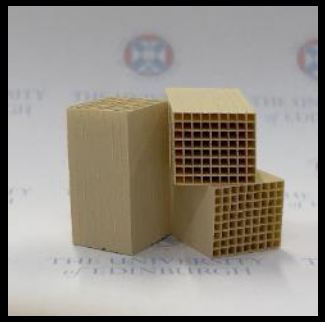
Turning Heat into Cooling

Laboratory of Emerging Sustainable Technologies
The University of Edinburgh – School of Engineering

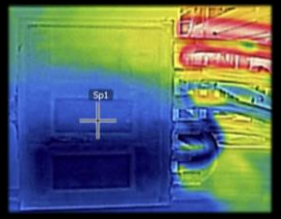










Giulio Santori
The University of Edinburgh
School of Engineering
Institute for Materials and Processes

2 May 2023
Sorption Friends III, Taormina

People first (past and present)

Giulio Santori (UK)
Shihab AL-Hasni (Oman, current)
Eloise Bevan (UK, current)
Marwan Mohammed (Sudan, current)
Amir Zivari (Iran, current)
Christopher Olkis (Germany)
Chiara Di Santis (Italy)
Charithea Charalambous (Cyprus)
Ahmed Askalany (Egypt)
Hongesheng Dong (China)

Outline

ESTech-Lab Remit

Approach

What we have done and why

What we are doing

ESTech-Lab Remit

1. The ESTech-Lab forges innovative zero-carbon and **carbon-negative** technologies powered by ultralow-grade heat **<60°C**, the least exploitable type of energy.

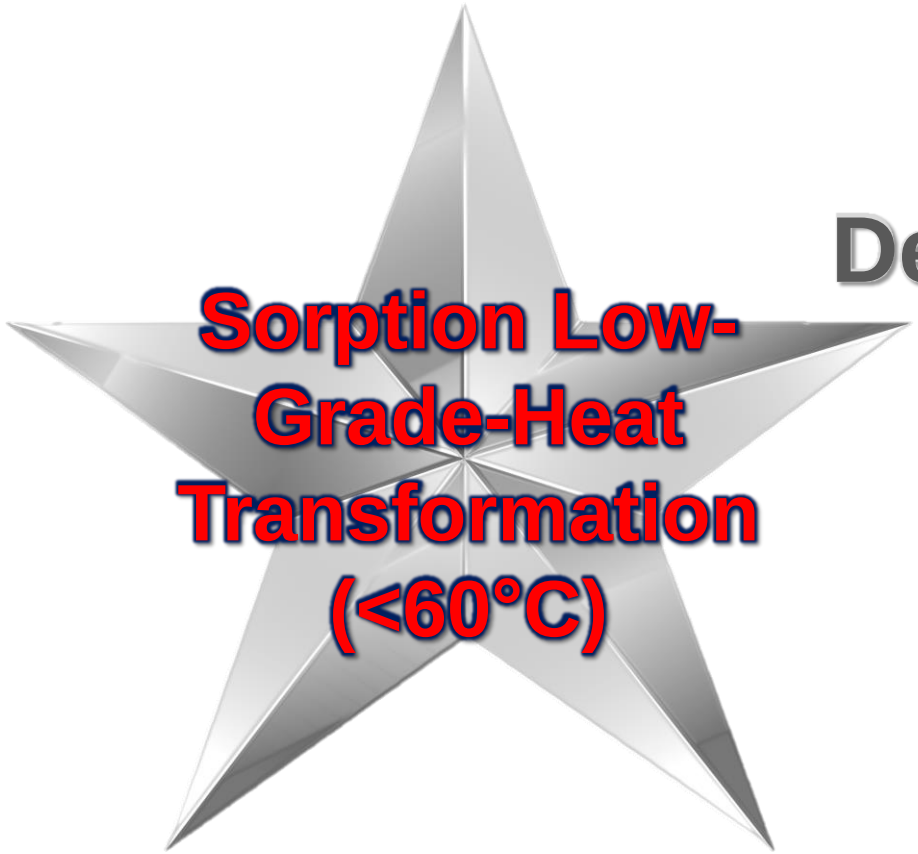
2. Despite its vast availability, no process is attractive enough to motivate ultralow-grade heat exploitation, leaving the resource wasted to the environment, a crime in the enduring energy shortage that society is facing.
In the ESTech-Lab this heat is an **opportunity**.

3. The ESTech-Lab demonstrates the **conversion** of ultralow-grade heat into other forms of **energy** or its **use** in **separation** processes.

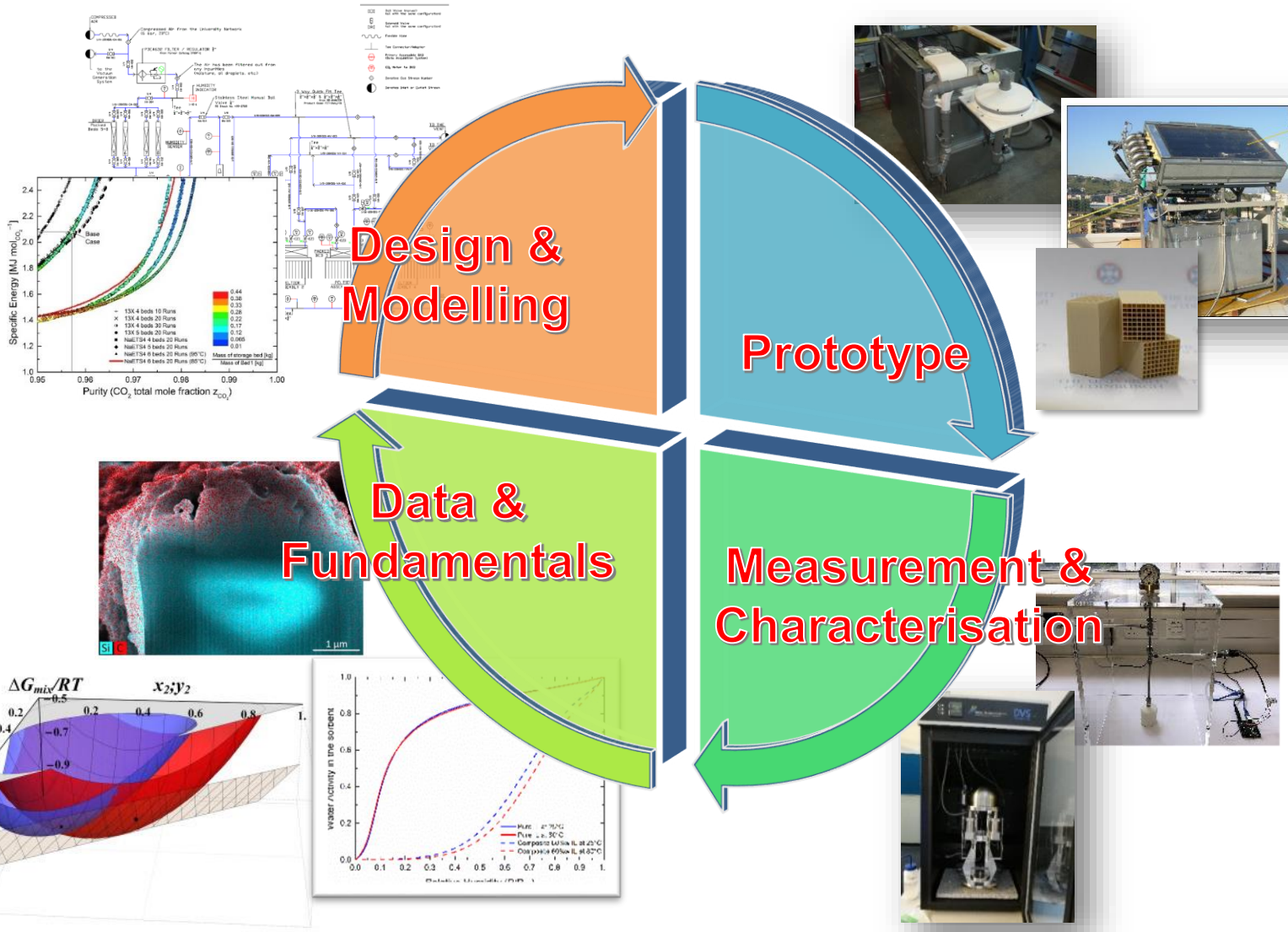
4. For all members, the ESTech-Lab is a school **educating ingenuity** and a nurturing environment for the conception and the growth of Heat-to-X technologies that can constitute the backbone of a new energy system.

Energy Journal Special Issue Solutions for Ultra-Low Temperature Heat Recovery and Utilization

Sorption Heat Transformation (or TSA)



ESTech-Lab research approach



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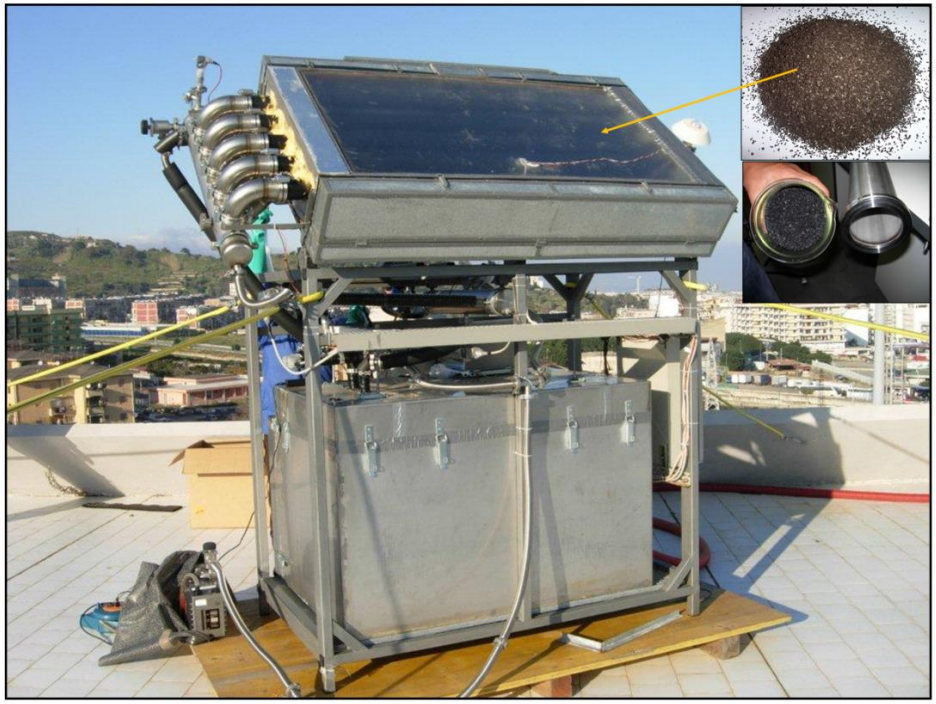
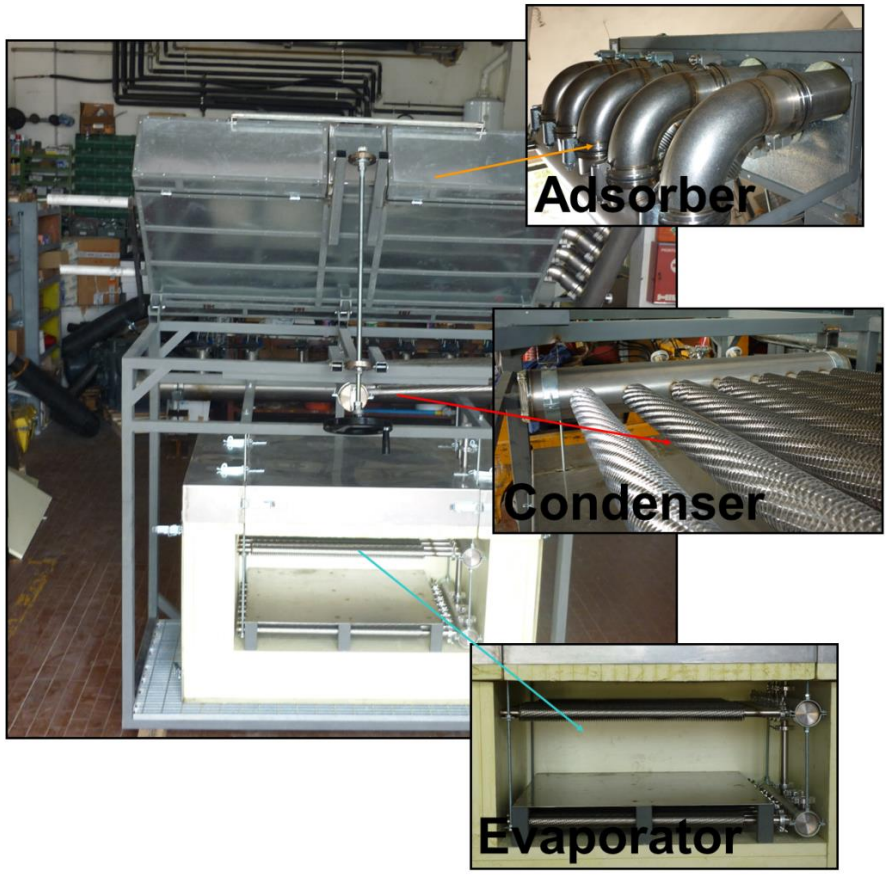
What we have done

Stand alone ice maker for cold storage (vaccine, food)





Effect: 5-10 kg of ice at -13°C

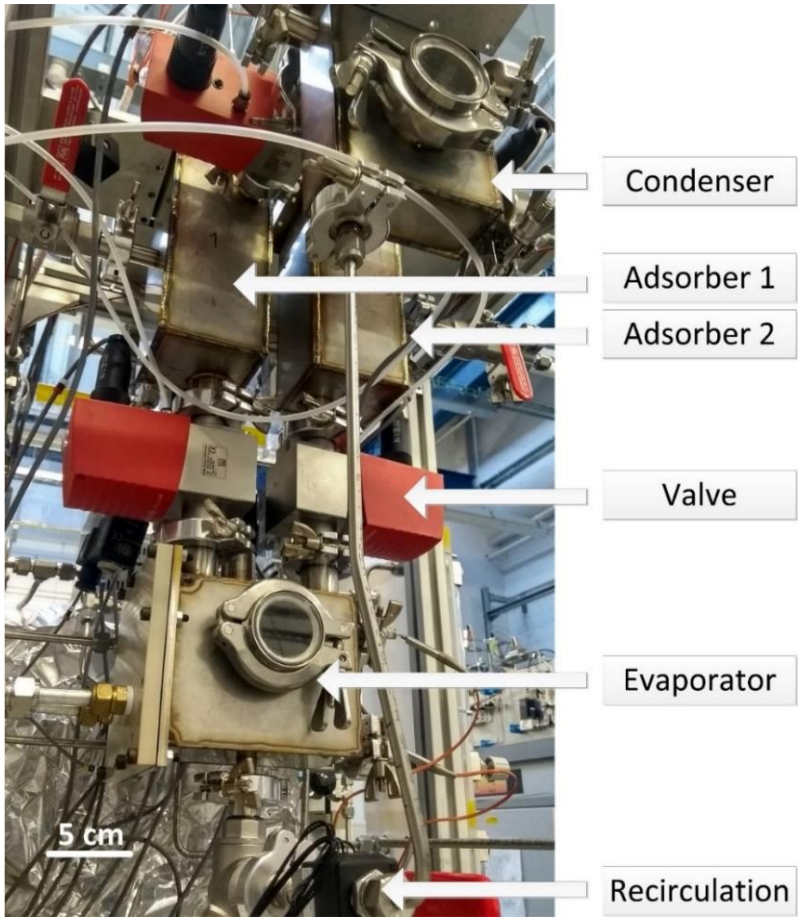
Solar Collector Surface: 1.2m^2

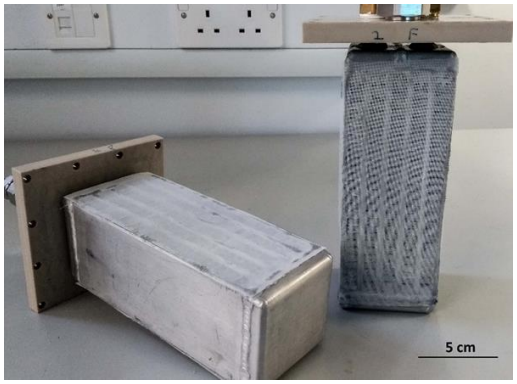
Activated Carbon Mass: 20kg

G. Santori et al. *Solar Energy* (2014) 100:172-178

What we have done

Scaling Down





Adsorption Beds

Silica Gel

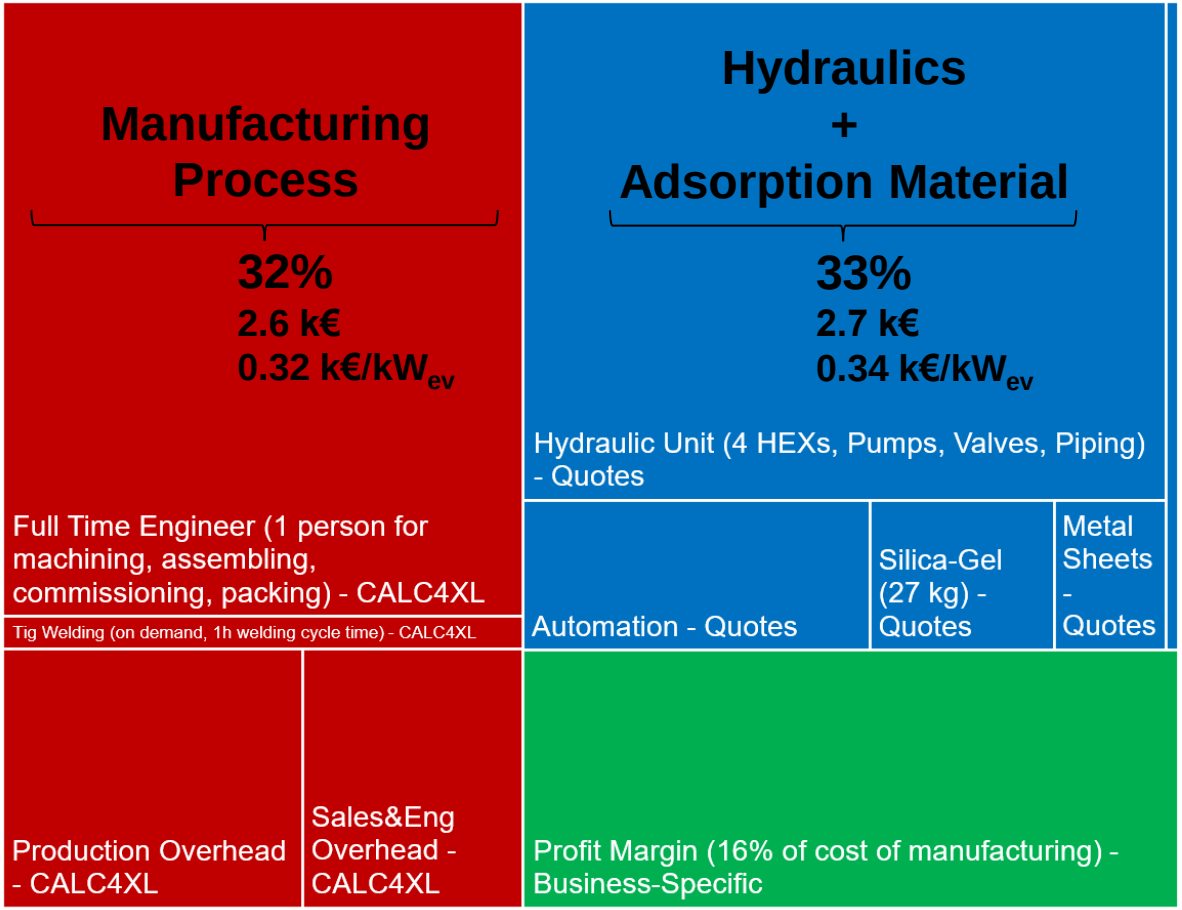
C. Olkis, S. Brandani, G. Santori. Cycle and performance analysis of a small-scale adsorption heat transformer for desalination and cooling applications. *Chemical Engineering Journal* 378 (2019) 122104

What we have done

Manufacturing: In and Out of the Lab

- **Labour (44%)**
- **Materials (40%)**
- **Profit Margin**

8kW Silica-Gel Chiller Price
8.1 k€
1.01 k€/kW$_{ev}$

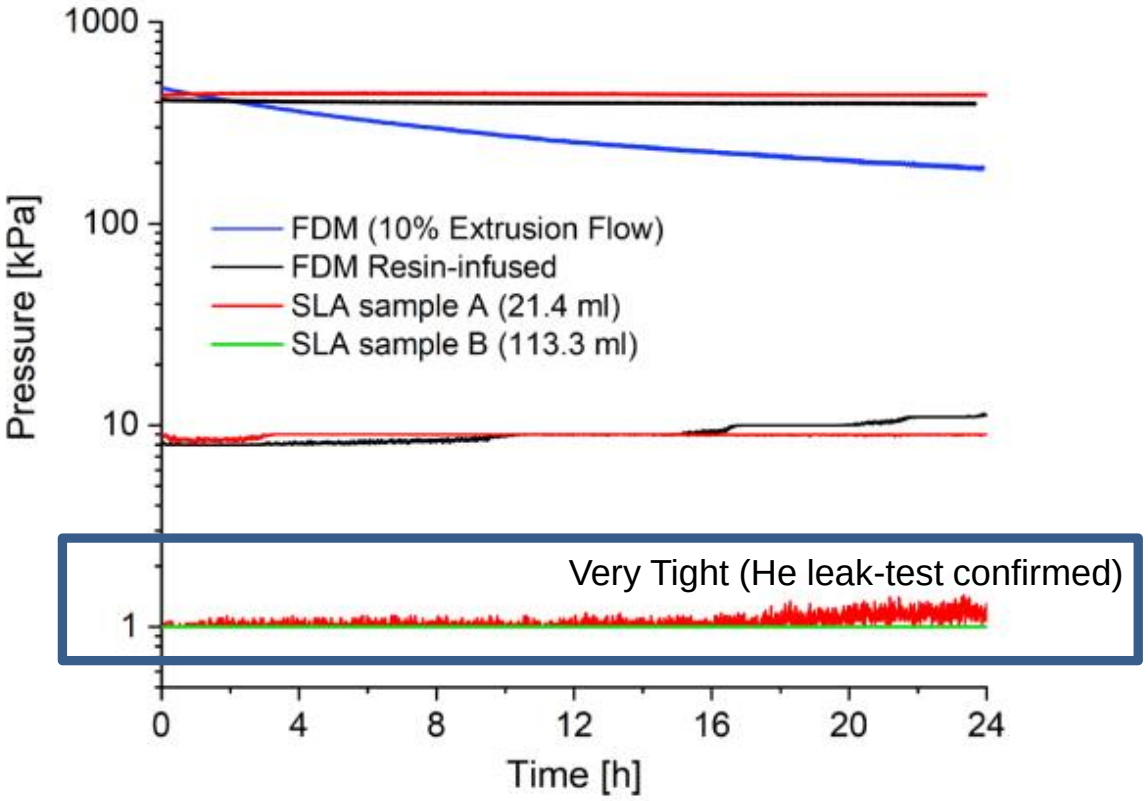


+ Annual Fixed Cost of a SME (infrastructure and fixed taxation) = 33.6 k€

S. AL-Hasni, G. Santori. The Cost of Manufacturing Adsorption Chillers. *Thermal Science and Engineering Progress* 39 (2023) 101685

What we have done

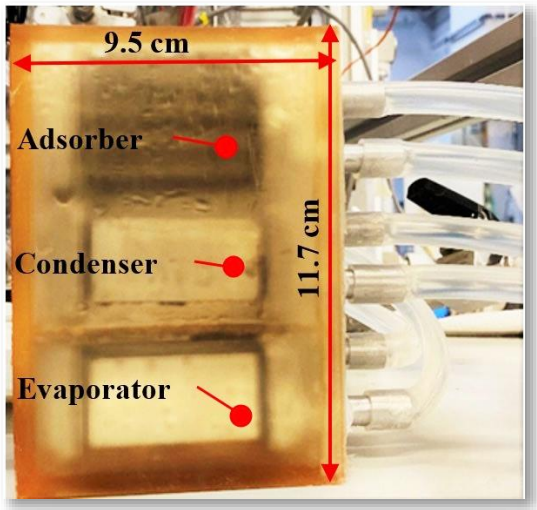
Rapid Manufacturing: 3D-Printing a soprtion heat transformer

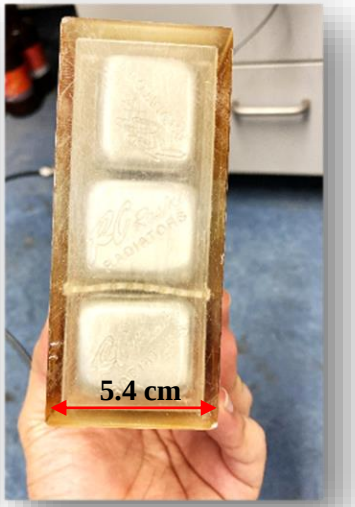


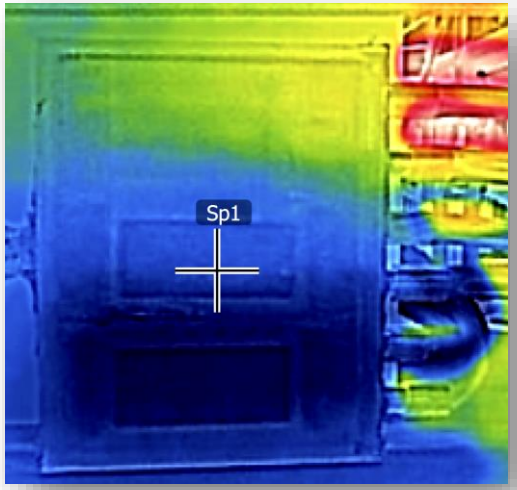
S. AL-Hasni, G. Santori. 3D printing of vacuum and pressure tight polymer vessels for thermally driven chillers and heat pumps. *Vacuum* 171 (2020) 109017

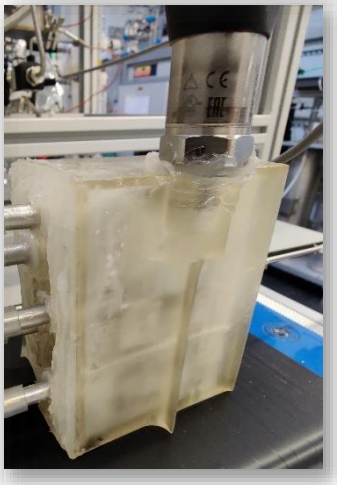
What we have done

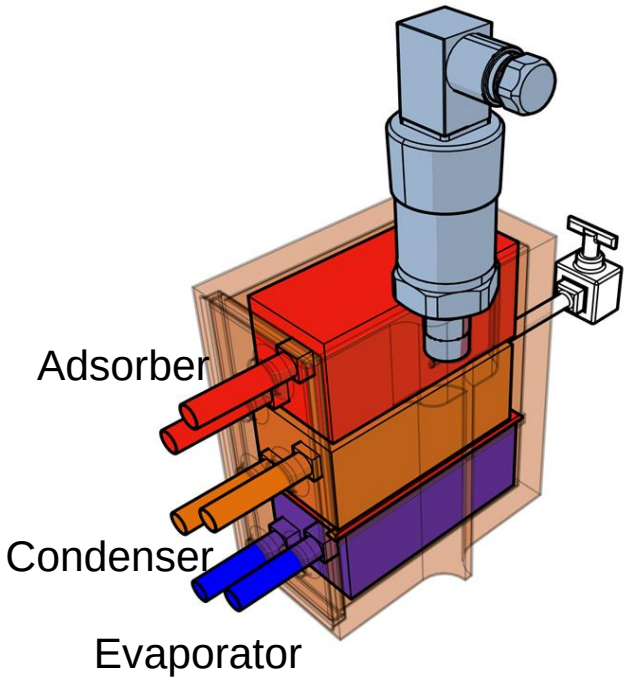
Rapid Manufacturing: 3D-Printing a soprtion heat transformer while reducing the scale







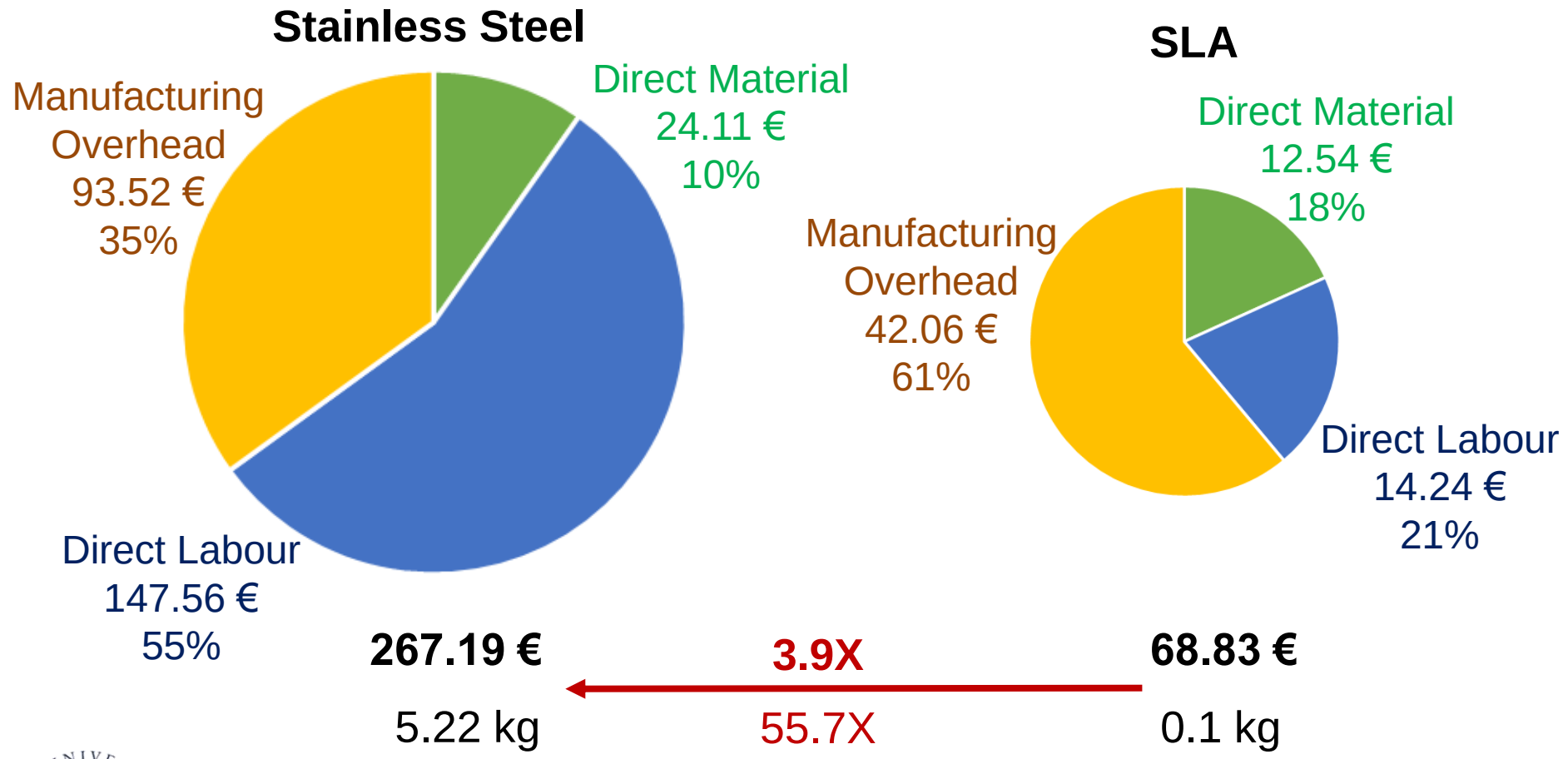




What we have done

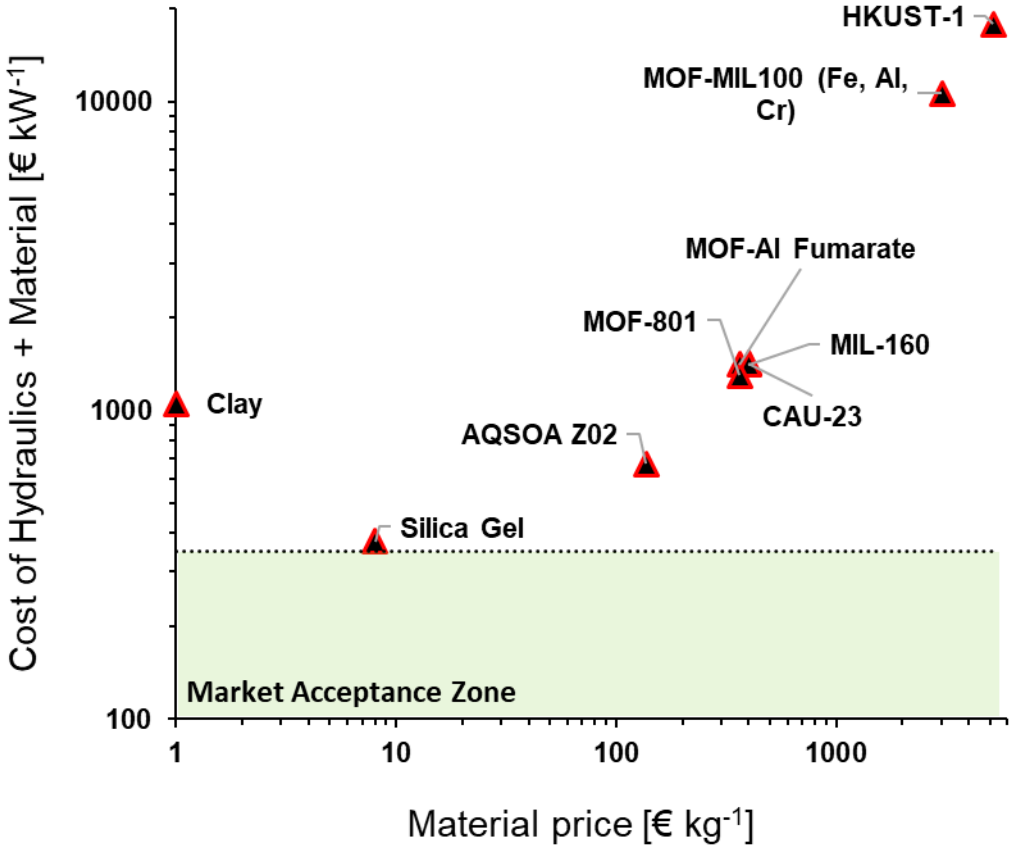
Rapid Manufacturing in the Lab

Breakdown of cost of manufacturing of vaccum-tight vessels (dimensions: 9.5 cm X 11.7 cm X 5.4 cm)



What we have done

Recognised the limit of current materials



$COH + COM = (349/PR) + 27\ CR$

$PR = SCP/SCP_{silicagel}$

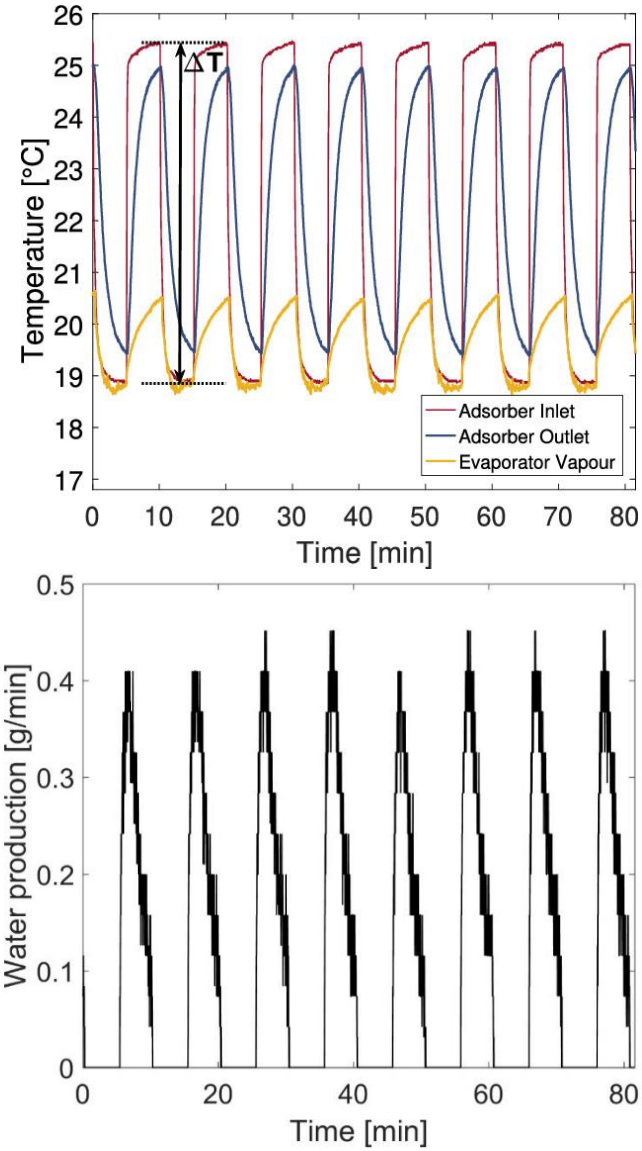
$CR = Price_{silicagel}/Price$

Threshold (Silica Gel) = 376 € kW^{-1}

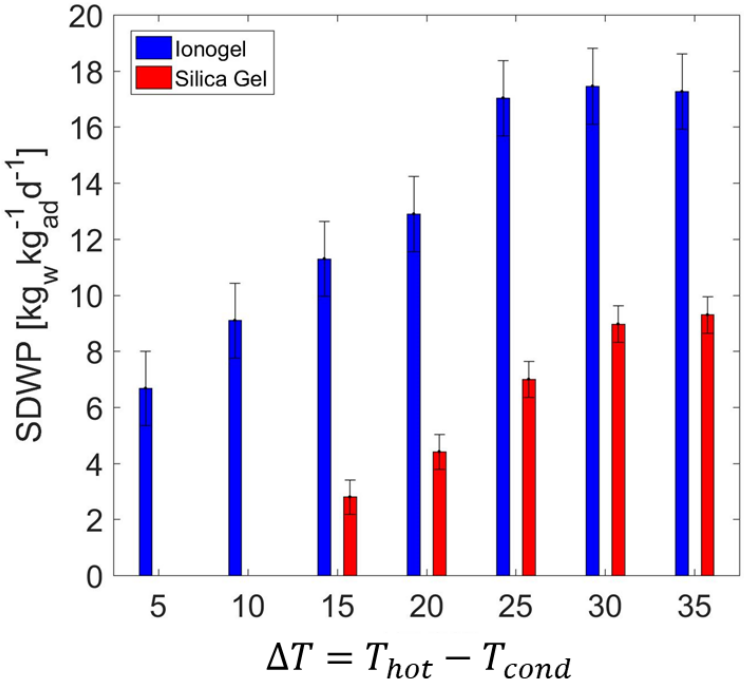
S. AL-Hasni, G. Santori. The Cost of Manufacturing Adsorption Chillers. *Thermal Science and Engineering Progress* 39 (2023) 101685

What we have done

Discovered Ionogels are good (only for for desalination so far)



Ionogel: 60 wt% [EMIM][Ac] + 40 wt% Syloid 72FP



Ionogel cycle time: 5 min
~4 times faster than Silica Gel
with a minimum temperature swing
only 5°C above ambient.

C. Olkis, H. Dong, S. Brandani, G. Santori, Ionogels at the Water-Energy Nexus for Desalination Powered by Ultralow-Grade Heat, *Environmental Science and Technology* 54 (2020) 3591-3598

What we have done

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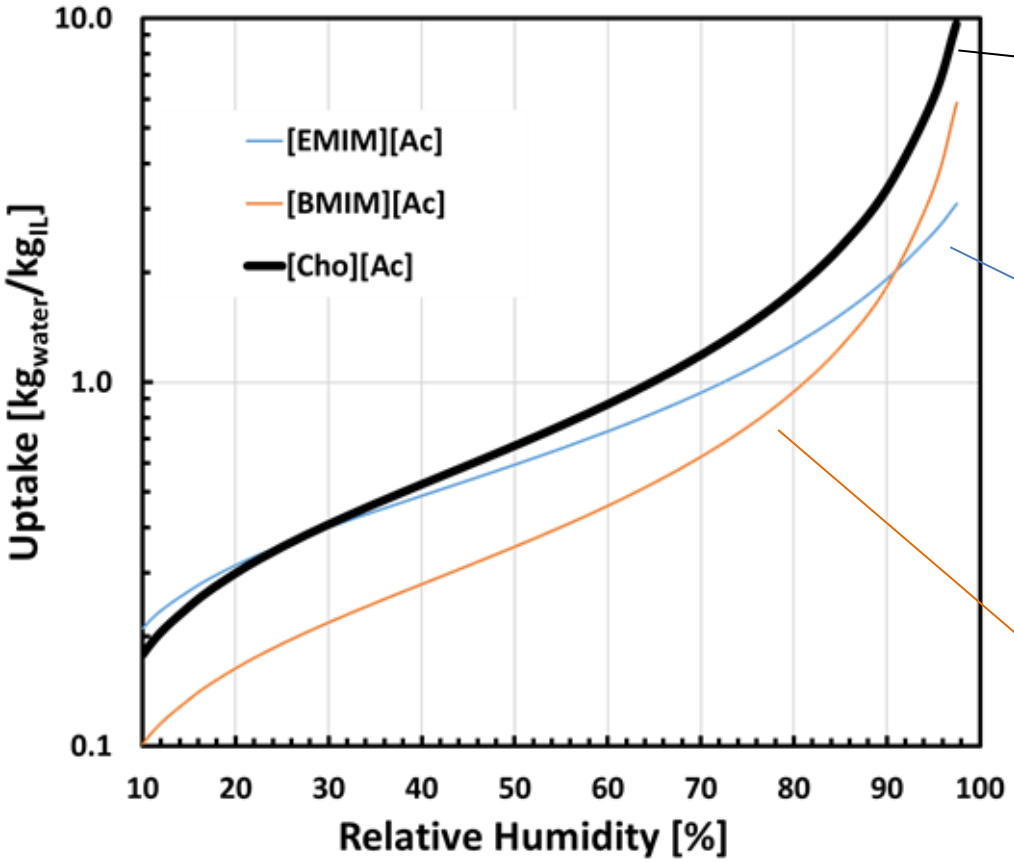
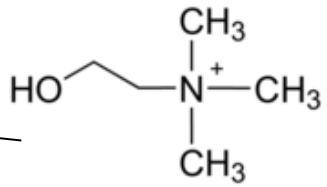
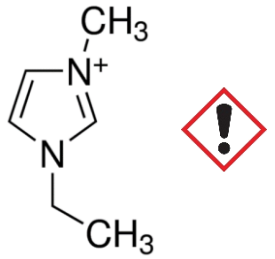


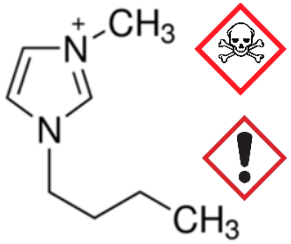


[Cho]$^+$



Irritant

[EMIM]$^+$



Acute Toxic

Irritant

[BMIM]$^+$

M. Luberti, C. Olkis, B. Gredy, G. Santori. Water sorption equilibrium on 2-hydroxyethyl-trimethylammonium acetate in the temperature range 298.25-349.55K. *Fluid Phase Equilibria* 522 (2020)

What we are doing

- Build Capability on adsorber Design and Production
  - Coatings (Isabella Quaranta)
  - Expanding the detail and applicability of current modelling platform to experiments (Amir Zivari)

- Develop design-agnostic protocols for adsorber characterisation (Shihab AL-Hasni)

- Hydrothermal carbonisation of Biomass for tuning Activated Carbons (Eloise Bevan)

- Partnering with Paul Wright's Laboratory at the University of St Andrews on zeolites and MOFs
- Partnering with Stefano Brandani's Laboratory at The University of Edinburgh on sorption kinetics measurements

SolDAC
FULL SPECTRUM SOLAR DIRECT AIR CAPTURE & CONVERSION

Royal Academy of Engineering

EPSRC
Engineering and Physical Sciences Research Council

What we are doing

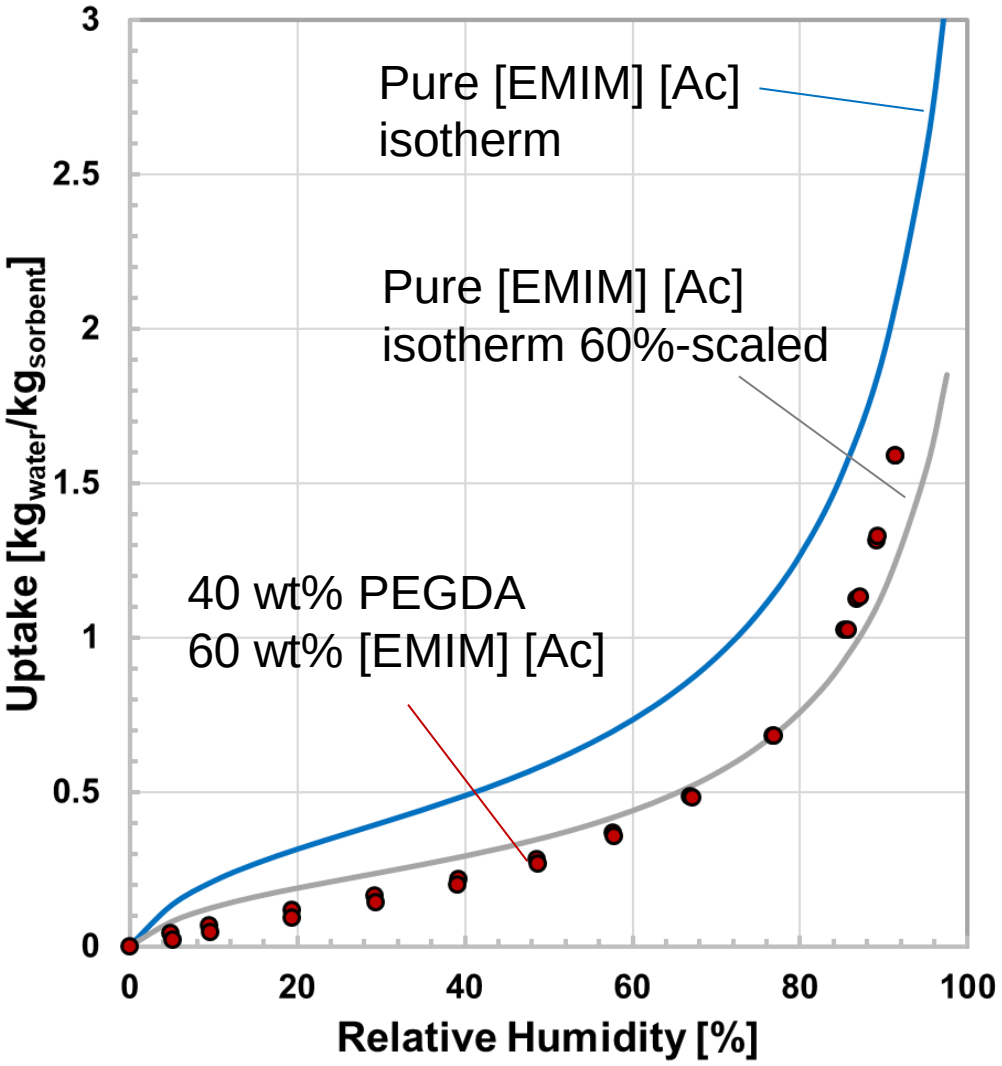
10th Heat Powered Cycles Conference

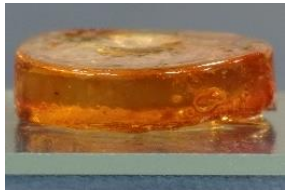
https://heatpoweredcycles.eng.ed.ac.uk/

What we have done

Discovered Ionogels are good (only for for desalination so far)

Ionic liquid immobilized in a polymeric network for higher loadings.





40%wt PEGDA
60%wt [EMIM][Ac]