The Only Way is Hydrogen

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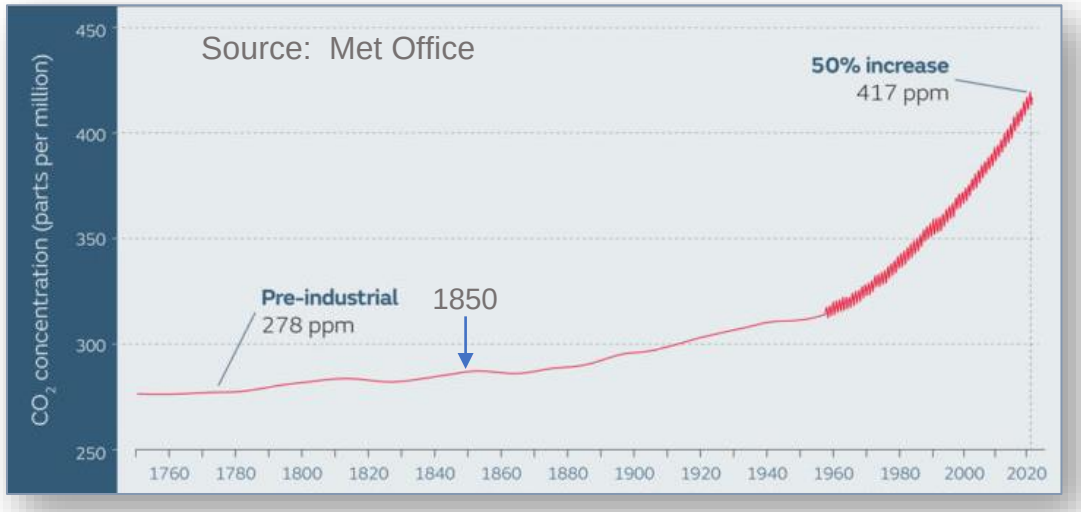
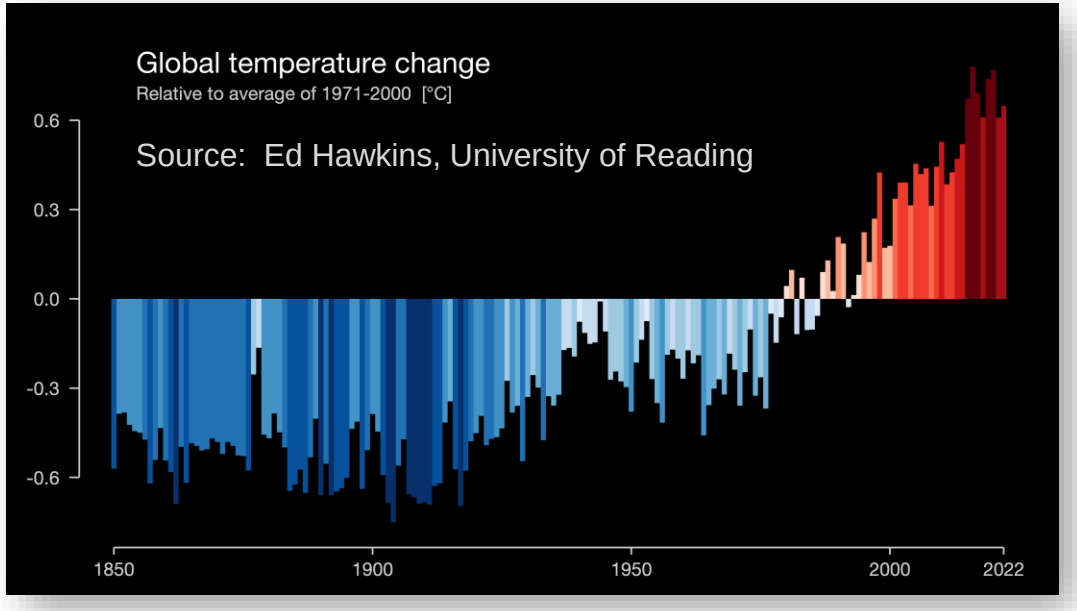
Minerva Series Lecture, The Mission Theatre, Bath
Wednesday 17 April 2024

Energy and Climate Change

- More and (on average) richer people globally leading to increased demand for energy
- Increased CO_2 emissions to air from declining fossil fuels leading to a global heating crisis
- Challenges to security of energy supply





STATUTORY INSTRUMENTS

2019 No. 1056

CLIMATE CHANGE

The Climate Change Act 2008 (2050 Target Amendment) Order 2019

Citation and commencement

1. This Order may be cited as the Climate Change Act 2008 (2050 Target Amendment) Order 2019 and comes into force on the day after the day on which it is made.

Amendment of the target for 2050

2.—(1) Section 1 of the Climate Change Act 2008 is amended as follows.

(2) In subsection (1), for "80%" substitute "100%".

UK Hydrogen Strategy

Department for Business, Energy & Industrial Strategy

HYDROGEN STRATEGY DELIVERY UPDATE

Hydrogen Strategy Update to the Market: December 2023

https://assets.publishing.service.gov.uk/media/65841578ed3c3400133bfcf7/hydrogen-strategy-update-to-market-december-2023.pdf

Introduction

Low carbon hydrogen will play an important role in UK energy security and achieving net zero, as a key enabler of a low carbon and renewables-based energy system. Produced using home-grown, clean British energy, hydrogen technologies can make our energy system more flexible, resilient and independent, and could lead to billions of pounds of savings by 2050. We have a clear ambition for the UK hydrogen economy and we are aligning our policy development with our wider efforts to decarbonise the UK economy, aiming to harness the industrial opportunities that the growing hydrogen sector presents.

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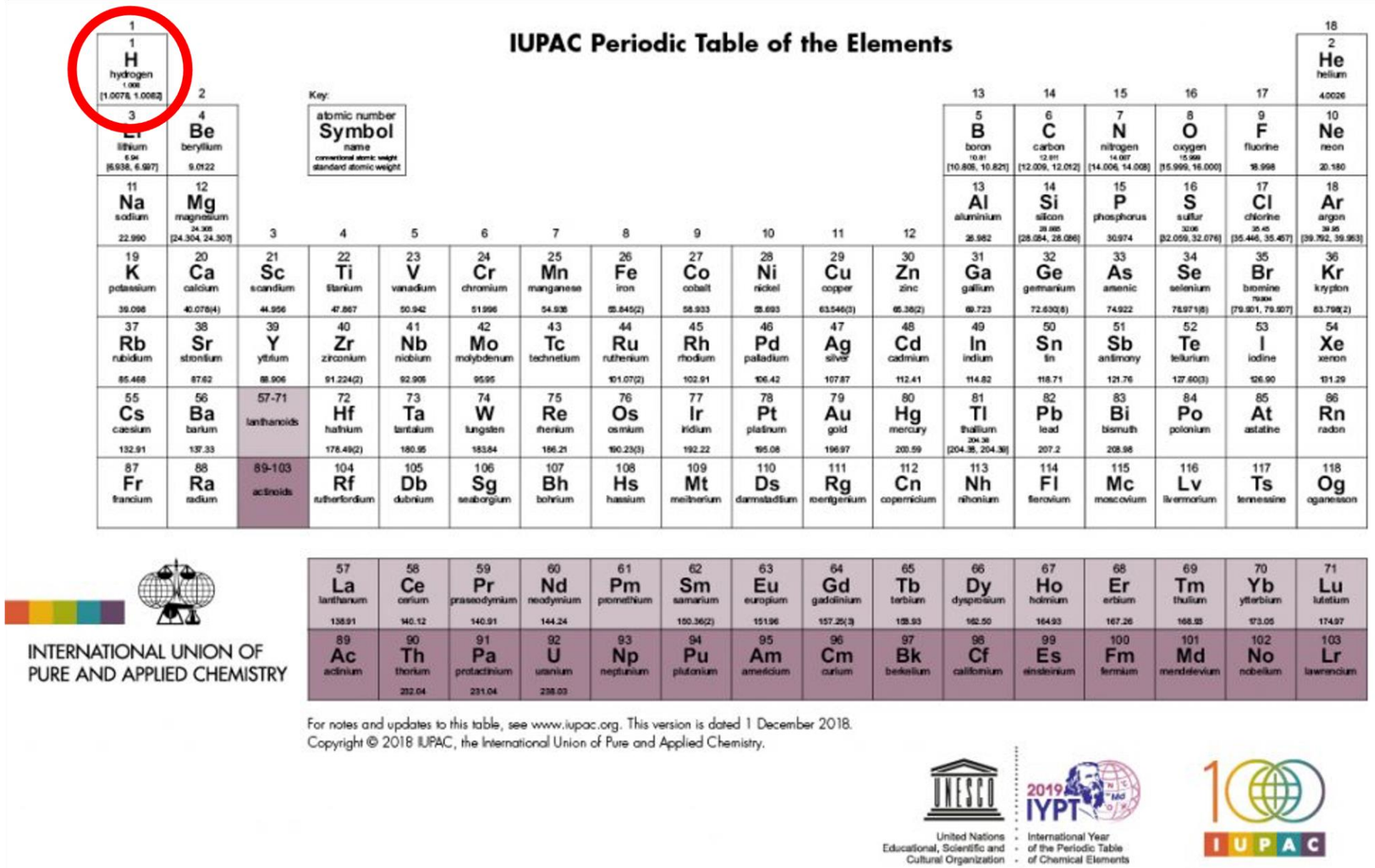
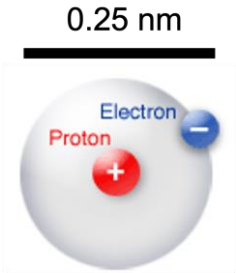
Number One Element



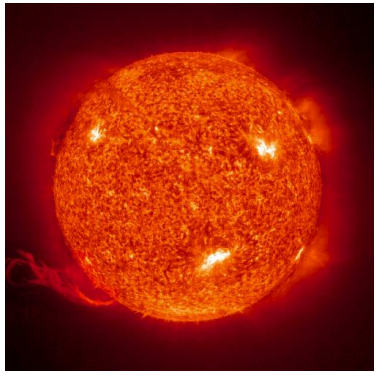
Universal Occurrence

- Consisting of the simplest, smallest and lightest of all atoms, hydrogen …



  - … was the first element formed in the Big Bang 13.8 billion years ago …

    - … and remains the commonest element in the observable Universe (75 % by mass, 90 % by number of atoms)

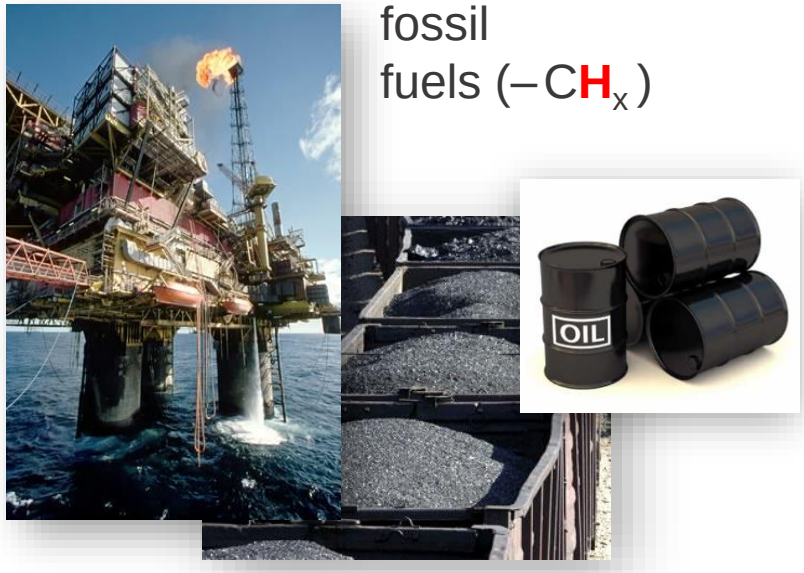


Terrestrial Occurrence

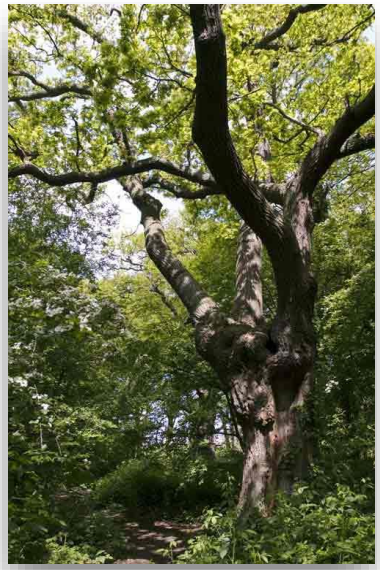
- Hydrogen is the third commonest element on the Earth's surface but almost all of it is contained in chemical compounds

water ($\mathbf{H}_2O$)

~10^{21} kg



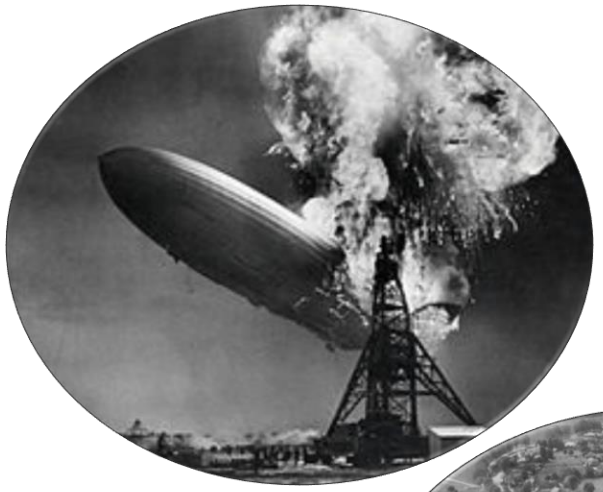
fossil fuels ($-C\mathbf{H}_x$)



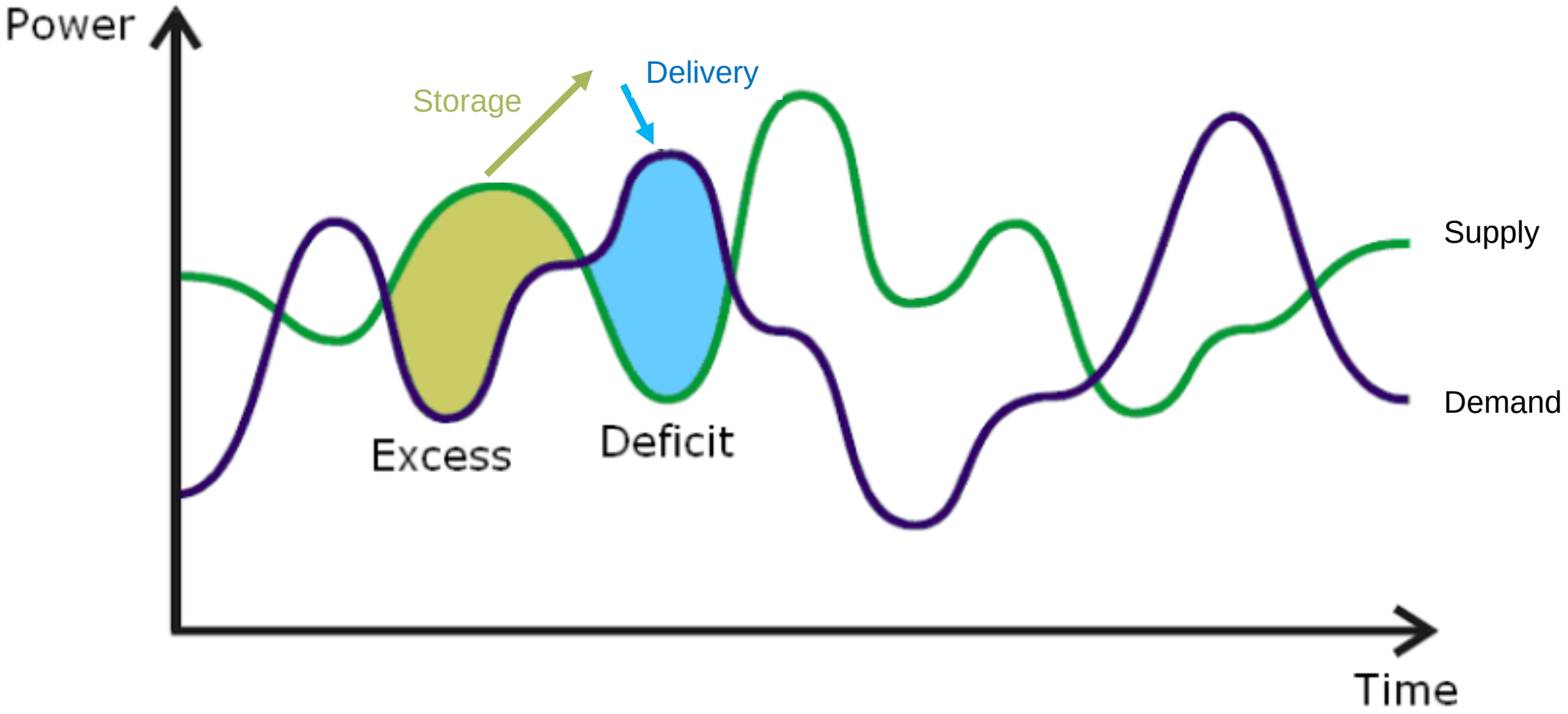
biomass ($-C\mathbf{H}_{2x}O_x$)

~10^{15} kg (dry)

Hydrogen in Real Life

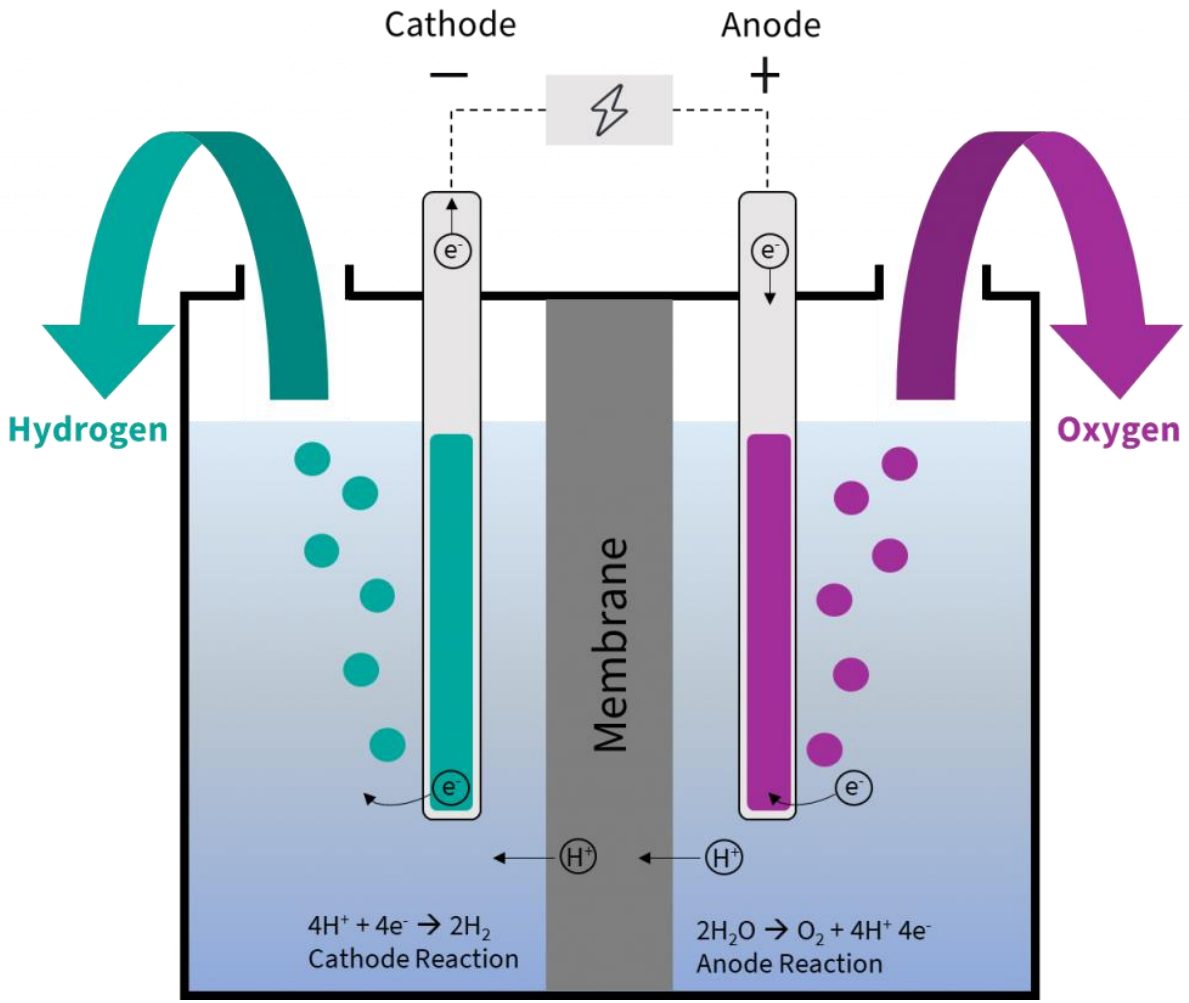


Buffering Intermittent Renewables



Electrolytic Water Splitting

$$2H_2O \rightarrow 2H_2 + O_2$$



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Hydrogen Colours

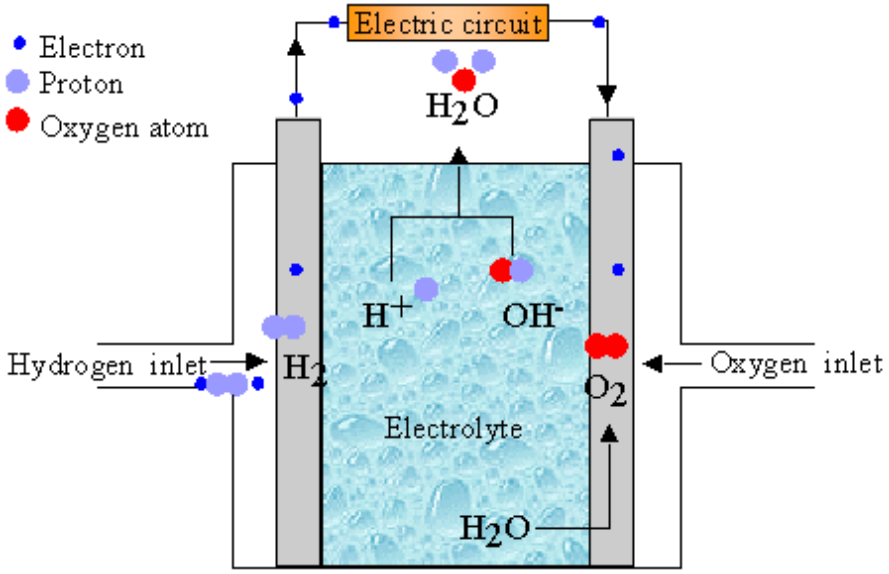
Colour	Fuel	Process	Products/Emissions
Brown/Black	Coal	Steam reforming or gasification	H_2 + CO_2 (released)
White/Gold	N/A	Naturally occurring	H_2
Grey	Natural Gas	Steam reforming	H_2 + CO_2 (released)
Blue	Natural Gas	Steam reforming	H_2 + CO_2 (% captured and stored)
Turquoise	Natural Gas	Pyrolysis	H_2 + C (solid)
Red	Nuclear Power	Catalytic splitting	H_2 + O_2
Purple/Pink	Nuclear Power	Electrolysis	H_2 + O_2
Yellow	Solar Power	Electrolysis	H_2 + O_2
Green	Renewable Electricity	Electrolysis	H_2 + O_2

Storage

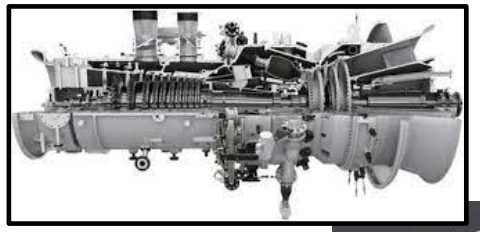
storing molecules
easy

storing electrons
not so easy

Energy Harvesting from Hydrogen

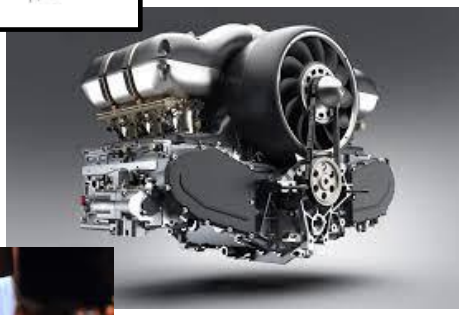


Electrochemical (fuel cell)



Gas turbine

Internal combustion engine



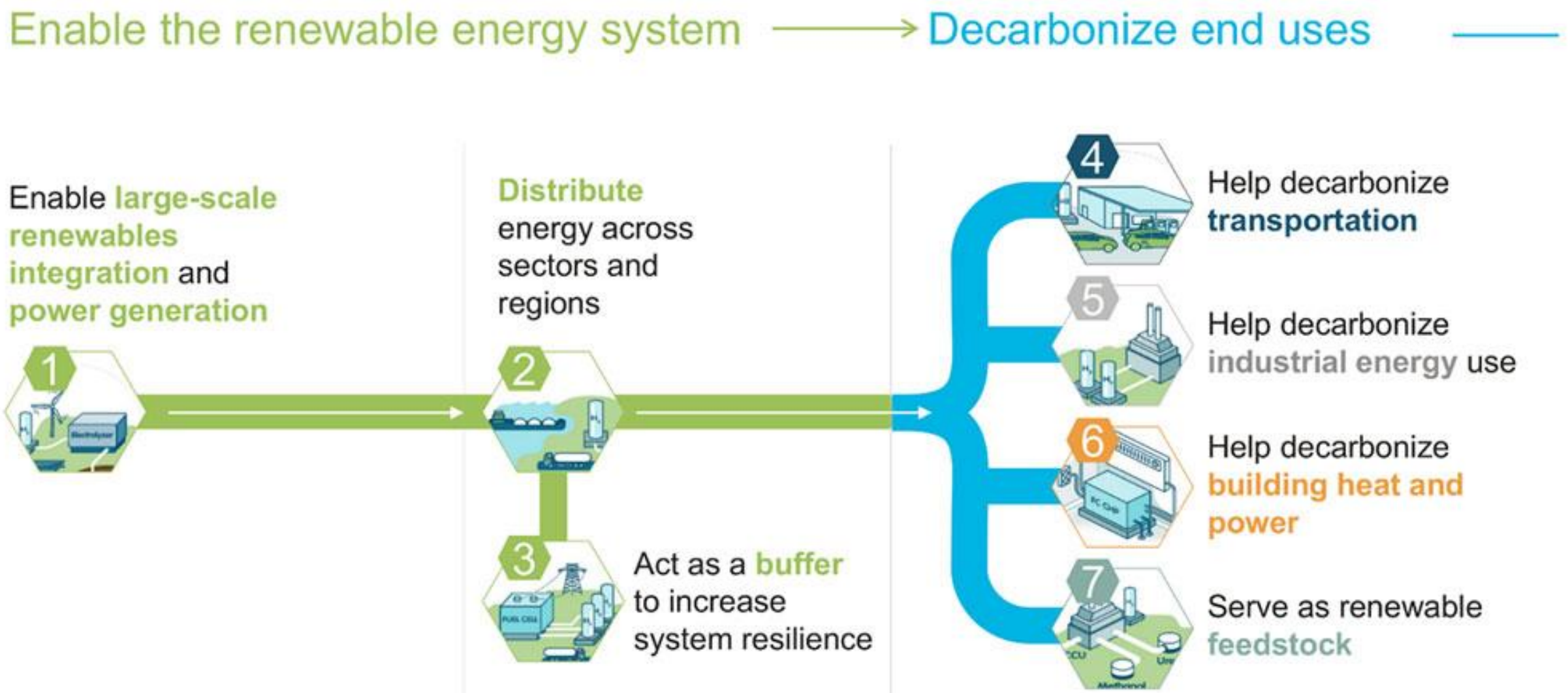
Flame burner

Boiler

Cooker

Thermochemical (combustion)

Hydrogen Value Chain



Challenges

- Need significant infrastructure development
- Need to develop the business case for hydrogen
- Hydrogen is an indirect greenhouse gas
- Effective public and policy engagement

- Hydrogen may not the only way to secure net zero (sorry about my lecture title!) but it really is an **exciting and important option alongside renewables, nuclear and demand management**

nature

19 February 2004 Volume 427 Issue no 6976

Leapfrogging the power grid

The desire to mitigate climate change, and opportunities to empower consumers in the developed and developing worlds, all point towards a need for less-centralized energy generation. It's time to further boost hydrogen research.

Hydrogen as a widely used energy carrier is essential and inevitable. Scientists, technologists, governments and philanthropists should do much more to hasten its arrival.


thank you

The Future of Sustainable Energy

EcoElegance: The Seamless Integration of Nature and Architecture

Presenter: Mohamed Katish – PhD researcher – University of Bath

Minerva SERIES

Institute for Sustainability

UNIVERSITY OF BATH

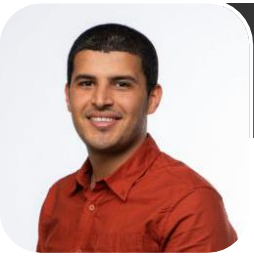
IDRIC

UKRI Engineering and Physical Sciences Research Council

THE UNIVERSITY OF EDINBURGH

Research Overview

- PhD, 2021 - 2025



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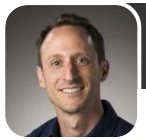
Lead supervisor

Steve Allen
Co-supervisor



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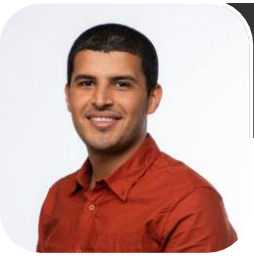

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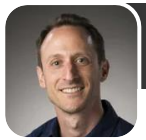

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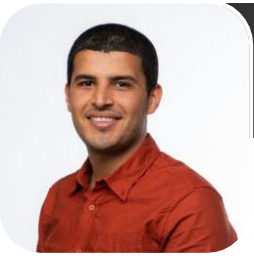

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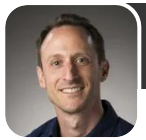

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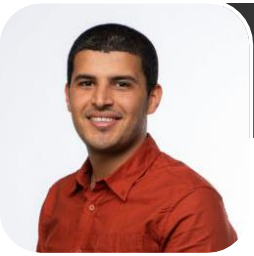

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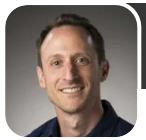

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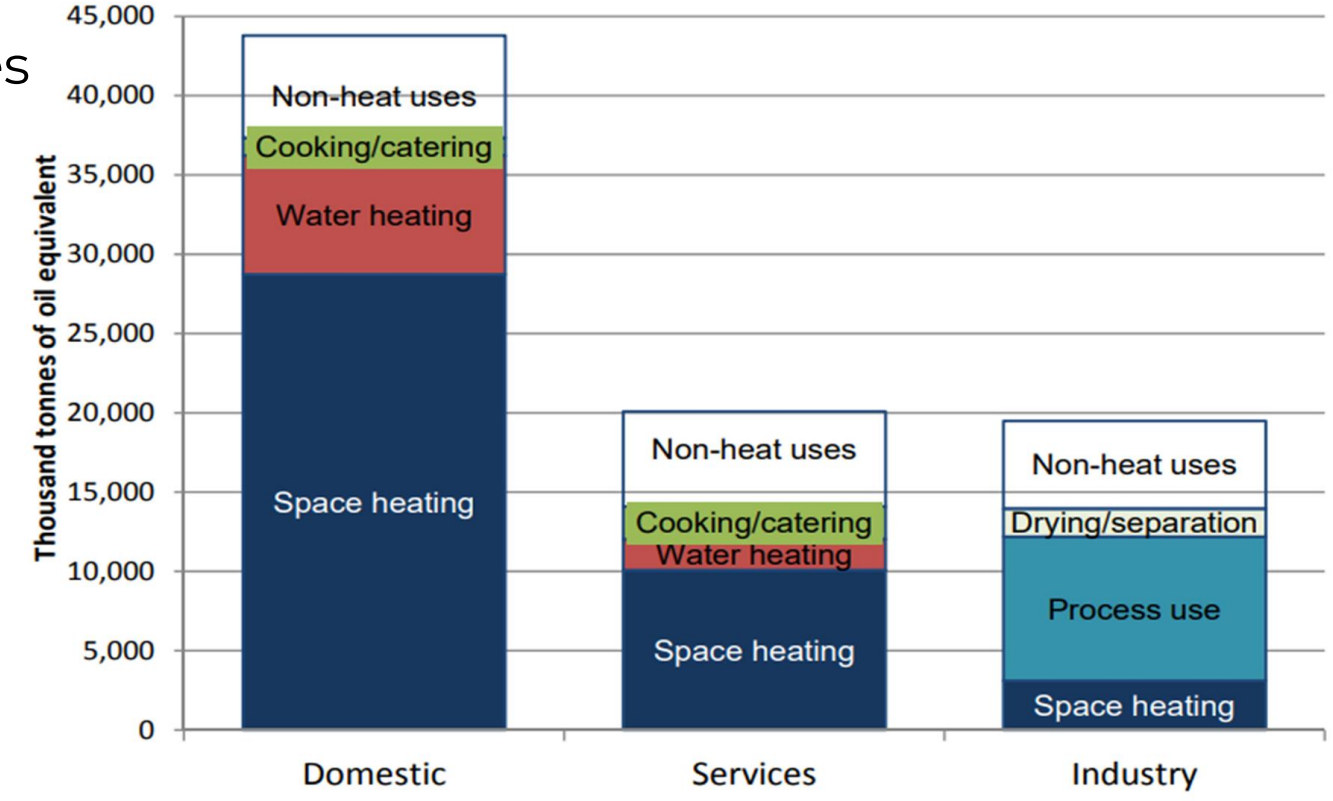
70% of the energy we use at home goes towards **Space Heating…**



1. https://www.statista.com/statistics/561839/total-gross-energy-consumption-heating-cooling-uk/

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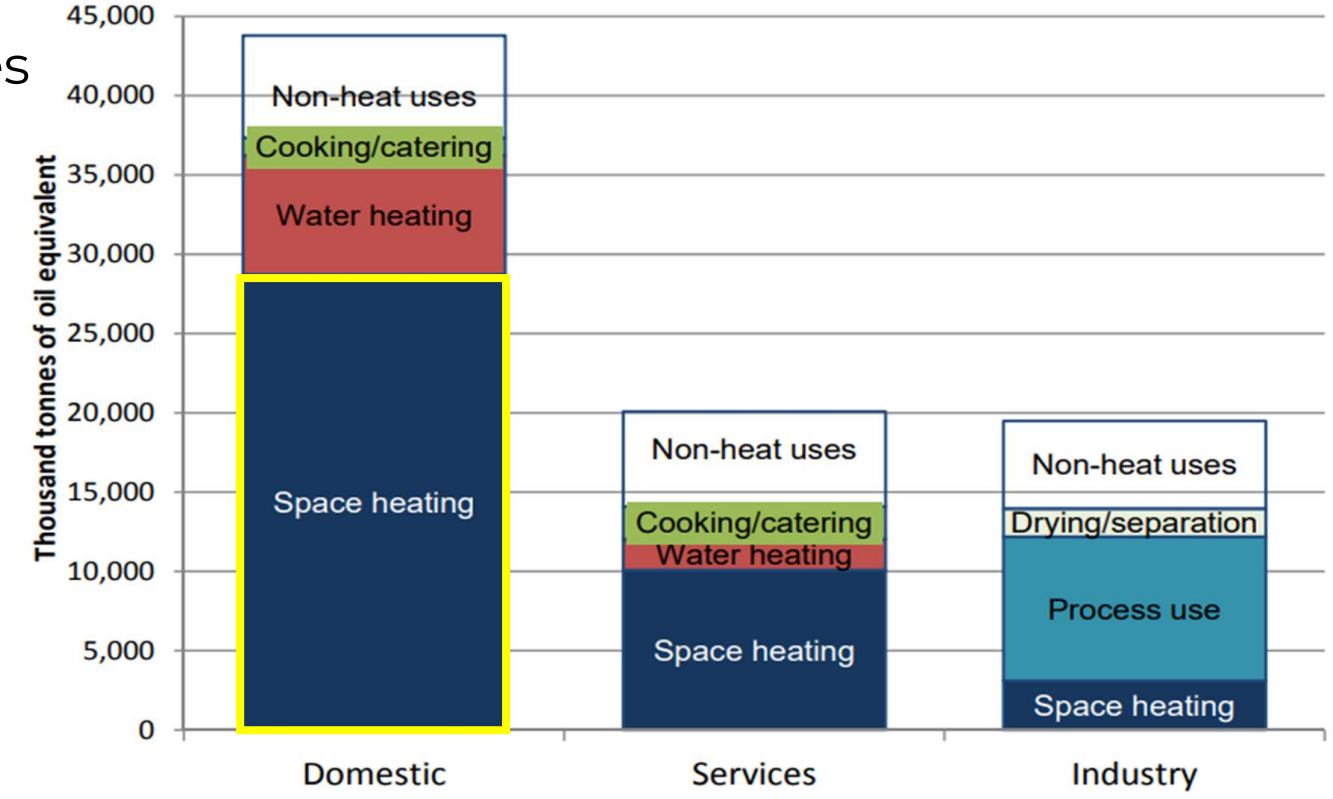

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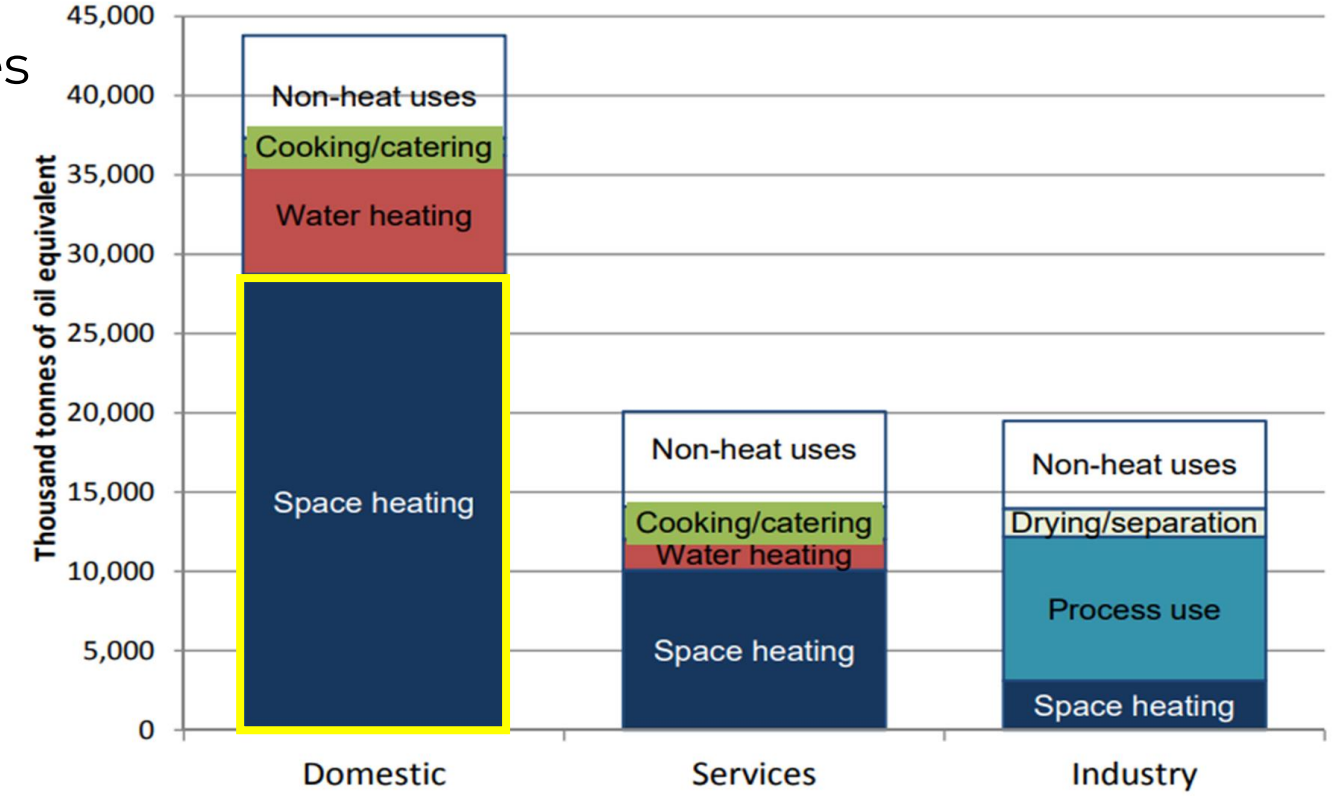
£6.5 billion were spent on space heating & cooling in 2022 UK…



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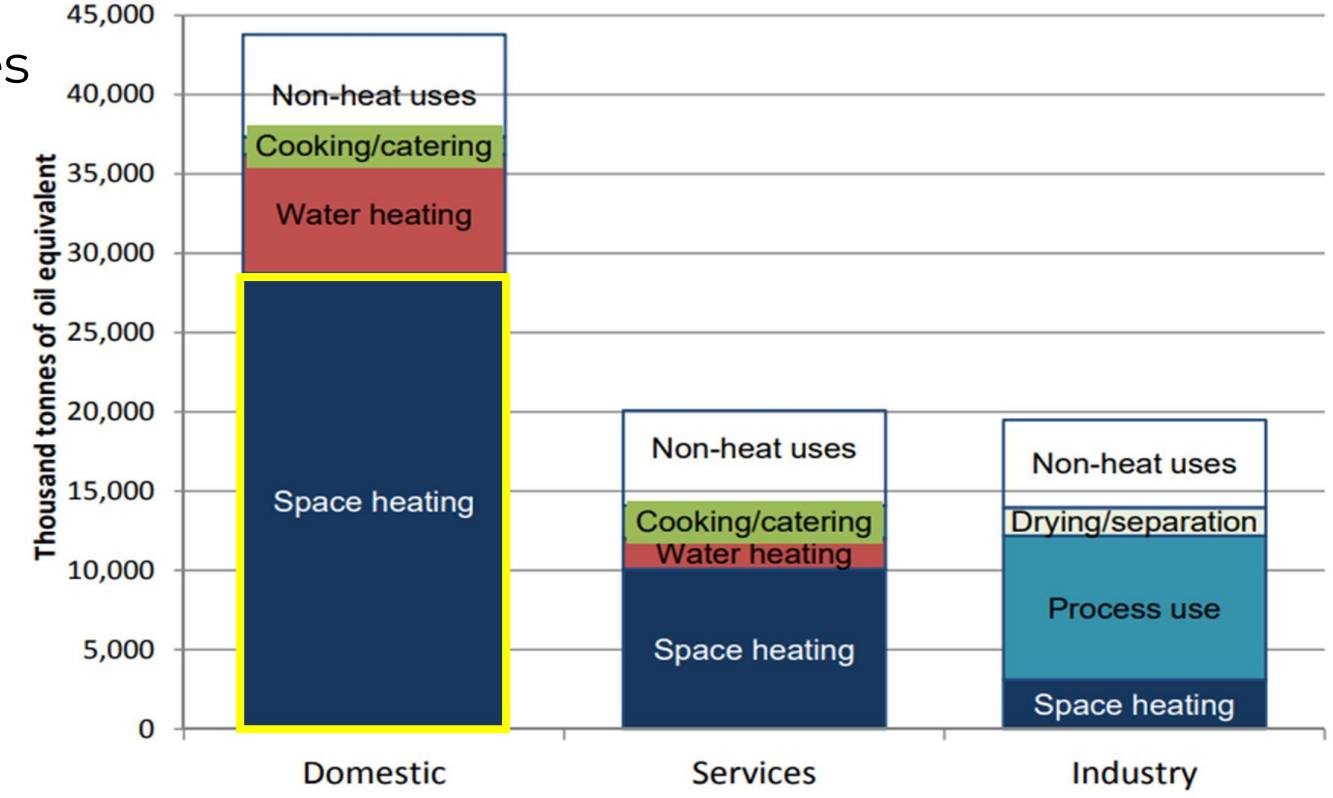

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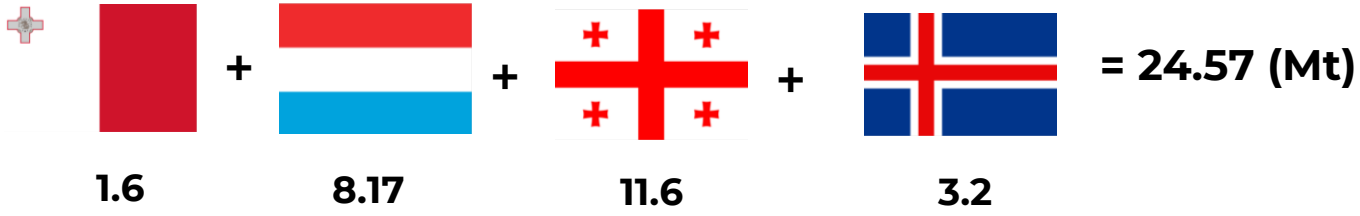
Research Overview

- Space heating and cooling in the UK was responsible for more than 16% of the UK's total CO2e.



28 million tonnes (Mt) CO2e

16% of the UK's total CO2e

1. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1064923/2021-provisional-emissions-statistics-report.pdf
2. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20200626-1

Research Overview

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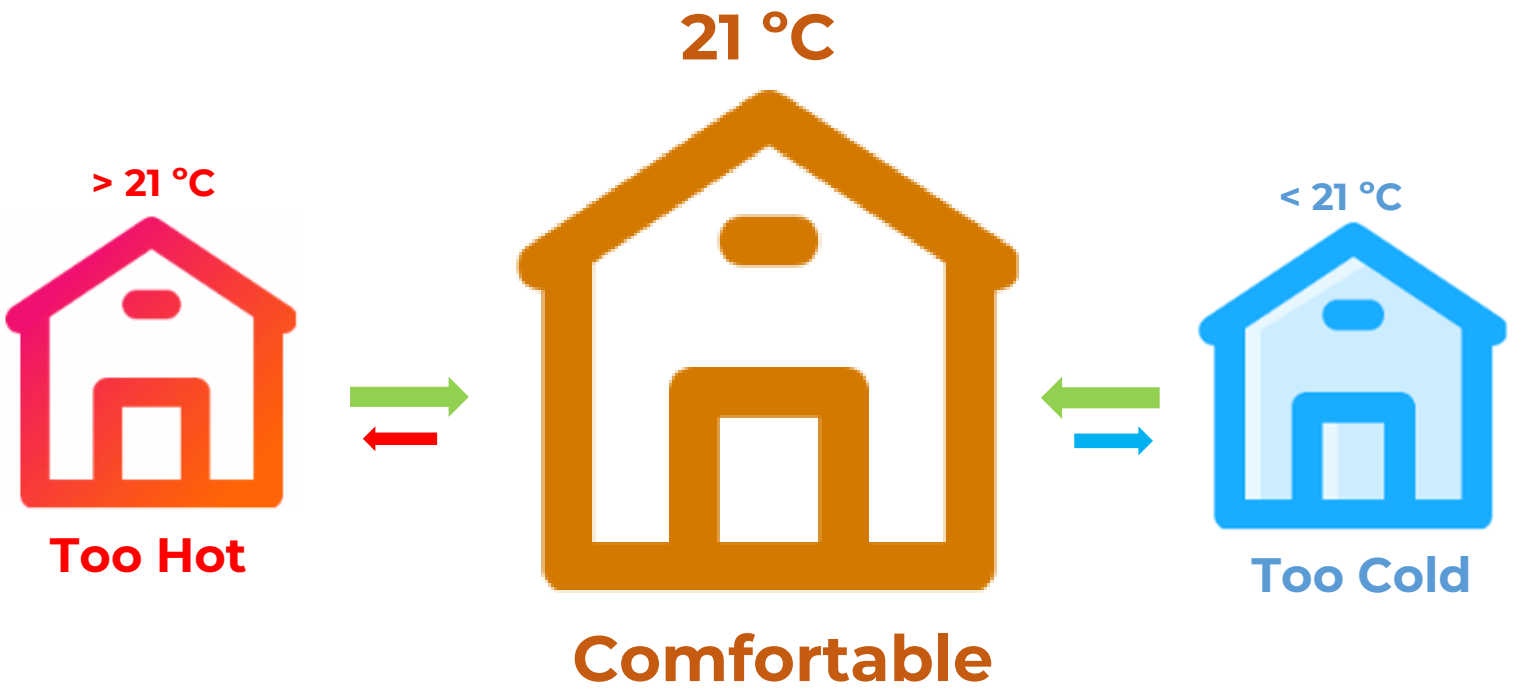
£6.5 billion were spent on space heating & cooling in 2022 UK...

Research Overview

- Altering the composition of building materials to make buildings which **regulate their own temperature**.



Methodology

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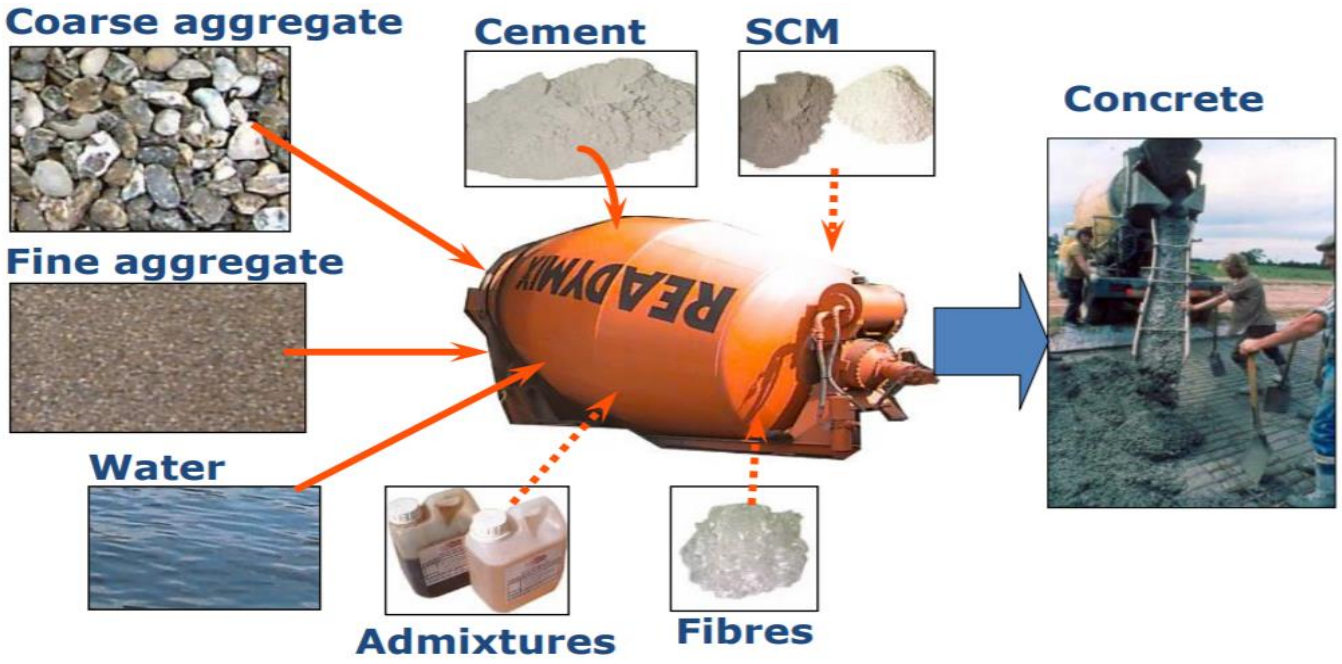

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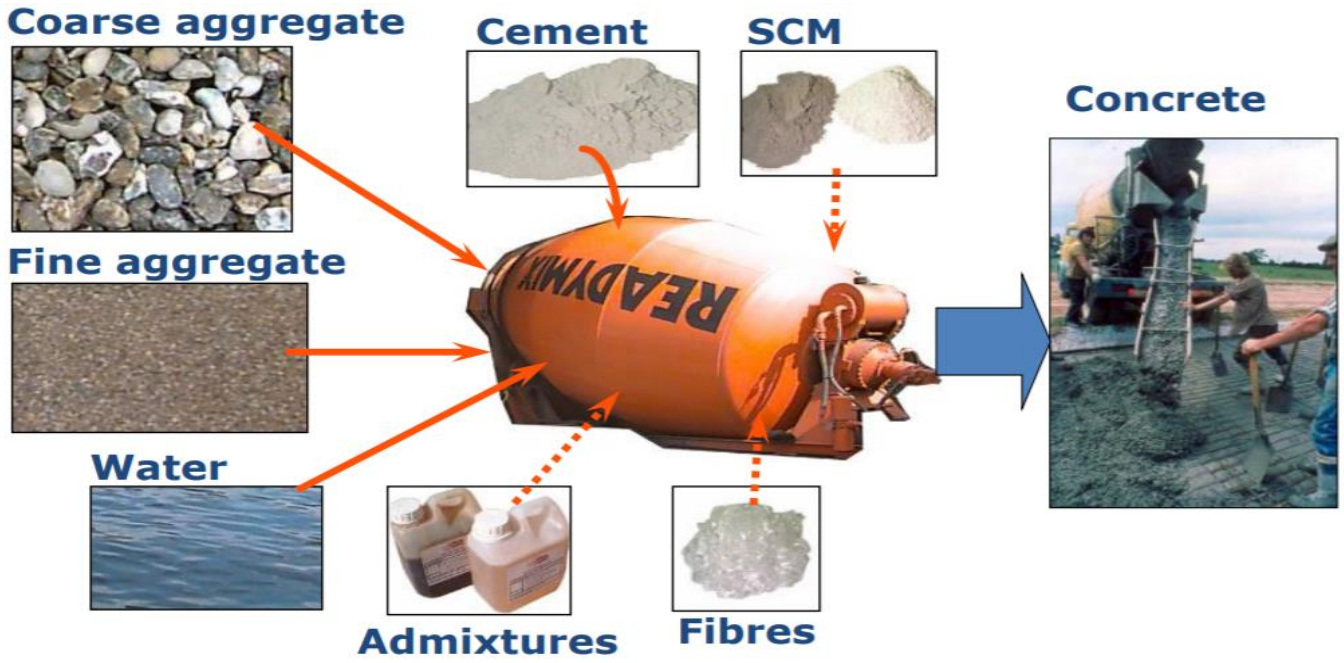

PCM: Phase Change Material

Methodology

-Phase Change Materials **PCMs** materials that absorbs and releases thermal energy by changing from one phase to another.

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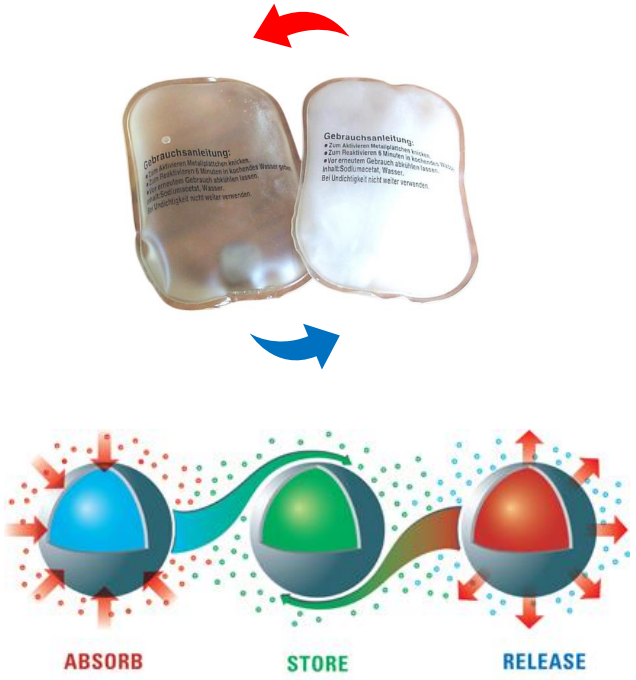

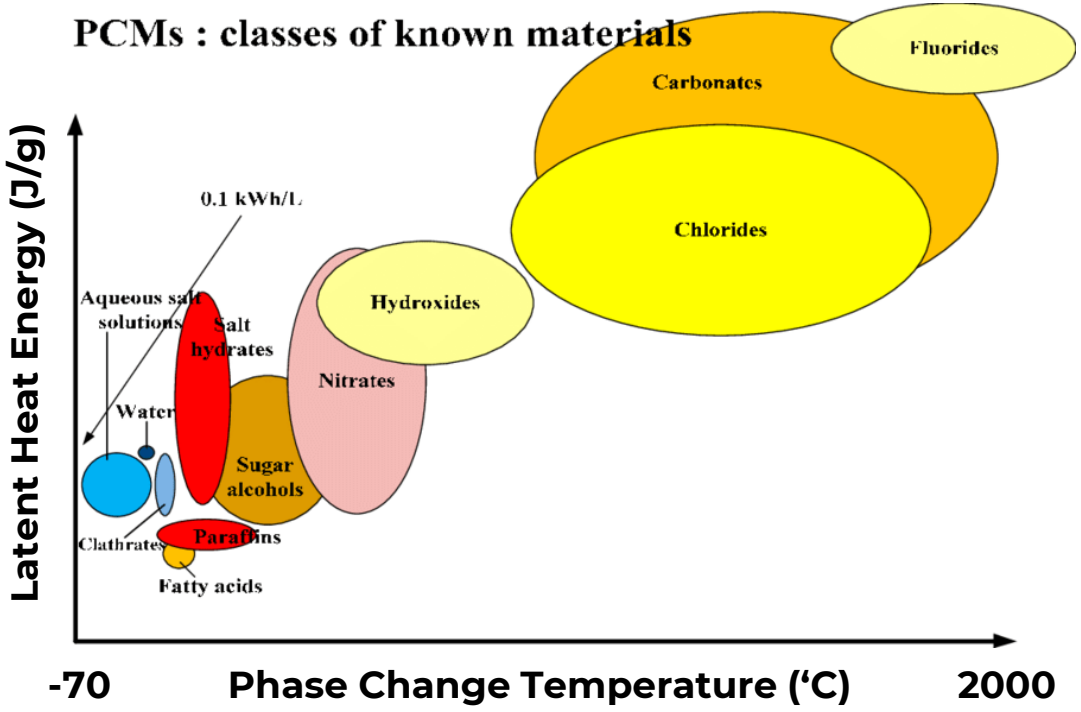

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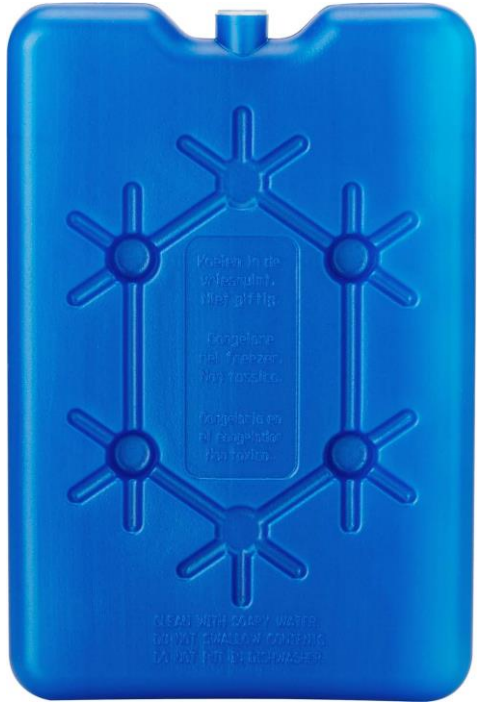

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Gaberoun - Oasis in Libya

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Mount Everest

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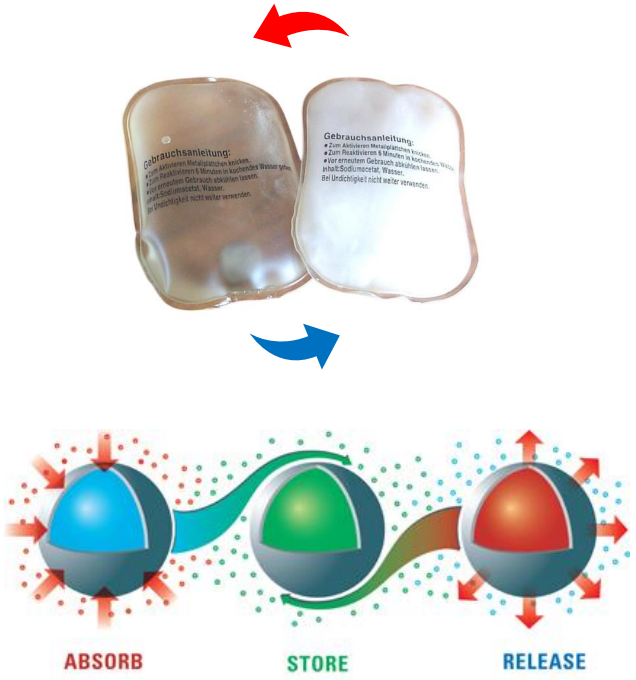

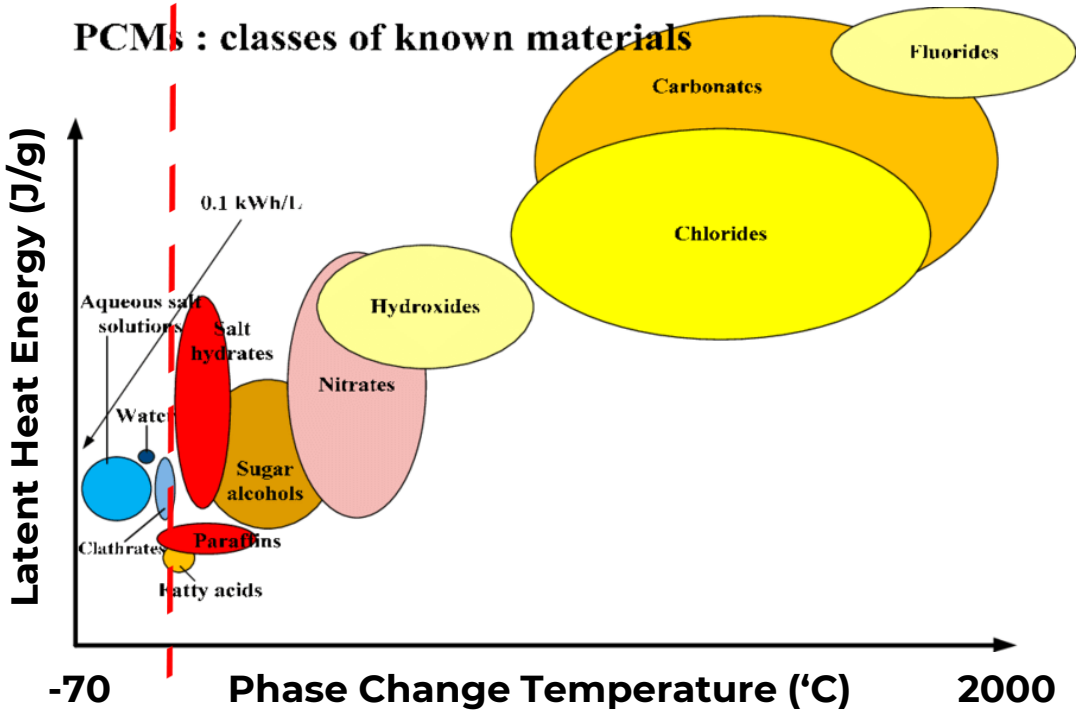

Methodology

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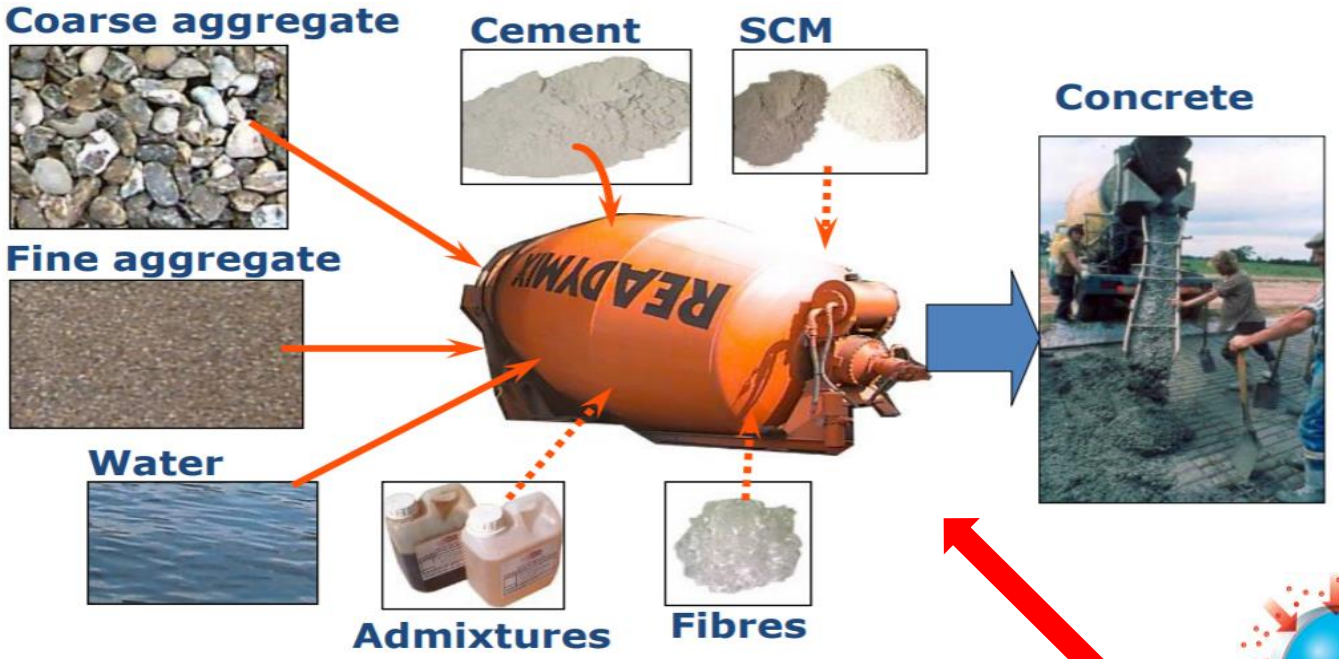

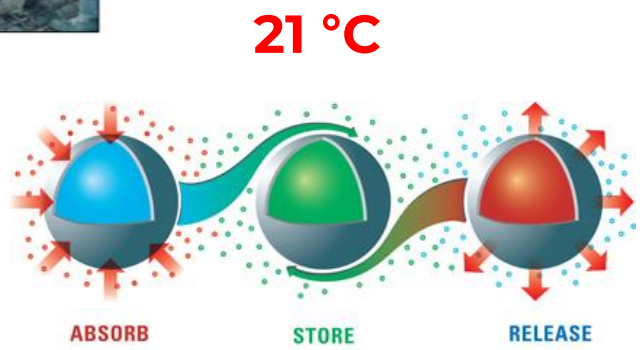

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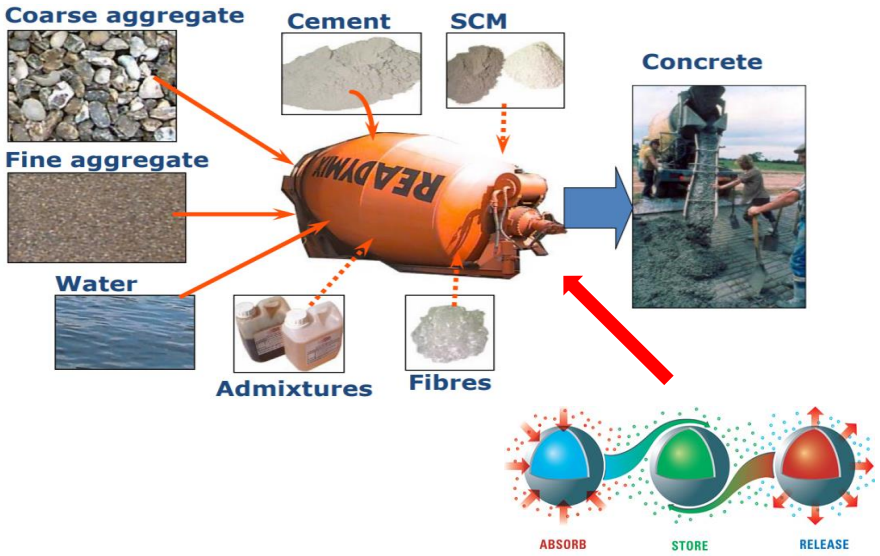

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Same principals...

Methodology

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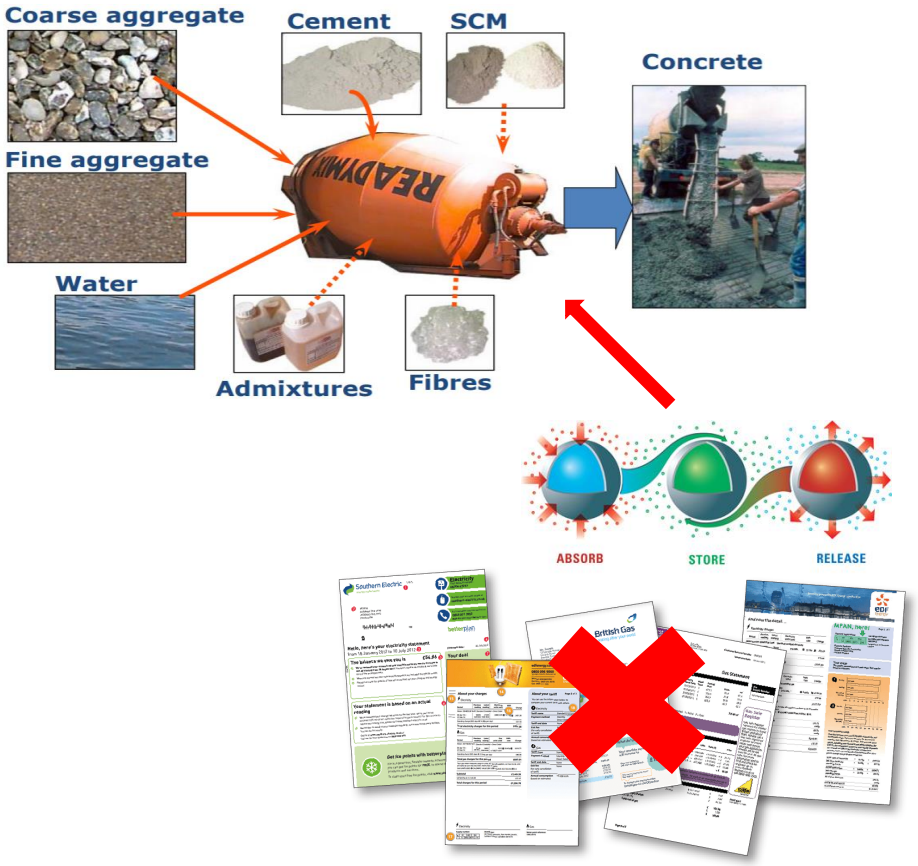

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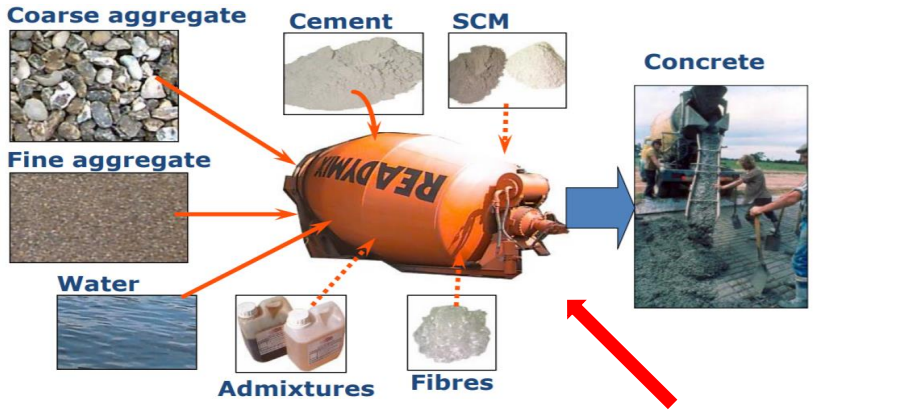

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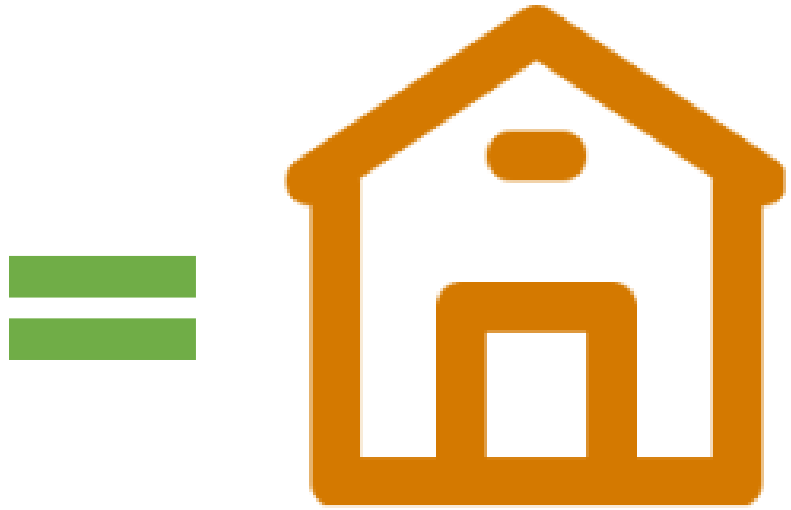


Methodology

Biochar

Methodology

Biochar

Scrap Wood

Methodology

Biochar

Sewage Sludge

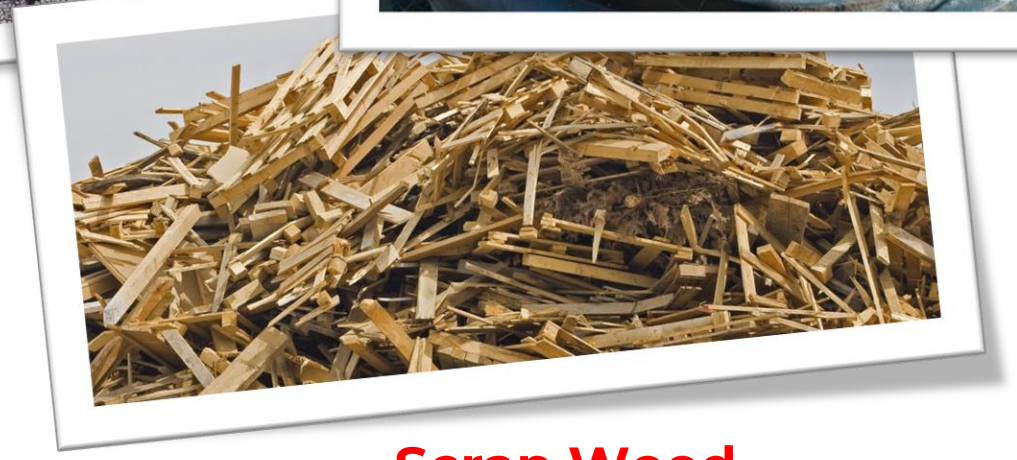
Scrap Wood

Methodology

Biochar

Sewage Sludge

Food waste



Scrap Wood

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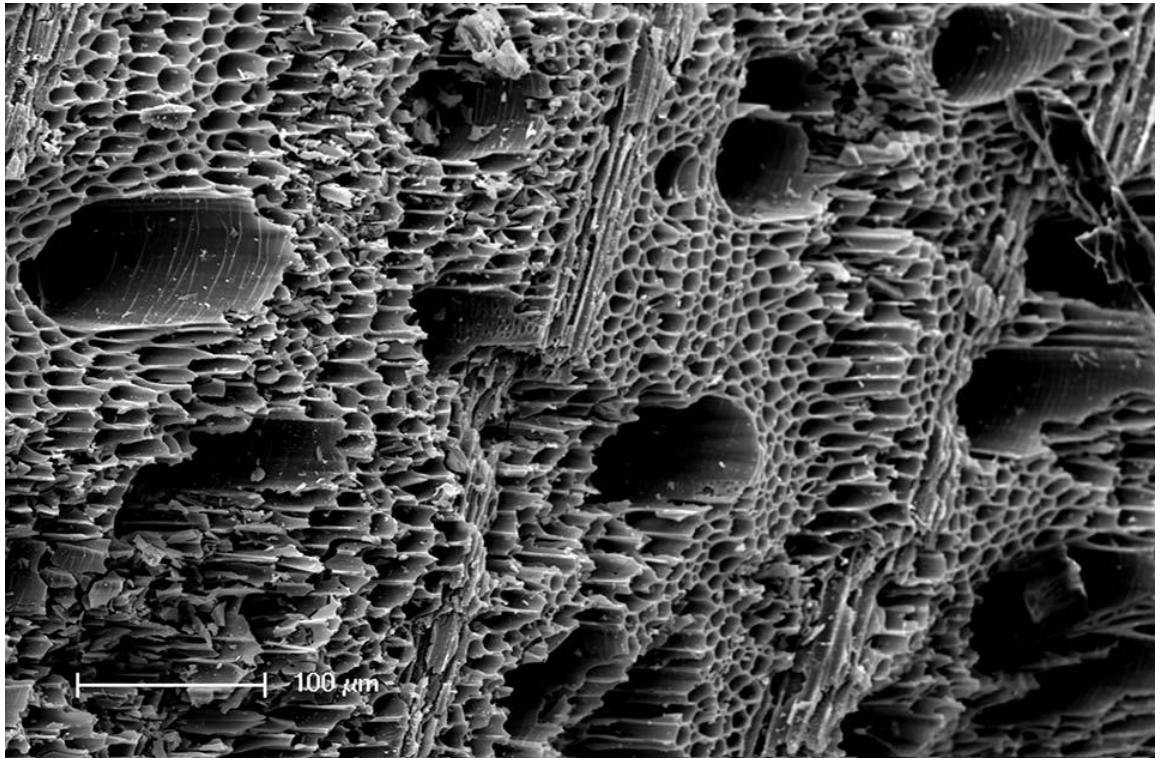


Biochar SEM

Biochar is **83% Porous**

Methodology

+

Biochar **PCM**

Under very **specific reaction** conditions

Methodology

Biochar + PCM

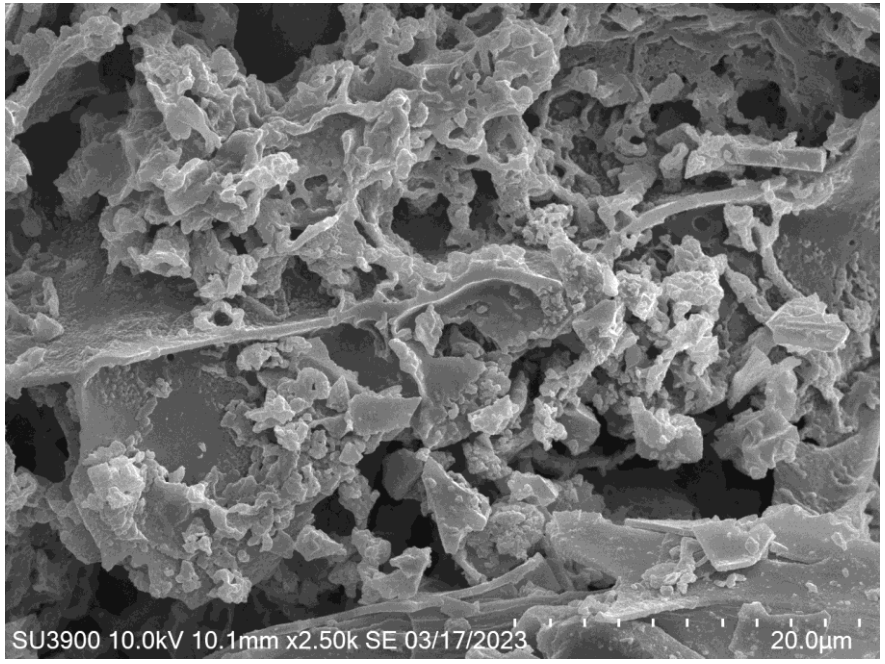
PCM-Biochar
(Approx. **60 wt% PCM loading**)

Under very **specific reaction** conditions

Methodology

SEM of Biochar sample

SEM of PCM-Biochar sample



PCM-Biochar

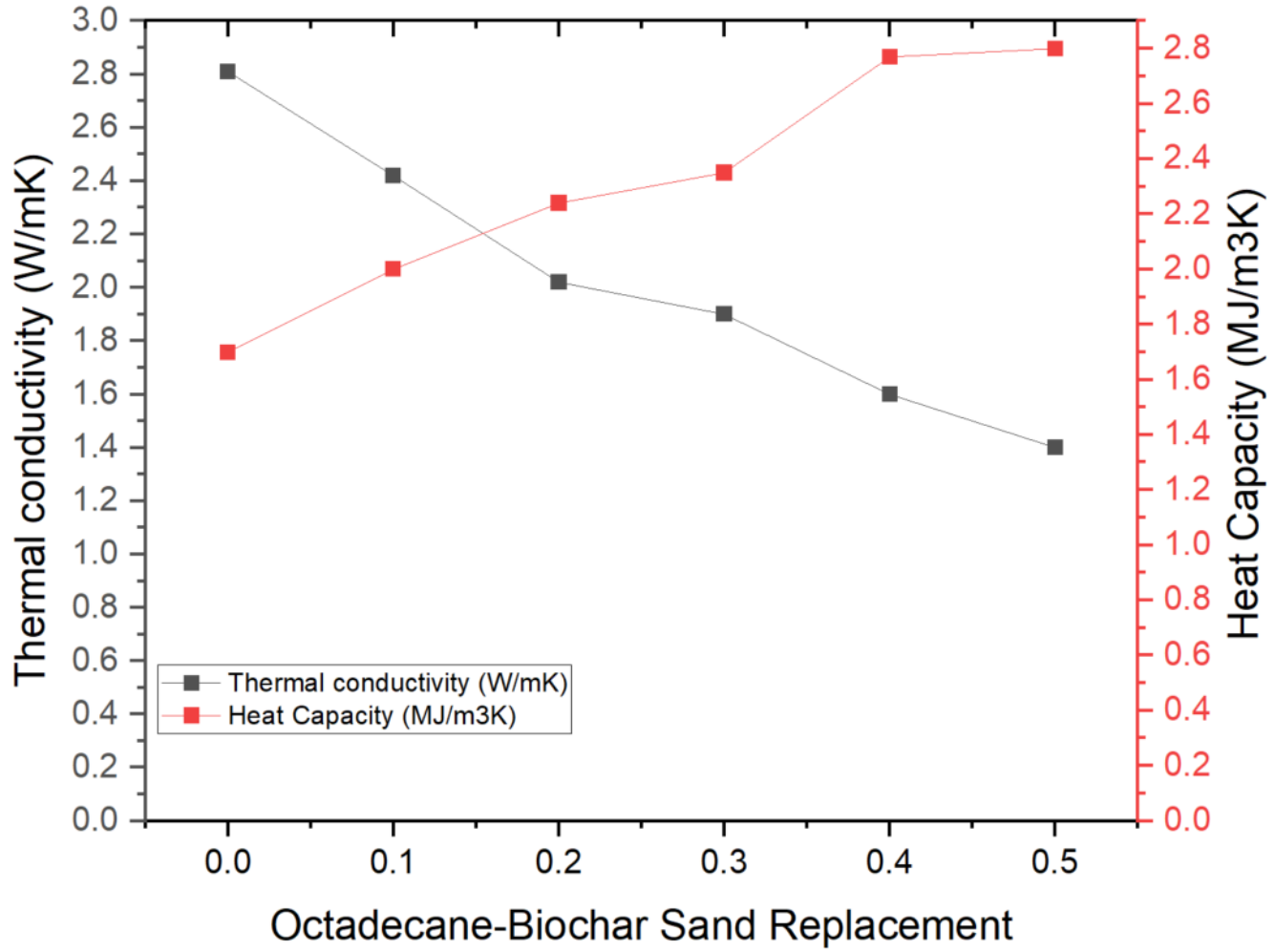
Results

PCM-Mortar

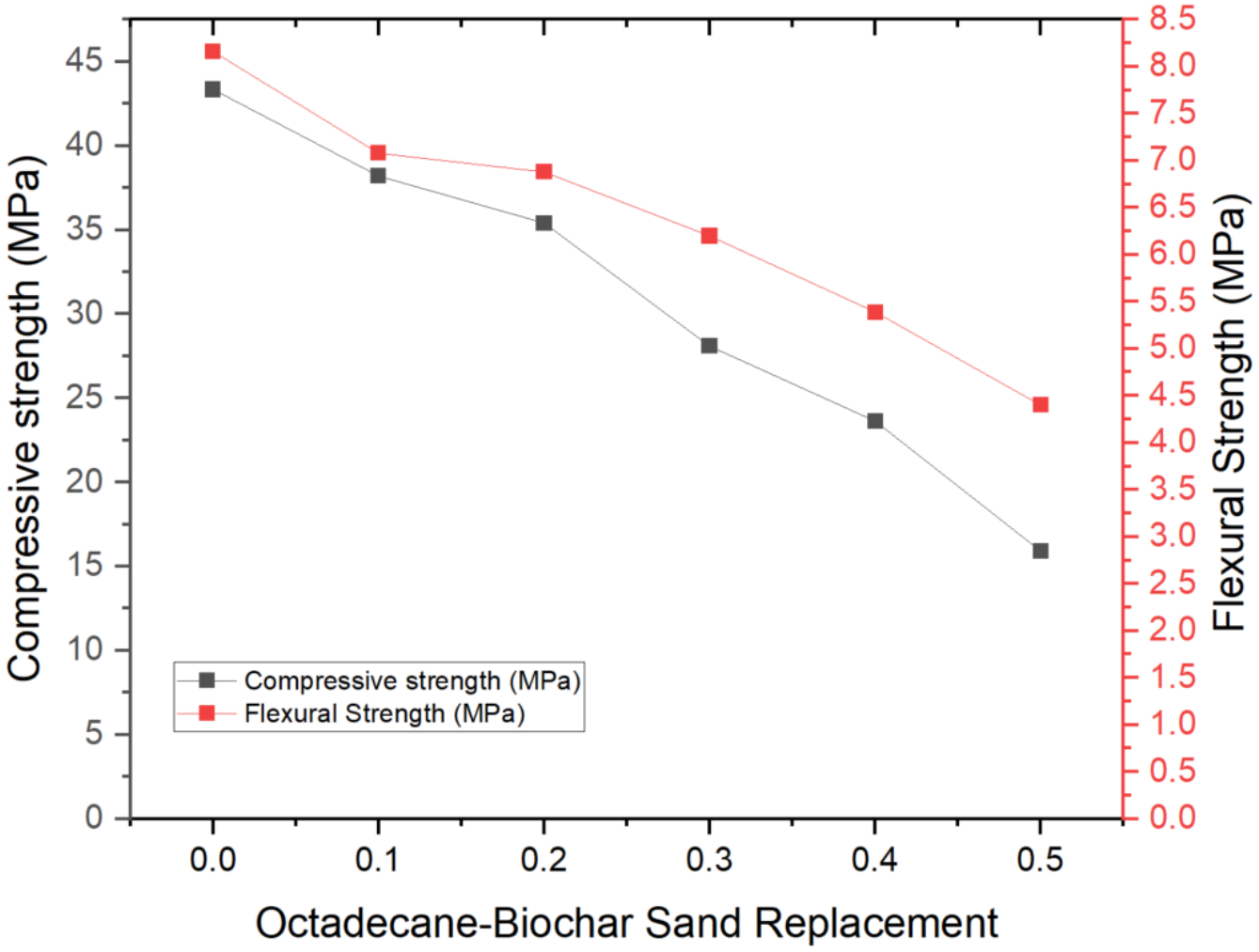
Mortar

PCM Biochar Samples at different loading ratios

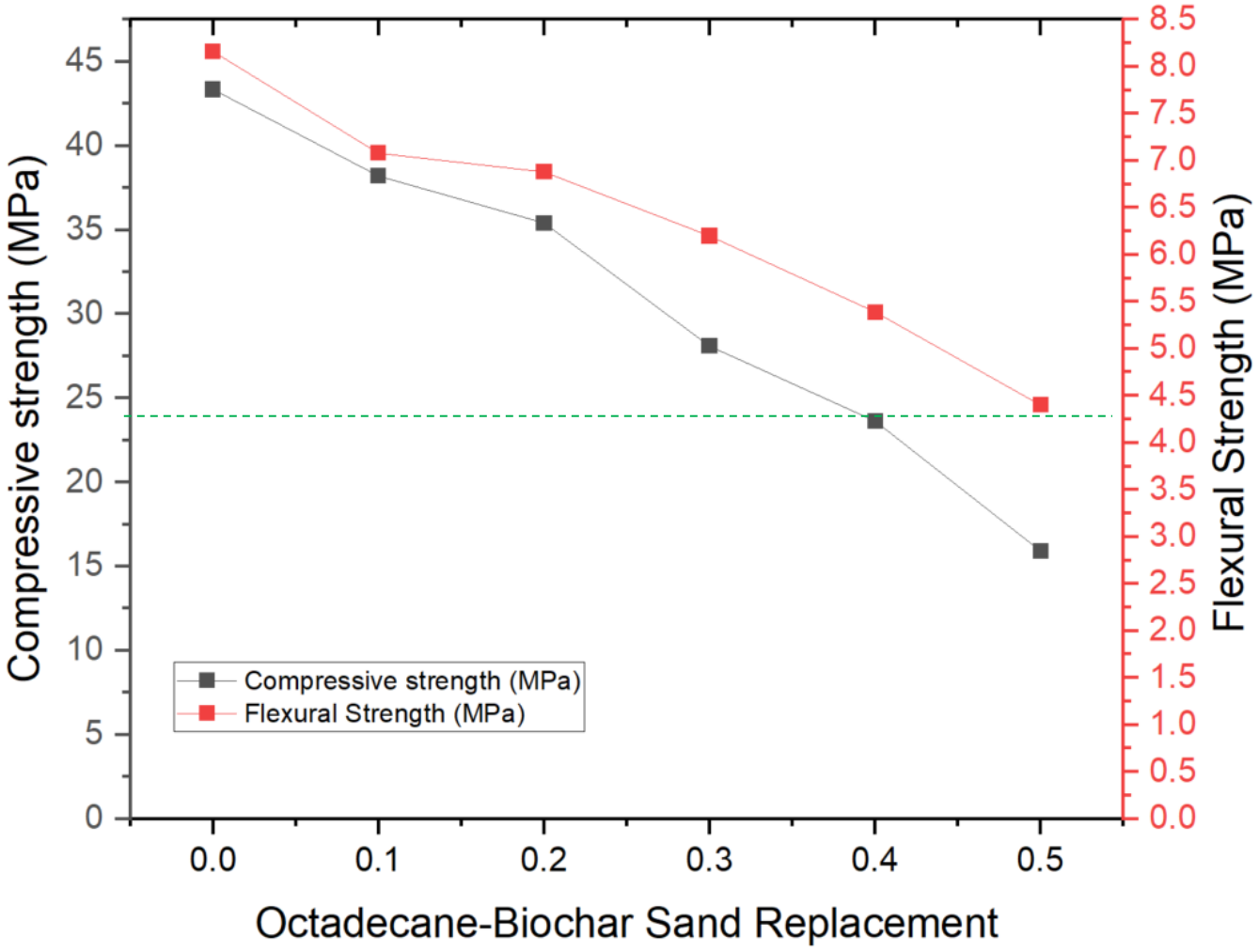
Results


Thermal conductivity (W/mK)
Heat Capacity (MJ/m3K)
Octadecane-Biochar Sand Replacement
Thermal conductivity (W/mK)
Heat Capacity (MJ/m3K)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
0.0
0.1
0.2
0.3
0.4
0.5

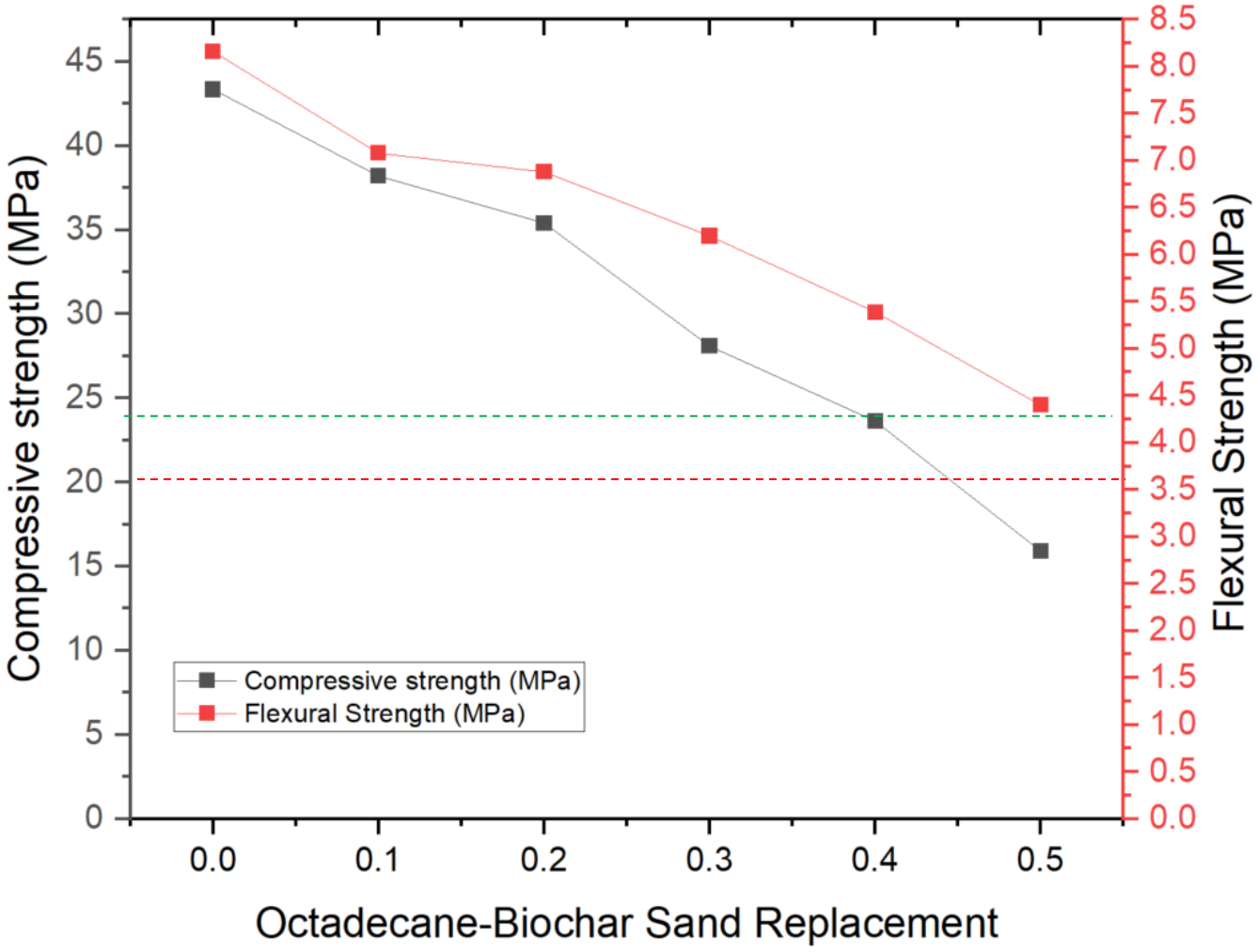
Results


Compressive strength (MPa)
Flexural Strength (MPa)
Octadecane-Biochar Sand Replacement
Compressive strength (MPa)
Flexural Strength (MPa)
0
5
10
15
20
25
30
35
40
45
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
0.0
0.1
0.2
0.3
0.4
0.5

Results

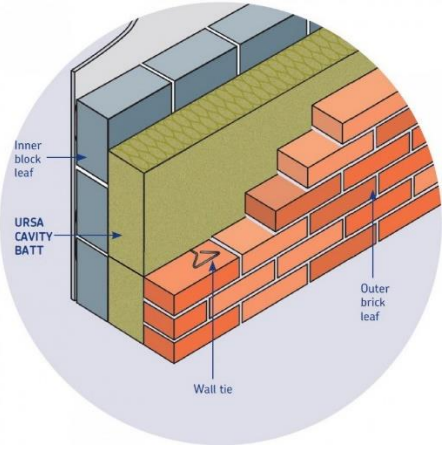

Compressive strength (MPa)
Flexural Strength (MPa)
Octadecane-Biochar Sand Replacement
Compressive strength (MPa)
Flexural Strength (MPa)
0
5
10
15
20
25
30
35
40
45
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
0.0
0.1
0.2
0.3
0.4
0.5

Results



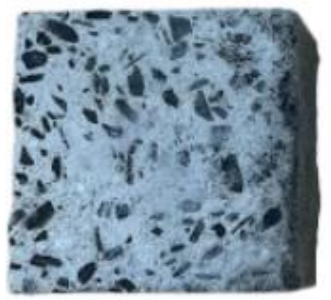
BSI 20 MPa for walls, columns, fireplaces and chimneys, footings, foundation walls, grade beams and piers.

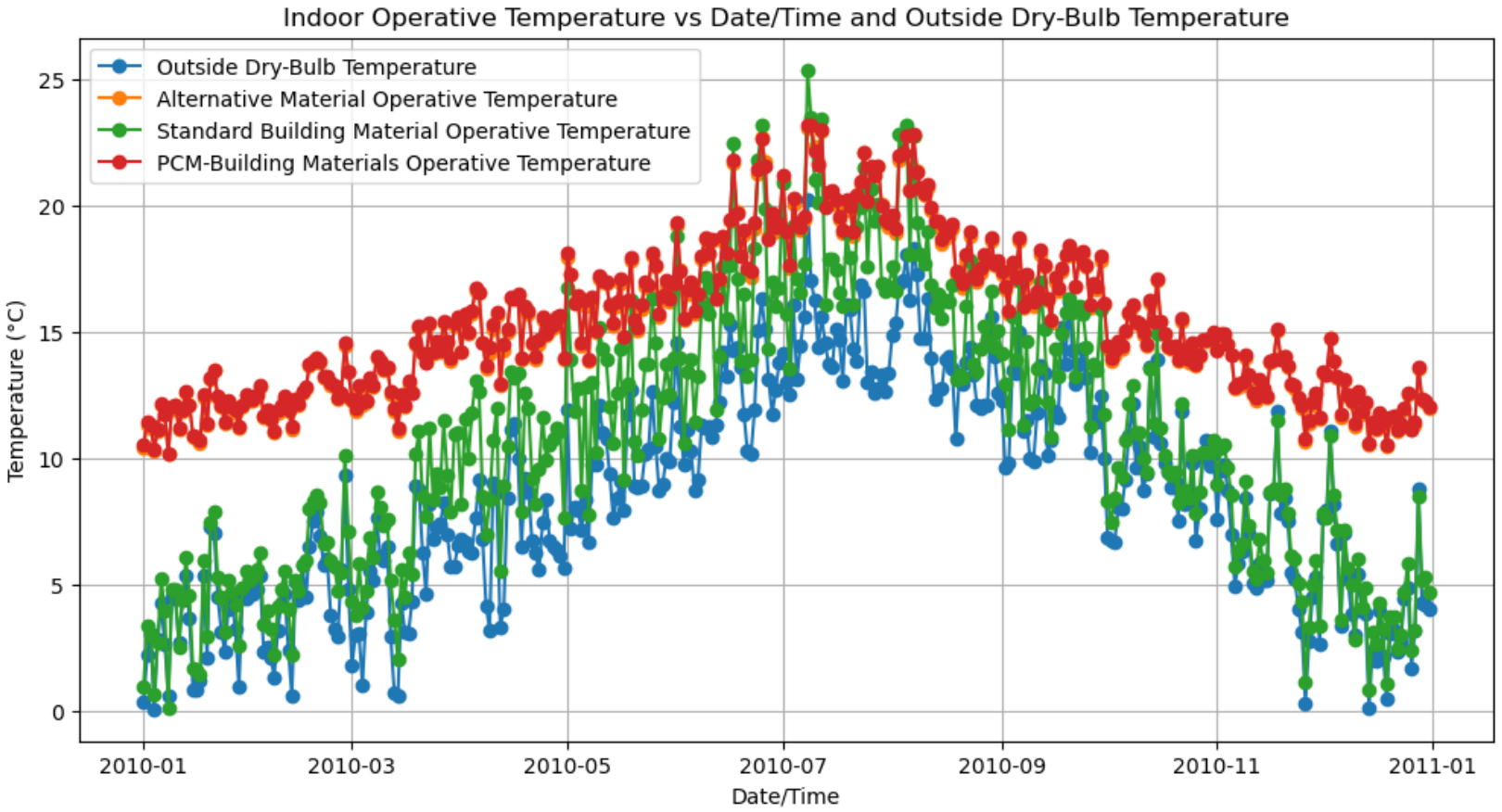
Results



DesignBuilder block of flats model located in Bristol.

Results

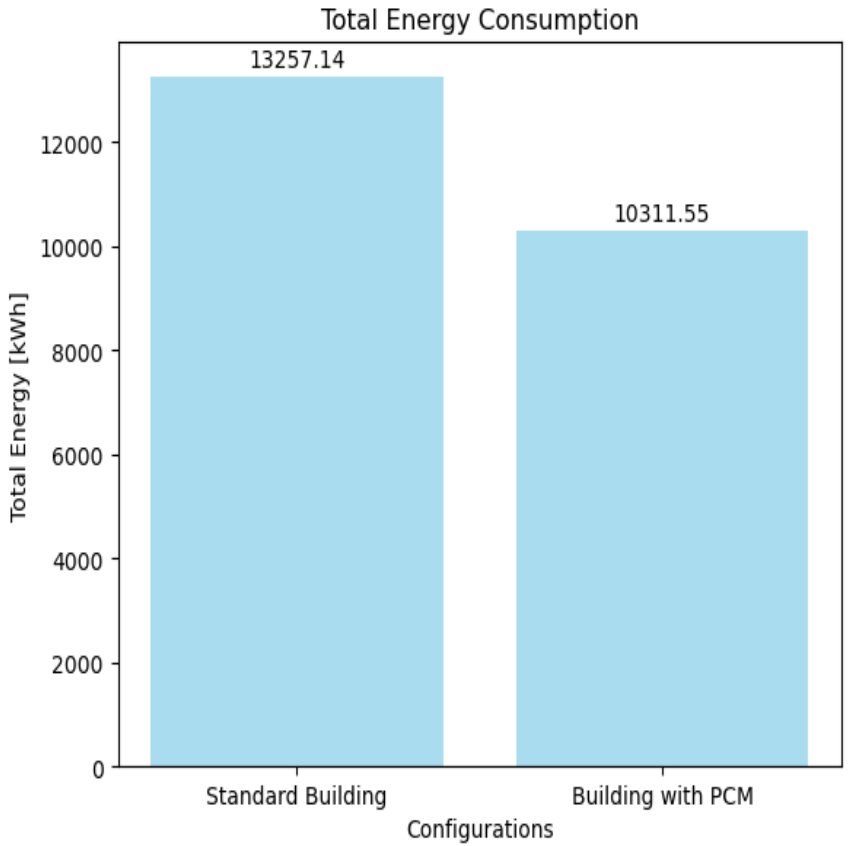


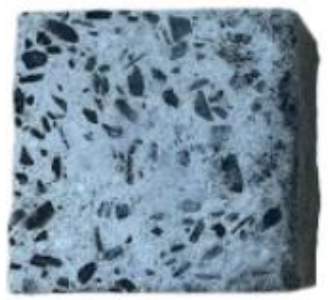


Simulation of indoor heat activity

Results

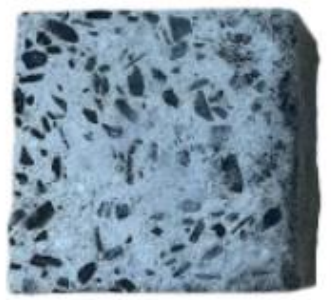
Energy saving of **22.5%**

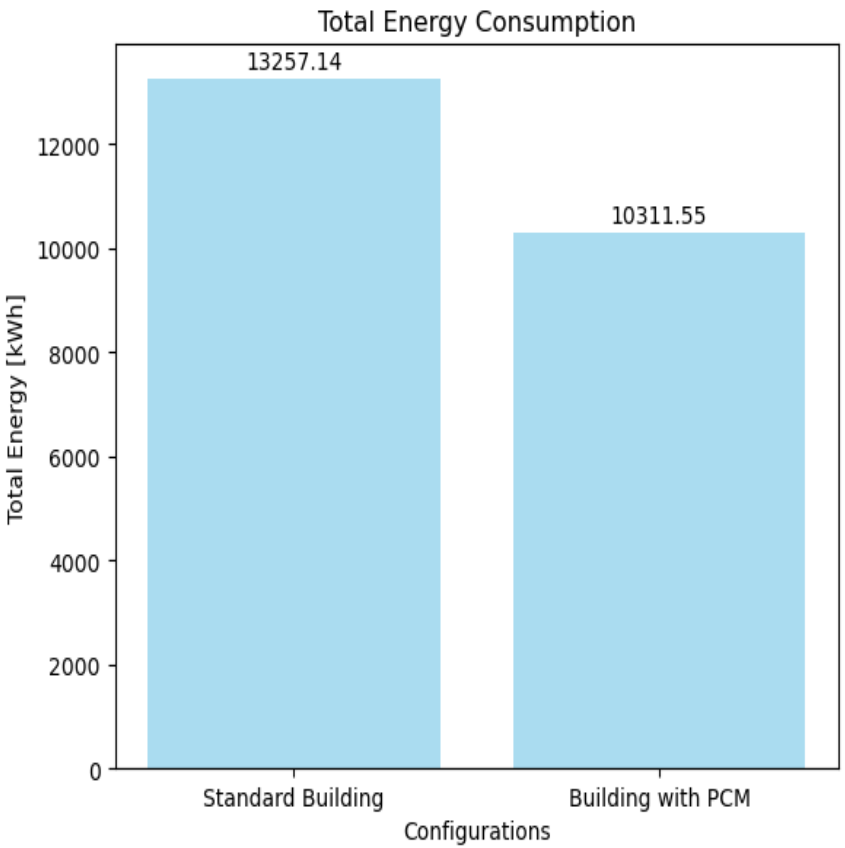


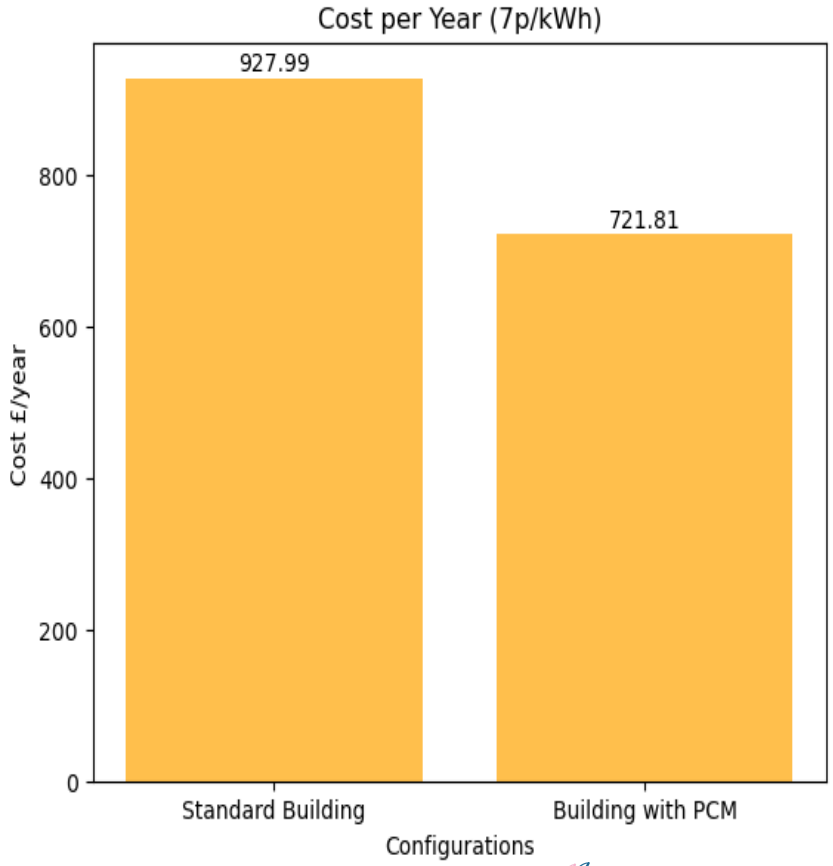


Results

Energy saving of **22.5%**

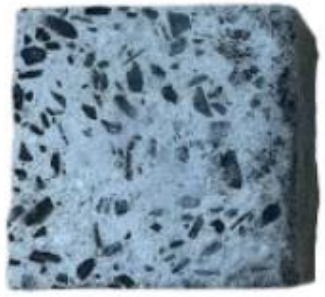






Conclusion/Future Work

- Investigate the **Upfront Costs** using **LCCA**
- Study the Environmental Impact of using this mix using LCA
- Build prototype building out of this material for testing.
- Incorporating PCM into other building materials such as insulation materials.



PCM-Mortar

Mortar

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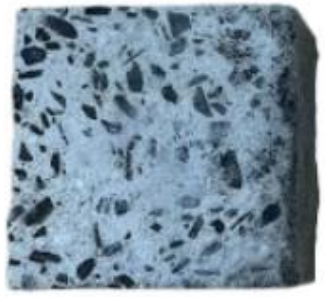

PCM-Mortar

Mortar

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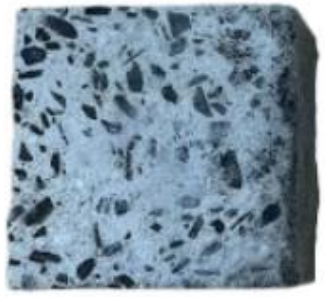

PCM-Mortar

Mortar

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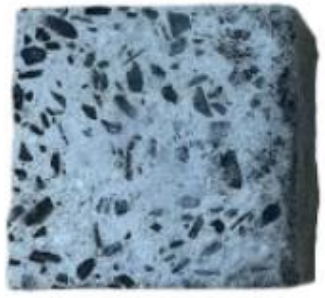

PCM-Mortar

Mortar

Insulation Materials

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Co-supervisor

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Co-supervisor

UNIVERSITY OF BATH
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Minerva SERIES

Thank you!