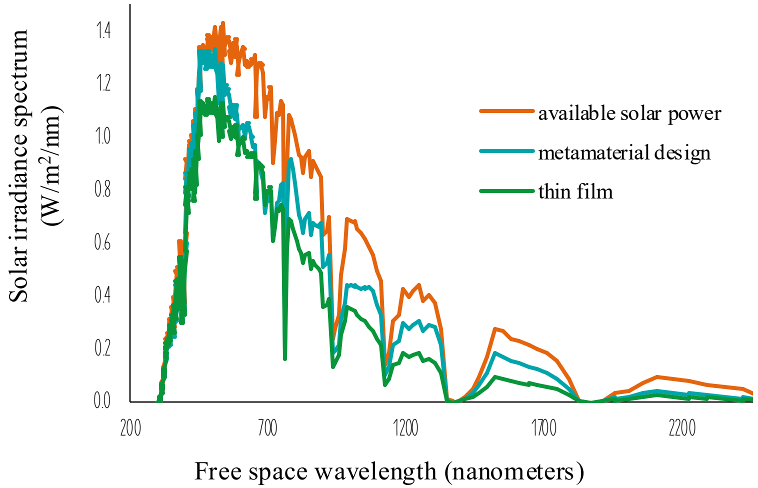


Fig 8.1 Total available solar energy and the captured energy

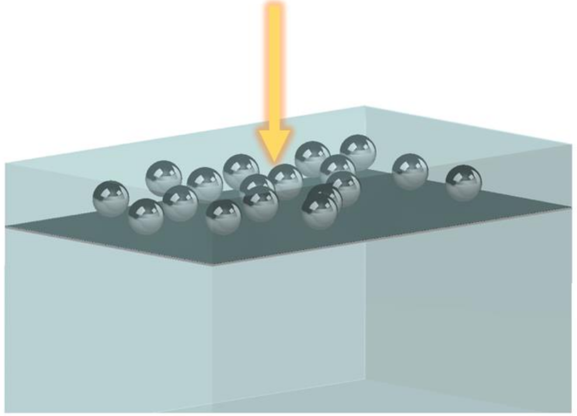


Fig 8.2 Conceptual rendering of the proposed metamaterial design (not to scale)

- The metamaterial design proposed was shown to improve capture of additional solar energy normally wasted by low-e glass using NPs that can be fabricated on a larger scale has been shown.
- The total effectiveness of the design was 11% improvement over the existing design based on the calculation procedures given by the ISO:9050 standard.
- Utilised FDTD EM wave propagation simulation to estimate the metamaterial performance.

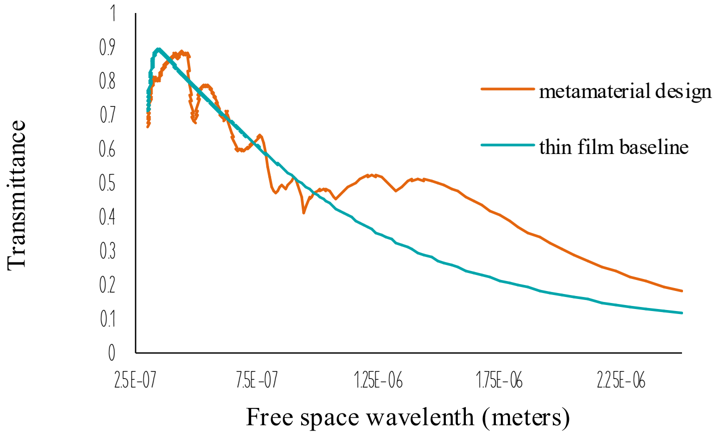


Fig 8.3 Spectral transmittance of solar irradiance of metamaterial design

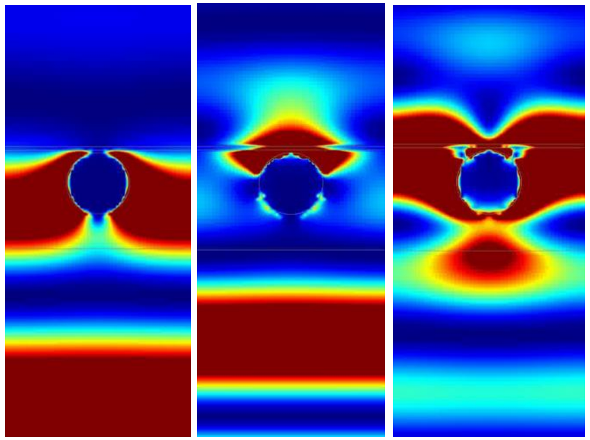
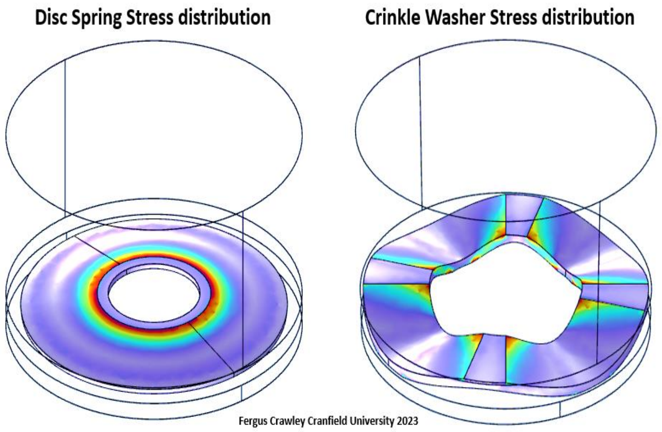


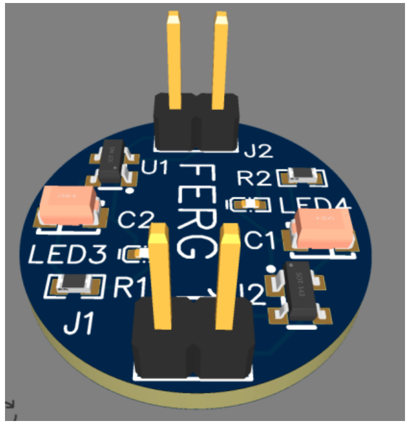
Fig 8.4 Sequence of contours of electric field showing the pulse interacting with the NP and the thin film. (The intensity of the field is normalised in each frame)

Recent research highlights – Energy harvesting for defense

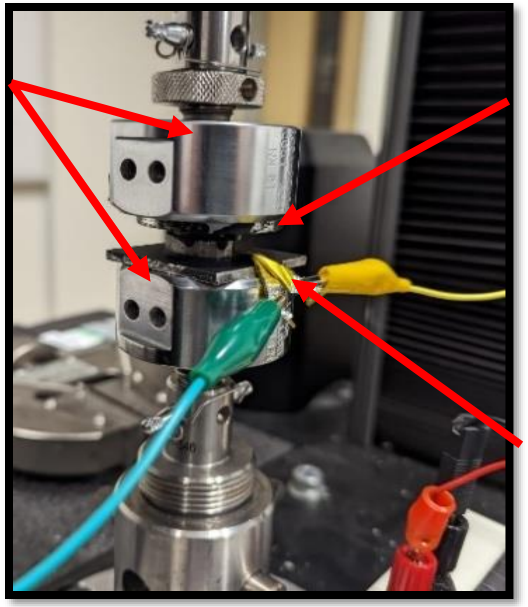
- Integrating energy harvesting systems into to projectiles
- Optimise electrical energy production of piezo electronics using novel springs
- Design energy harvester and electronics into small forms
- Simulate electrical and mechanical integrations



6.1 Simulation



6.2 PCB



6.3 Experiment

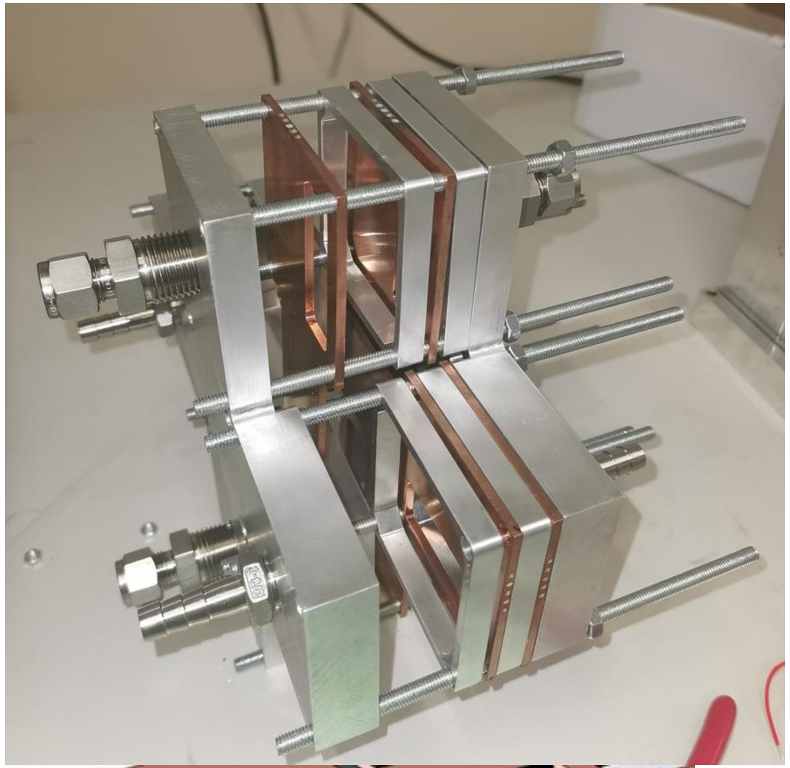
Recent research highlights – Thermo-electric generator research

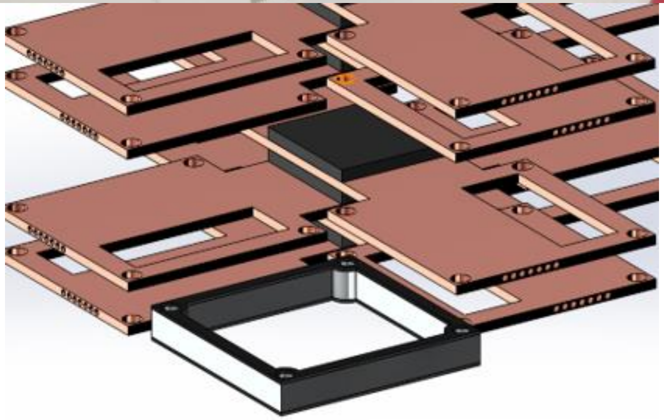
- Novel Thermal energy recovery system using thermoelectric generators.

- Heat tube integrated copper plates that allow high density generation and thermal transfer.

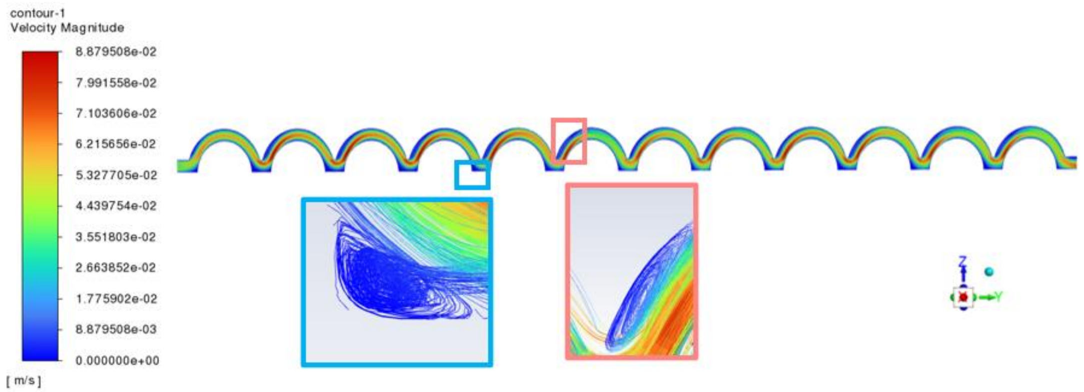
- The system was designed for large scale thermal waste, such as gas generators and industrial processes that have high temperature thermal loss.

7.1 Fabricated energy recovery system



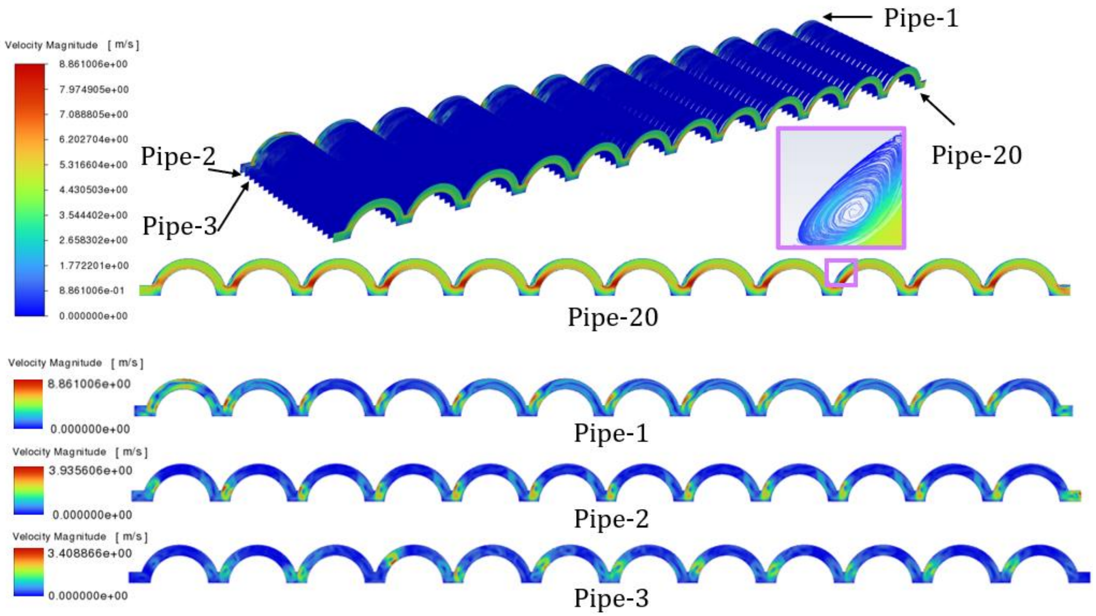


Recent research highlights – Novel thermal management technique for battery cooling



Continuous cooling

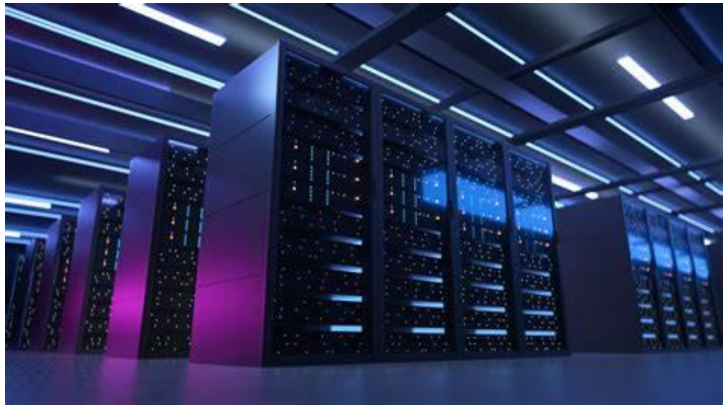
- The flow in the pipe reaches steady state for continuous cooling
- Thick low velocity flow layers at constant position
- Local hot spot generated at low-speed flow locations



Scanning cooling

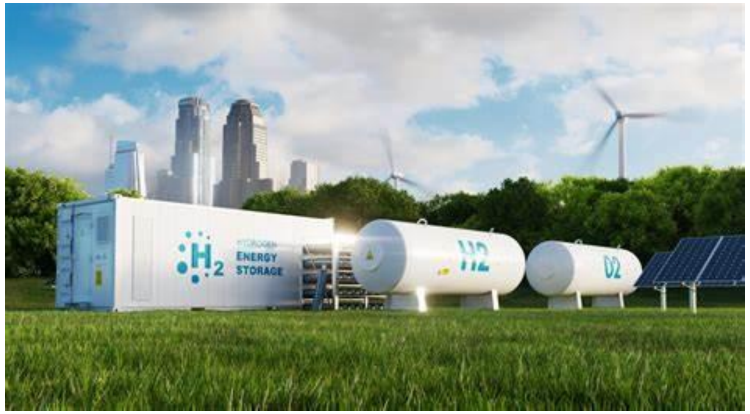
- The flow in pipe changes all the time for scanning cooling
- Scanning flow reduced the boundary layer thickness
- The flow state in pipe is constantly changing
- No local heat spot generates

Other applications of the thermal management innovation



Data centre

Concentrated PV



Hydrogen electrolyser
and fuel cell

EV ultra-fast charger
and DC bus

Examples of Our Clients, Collaborations, and Sponsors

UKRI Innovate UK

THE ROYAL SOCIETY

ENERGY RESEARCH LAB

UK Power Networks
Delivering your electricity

NetworkRail

Royal Academy of Engineering

Newton Fund

UKRI Engineering and Physical Sciences Research Council

Ministry of Defence

Fraunhofer

HyWaves

TCS
TEconversion.com
THERMOELECTRIC CONVERSION SYSTEMS

TARDEC

5B

BAE

BRITISH COUNCIL

FAW

bp

lightsource bp

MITSUBISHI MOTORS
Drive your Ambition

UKRI UK Research and Innovation

heif HIGHER EDUCATION INNOVATION FUND