Presentation to the visiting students of
Minzu University of China

Environmental Research Institute

"Pathways of Water, Heat and Light to Novel Renewable Energy Sources: The *Translate* and *FreeHydroCells* Projects"

translate
waste heat to electricity

Dr Ailbe (Scott) Ó Manacháin (Monaghan)

with ***Dr Jun Lin*** *supporting…*

Environmental Research Institute (ERI)
University College Cork, Ireland

Free Hydro Cells

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 964251.

Funded by the European Union

20 March 2024

~€3.4M, 48 Months

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UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

TECHNISCHE UNIVERSITÄT DARMSTADT

UNIVERSITY OF LATVIA

CIDETE
EL ARTE DE REFRIGERAR
TERMOELECTRICIDAD

UCC ACADEMY

~€4.8M, 40 Months

Free Hydro Cells

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

RWTH AACHEN UNIVERSITY

Consiglio Nazionale delle Ricerche

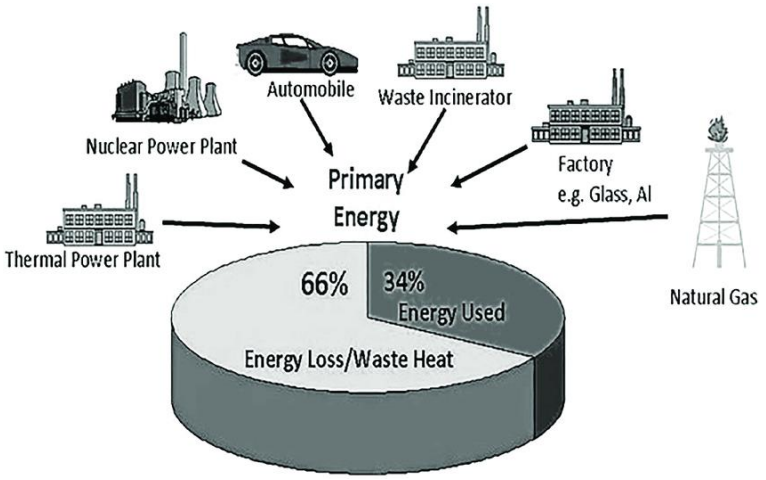
cea

AMO

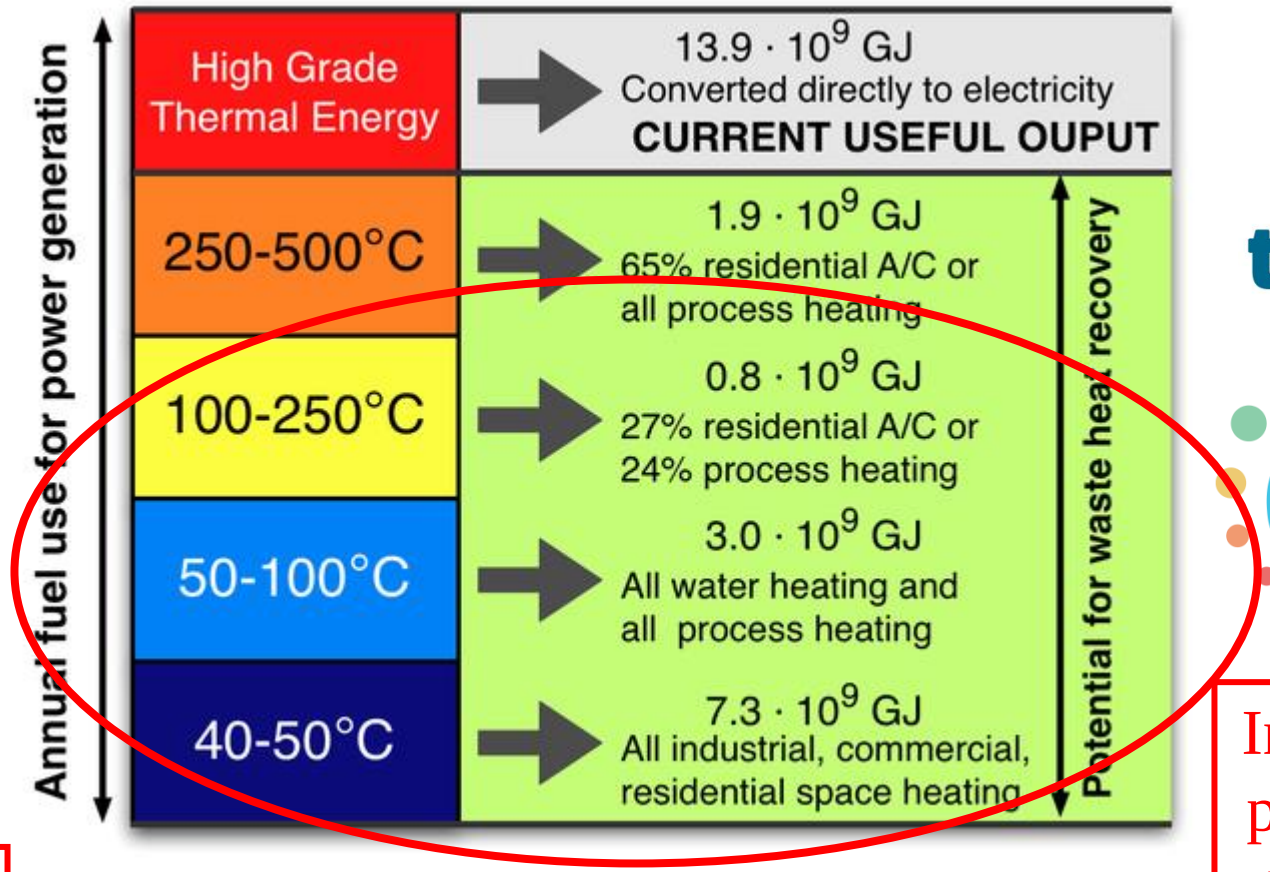
BARDS
A Sound Approach to Chemical Analysis

UCC ACADEMY

Introduction – Waste Heat Energy



Waste heat energy from various sources: "Thermal Energy Systems, Design, Computational Techniques, and Apps: https://doi.org/10.1201/9781003395768



Optimal USA energy usage that could be achieved by employing waste heat at each temperature range (https://sites.psu.edu/mtfe/us-waste-heat-resources/)

For all the energy we generate
66 %
is lost as waste heat!

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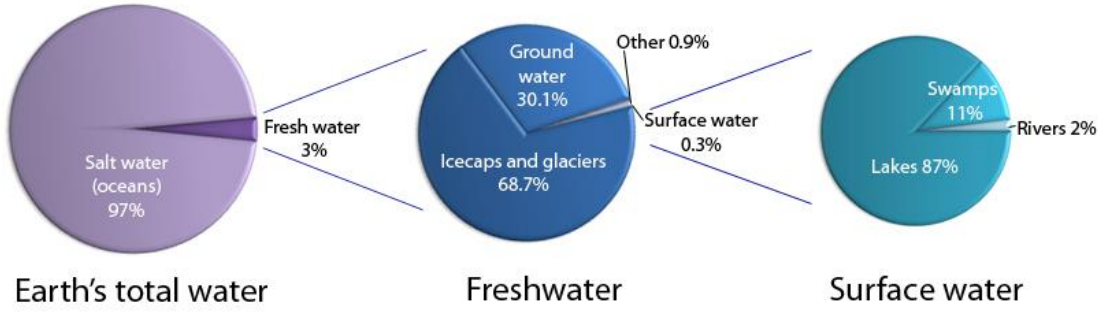
Free Hydro Cells

In the *Translate* project, we aim to capture low grade waste heat!

Introduction – Energy in Water

https://www.earth.com



Earth is ~70 % water!

A water molecule (H_2O)

- 2 hydrogen (2H)
- 1 oxygen (1O)

If we can split water

- 2H → H_2 gas
- Endless fuel source
- Energy storage

H_2 gas is the most efficient fuel in the universe, and with no harmful emissions!

In the *FreeHydroCells* project, we aim to split water and make H_2!

But…?

Introduction – Energy in Light for H_2 Fuel

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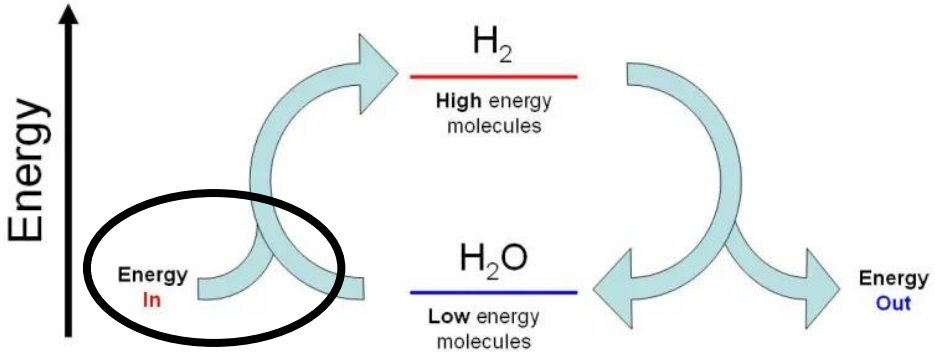
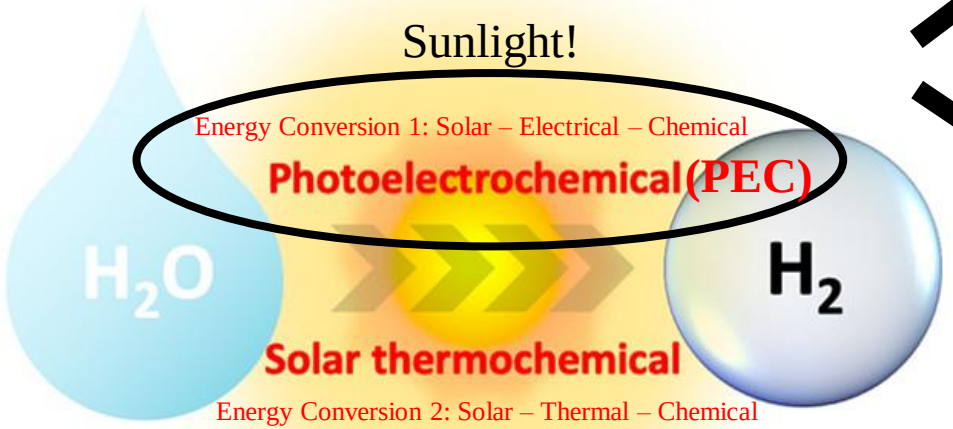
BUT…splitting water needs ENERGY input!?



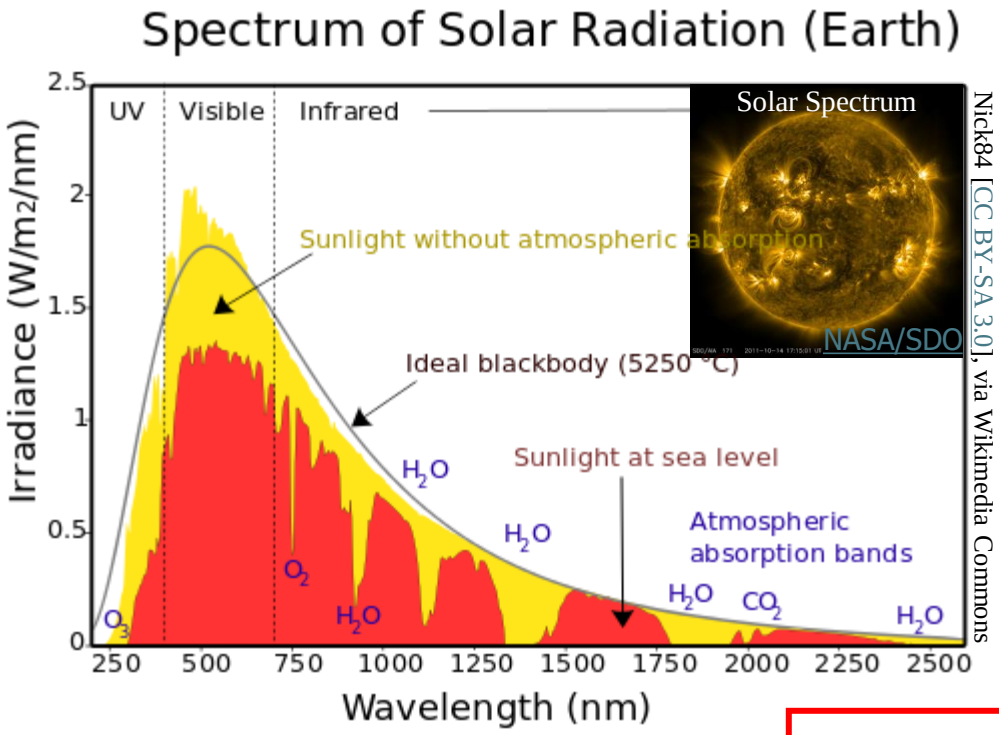
https://electroncafe.wordpress.com/2011/04/11/split-that-water-part-i/

What free source of ENERGY could we use?

Sunlight!



ACS Energy Lett. 2021, 6, 9, 3096–3113
https://doi.org/10.1021/acsenergylett.1c00758



Nick84 [CC BY-SA 3.0], via Wikimedia Commons

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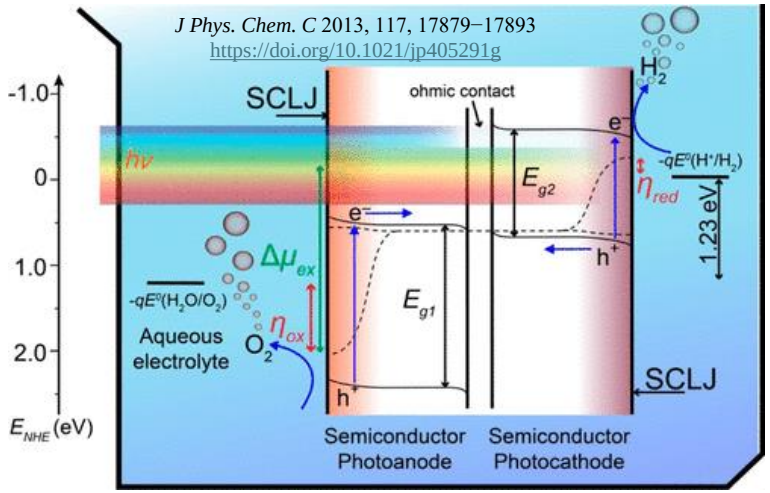
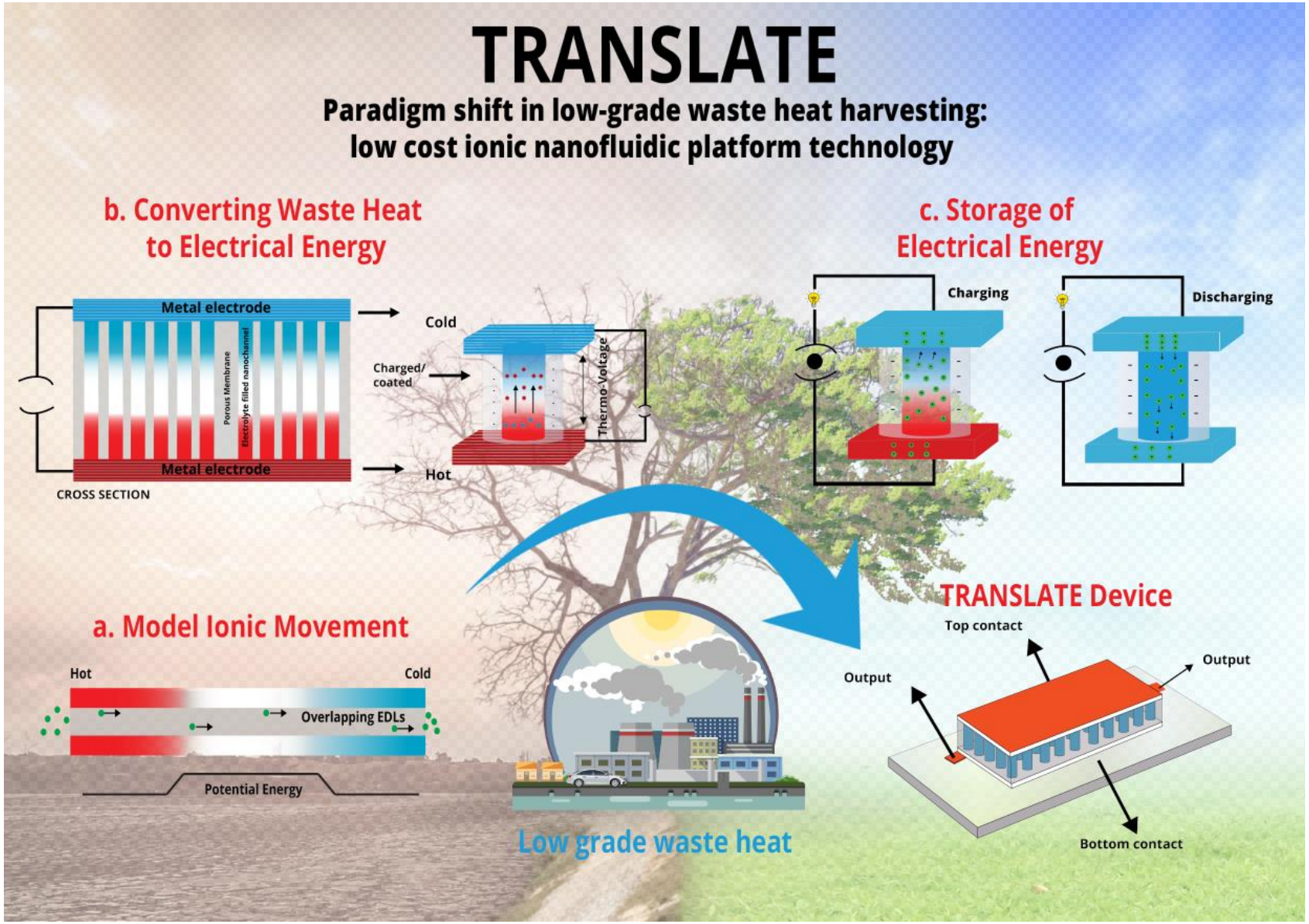
Free Hydro Cells



In the *FreeHydroCells* project, we aim to capture enough sunlight to provide the energy to split water and make H_2 fuel!

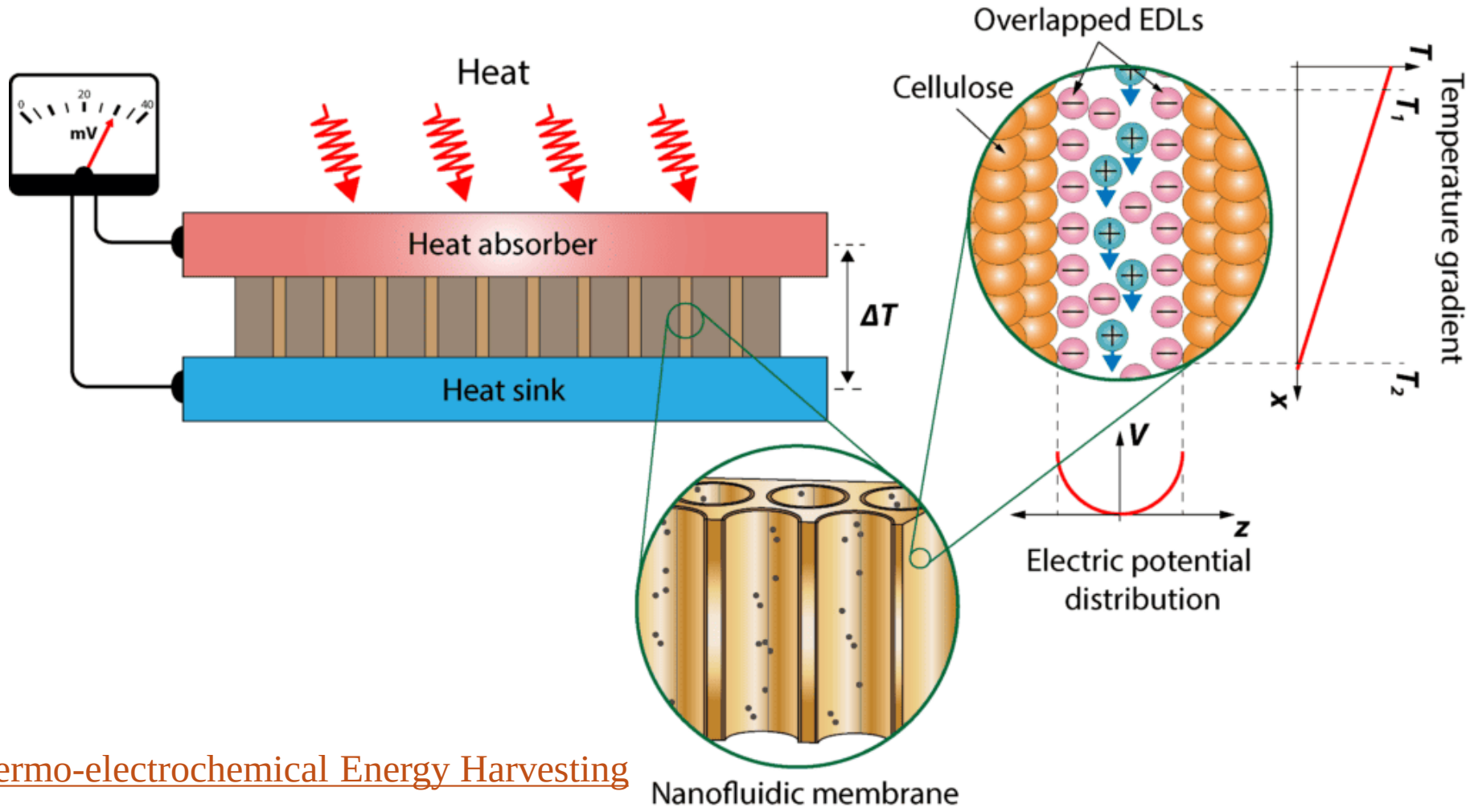
The *Translate* Project



In the *Translate* project, we aim to capture low grade waste heat!

Objectives of the *Translate* Project: Thermo-electrochemical energy harvesting and storage

The *Translate* Project

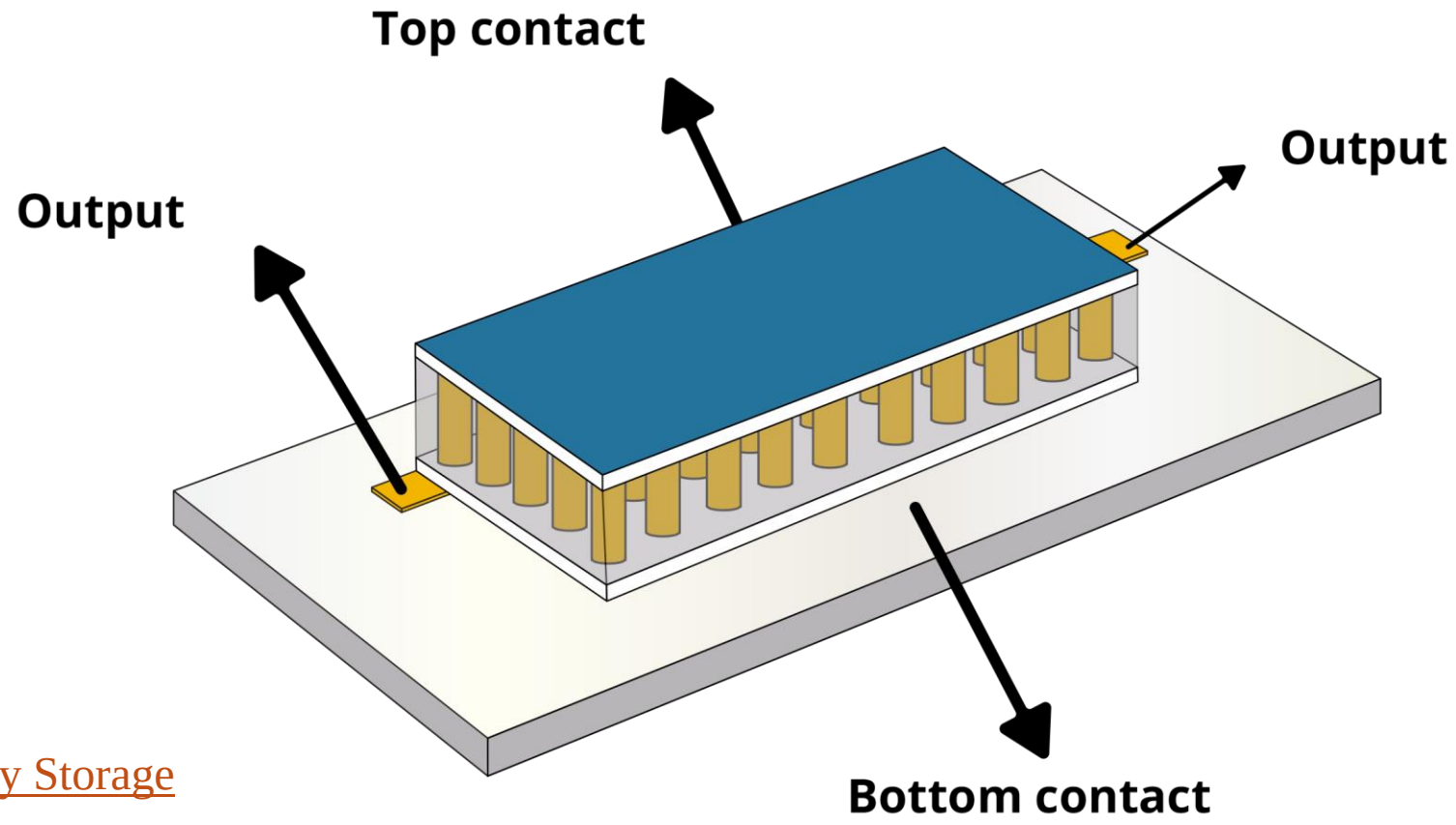


In the *Translate* project, we aim to capture low grade waste heat!

Thermo-electrochemical Energy Harvesting

- Development of a functionalised nanochannel platform based on optimal design.
- Integration of electrode and infiltration of electrolyte to fabricate nanofluidic energy harvester.
- Thermoelectric, electrical and structural characterisation of nanofluidic device.

The *Translate* Project



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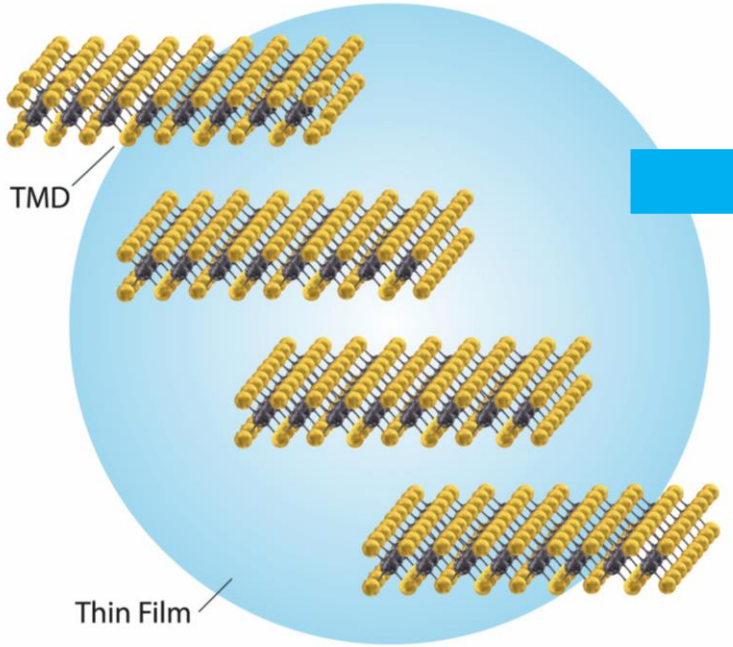
Novel Energy Storage

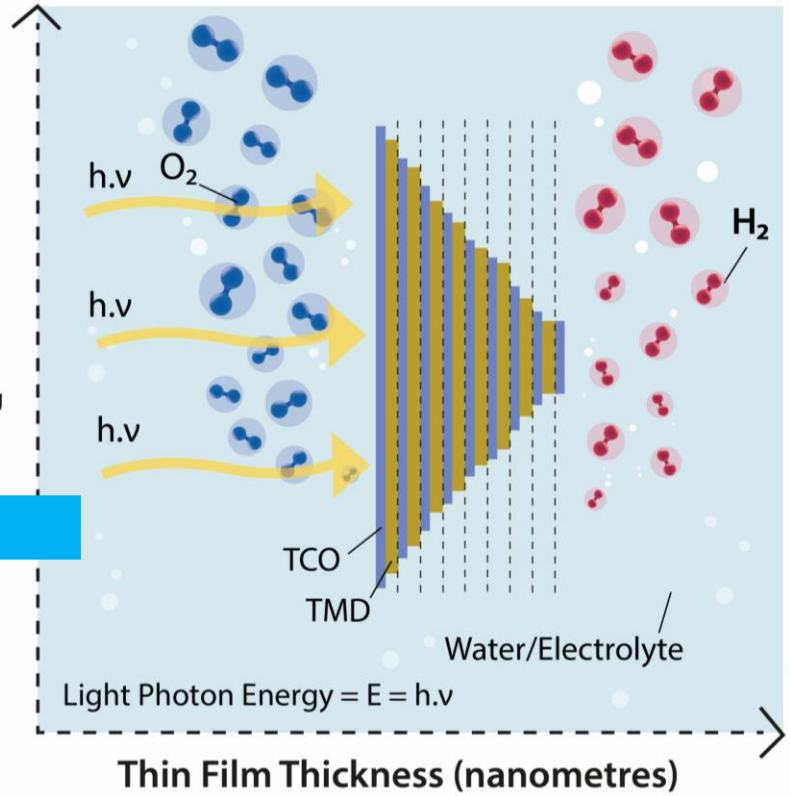
- Synthesis and structural characterisation of electrode materials
- Initial electrochemical testing, under thermal gradient, of intercalation based cells for suitable electrolyte determination
- Systematic investigation of electrolyte salt, solvents and additives
- Detailed electrochemical characterisation of nanofluidic battery-like energy harvesting storage devices, based on the optimal design.

The *FreeHydroCells* Project



Novel Materials

- Thickness, bandgap, conductivity
- Defect saturation, recombination reduction
- Solar irradiation & absorption optimisation
- Doping as N-type or P-type semiconductor



Photoelectrochemical (PEC) Materials Integration & Device/Cell Engineering

- Maximum light absorption
- Cascading bandgap alignment
- Redox alignment
- PN-junctions
- STH Efficiency (diagnostics and benchmarking)

In the *FreeHydroCells* project, we aim to capture enough sunlight to provide the energy to split water and make H_2 fuel!

The *FreeHydroCells* Project – Dr Jun Lin

- **Undergraduate**

Sep 2006 – Aug 2008 Guilin University of Electronic Technology, China

Sep 2008 – Sep 2010: Electrical and Electronic Engineering, UCC, Ireland

1st class honours degree

- **Phd**

Jan 2011 – Dec 2016

Thesis title: "An investigation of border traps and interface states in high-k/InGaAs metal-oxide-semiconductor systems"

Nanoelectronic Materials and Devices Research Group

Tyndall National Institute, UCC

- **Postdoctoral researcher**

Feb 2017- Feb 2023

Advanced Materials and Surfaces Group

Staff Researcher

- Co-PIs of FreeHydroCells, SYNERGY (EU networking project) and AMBER-AMAT project
- Co-supervisor of 2 PhD students
- Lab managers and equipment responsible

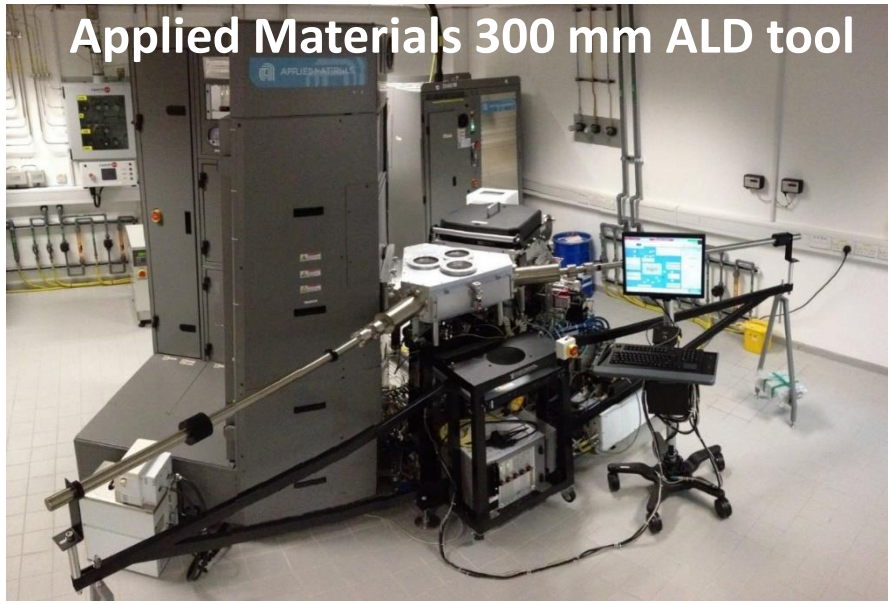
Dr Jun Lin

❑ Labs/Equipment

- Materials: 2D materials (mainly MoS_2) and TCOs
- Chemical vapor deposition (CVD) and atomic layer deposition (ALD)
- Electrical characterisation (Hall-effect)

Research tool with *in situ* monitoring capability

Manufacturing-compatible deposition tool



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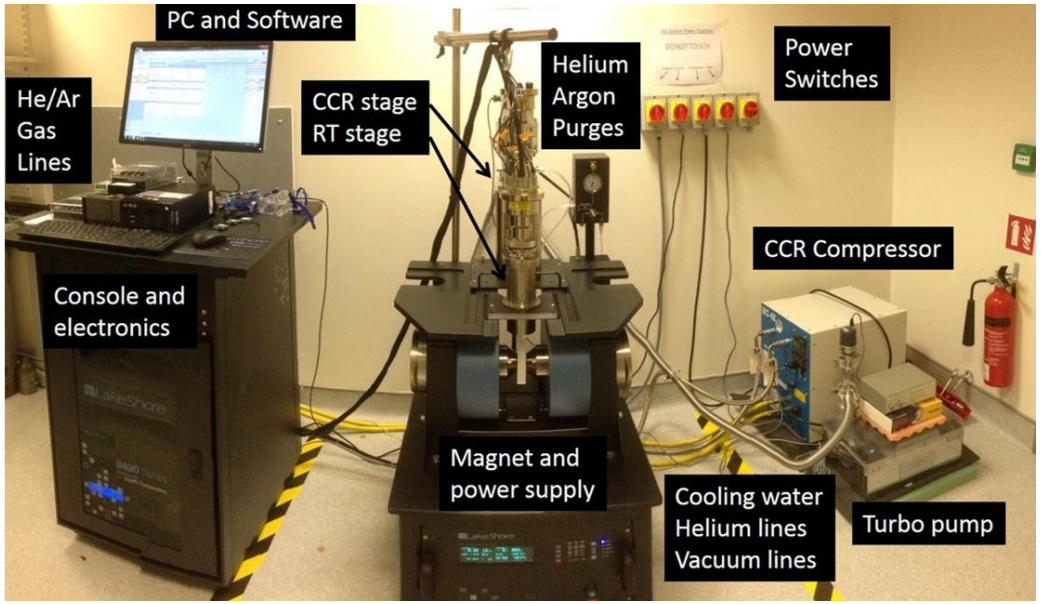
Lakeshore Hall-effect Measurement System



Dr Jun Lin

❑ CVD/ALD

Sub nano-meter growth of the 2D MoS_2 in a 300 mm ALD reactor by CVD.

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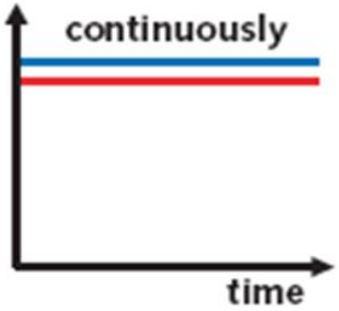
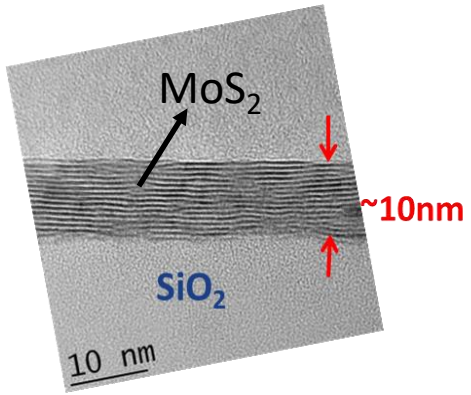
Conventional CVD mode

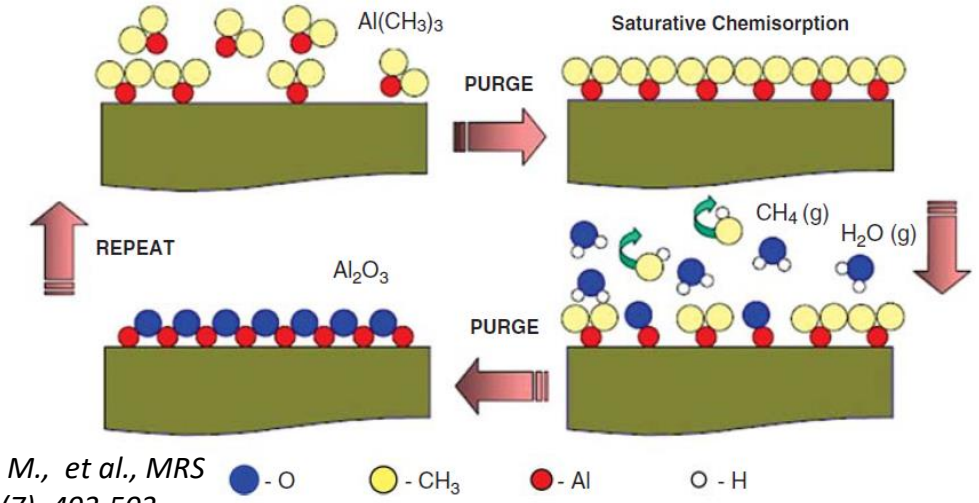




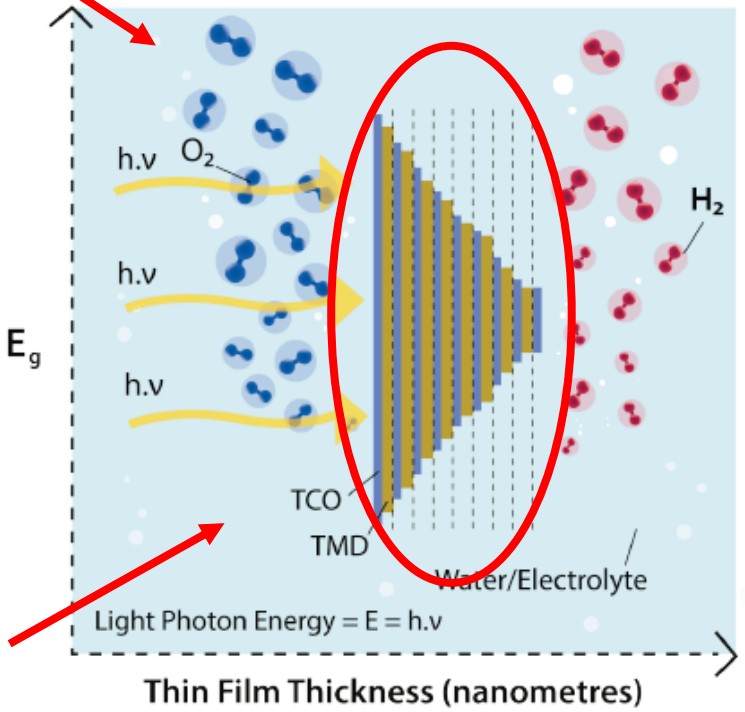
2D MoS_2 by CVD

ALD mode

e.g.



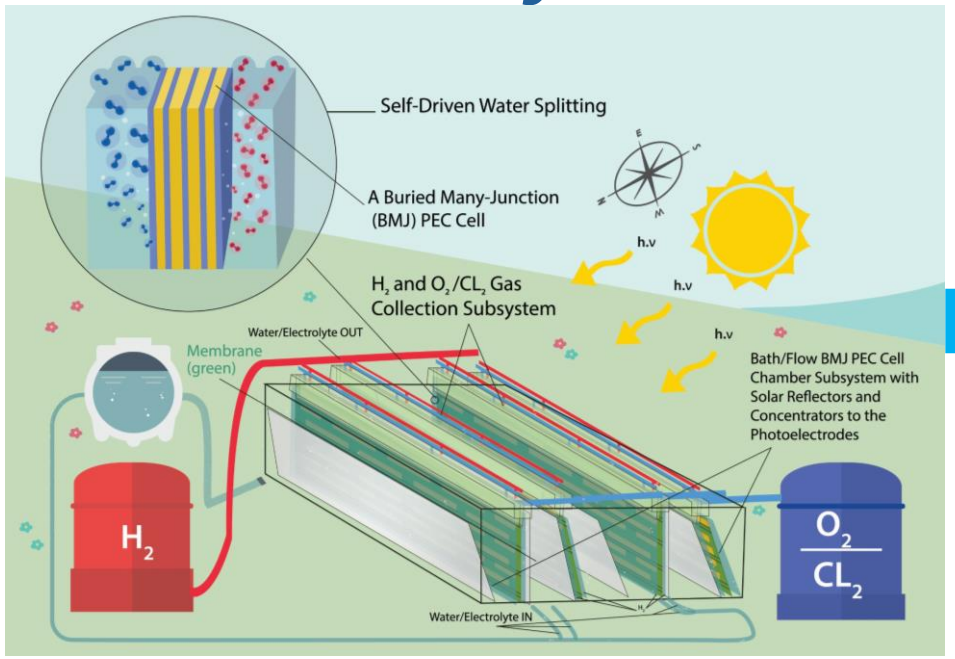
Wallace, R. M., et al., MRS bulletin, 34(7), 493-503



TCOs and protection layers by ALD

- Self-limiting growth (atom scale thickness tuning)
- Highly conformal growth (on complex 3D structure)
- Low temperature growth (delicate substrates)

The *FreeHydroCells* Project

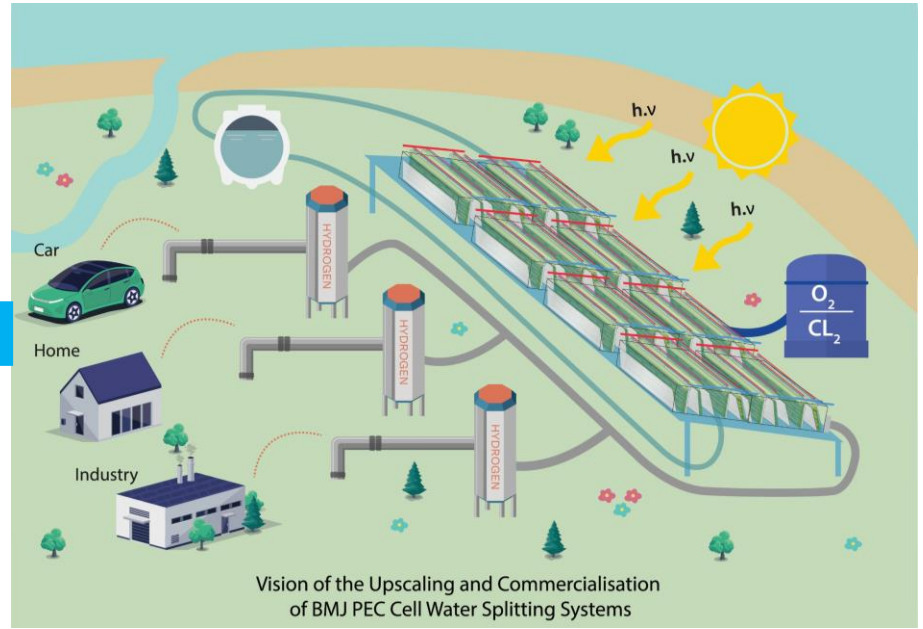


[PEC Cell-to-System Development and Benchmarking]

- System Integration
- Operationally efficiency
- Viable for H_2 gas collection
- Durable with long service life
- Good STH efficiency benchmark

[PEC System Upscaling and Commercialisation]

- Environmentally-benign
- Cost-effective production
- Sufficient sustainability
- Good life-cycle predictions
- Commercially viable



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The *FreeHydroCells* Project

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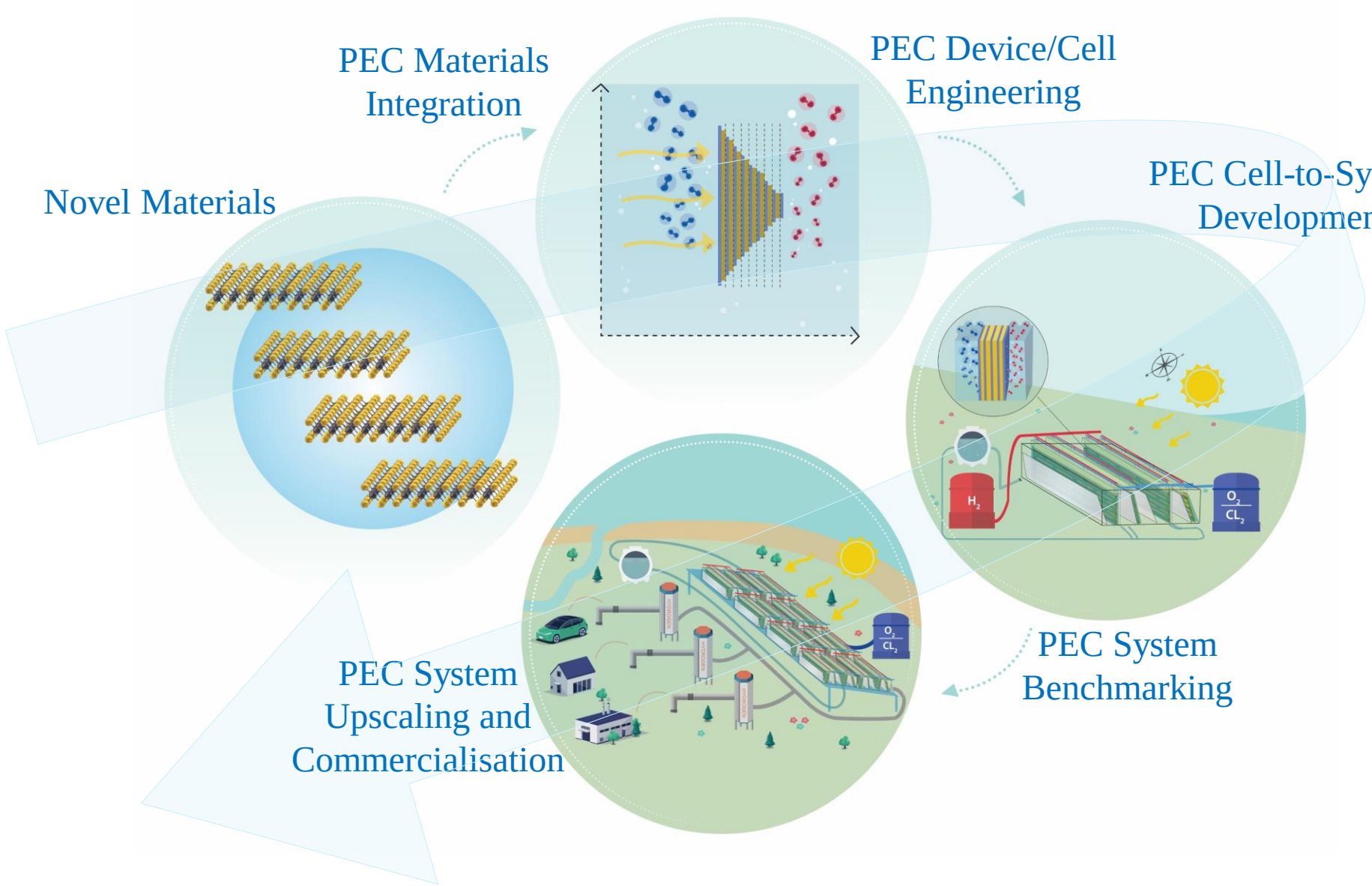
Free Hydro Cells



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Acknowledgements

Dr Jun Lin (TNI, UCC)

Abhisweta Bhattacharjee, Rebecca Buckley and Anna Power (UCC Academy)

Translate and *FreeHydroCells* Project Teams

Thank you!

Questions?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 964251.

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