

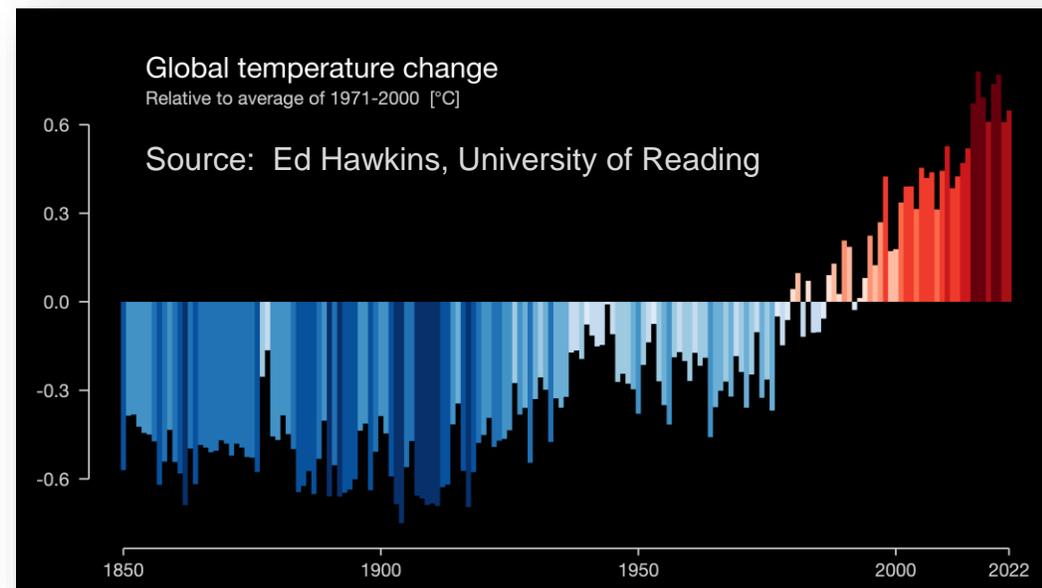
# The Only Way is Hydrogen

**Tim Mays**

Department of Chemical Engineering  
University of Bath  
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Minerva Series Lecture, The Mission Theatre, Bath  
Wednesday 17 April 2024

- More and (on average) richer people globally leading to increased demand for energy
- Increased CO<sub>2</sub> emissions to air from declining fossil fuels leading to a global heating crisis
- Challenges to security of energy supply



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## STATUTORY INSTRUMENTS

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**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%”.



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.

# Number One Element

**IUPAC Periodic Table of the Elements**

													13	14	15	16	17	18		
1 <b>H</b> hydrogen 1.008 (1.0078, 1.0082)												5 <b>B</b> boron 10.81 (10.808, 10.821)	6 <b>C</b> carbon 12.011 (12.009, 12.012)	7 <b>N</b> nitrogen 14.007 (14.006, 14.008)	8 <b>O</b> oxygen 15.999 (15.999, 16.000)	9 <b>F</b> fluorine 18.998	10 <b>Ne</b> neon 20.180			
3 <b>Li</b> lithium 6.94 (6.938, 6.957)	4 <b>Be</b> beryllium 9.0122												13 <b>Al</b> aluminium 26.982	14 <b>Si</b> silicon 28.085 (28.084, 28.086)	15 <b>P</b> phosphorus 30.974	16 <b>S</b> sulfur 32.06 (32.059, 32.076)	17 <b>Cl</b> chlorine 35.45 (35.446, 35.457)	18 <b>Ar</b> argon 39.96 (39.962, 39.963)		
11 <b>Na</b> sodium 22.990	12 <b>Mg</b> magnesium 24.305 (24.304, 24.307)												29 <b>Cu</b> copper 63.546(2)	30 <b>Zn</b> zinc 65.38(2)	31 <b>Ga</b> gallium 69.723	32 <b>Ge</b> germanium 72.630(6)	33 <b>As</b> arsenic 74.922	34 <b>Se</b> selenium 78.971(8)	35 <b>Br</b> bromine 79.904 (79.901, 79.907)	36 <b>Kr</b> krypton 83.798(2)
19 <b>K</b> potassium 39.098	20 <b>Ca</b> calcium 40.078(4)	21 <b>Sc</b> scandium 44.956	22 <b>Ti</b> titanium 47.867	23 <b>V</b> vanadium 50.942	24 <b>Cr</b> chromium 51.996	25 <b>Mn</b> manganese 54.938	26 <b>Fe</b> iron 55.845(2)	27 <b>Co</b> cobalt 58.933	28 <b>Ni</b> nickel 58.693	29 <b>Cu</b> copper 63.546(2)	30 <b>Zn</b> zinc 65.38(2)	31 <b>Ga</b> gallium 69.723	32 <b>Ge</b> germanium 72.630(6)	33 <b>As</b> arsenic 74.922	34 <b>Se</b> selenium 78.971(8)	35 <b>Br</b> bromine 79.904 (79.901, 79.907)	36 <b>Kr</b> krypton 83.798(2)			
37 <b>Rb</b> rubidium 85.468	38 <b>Sr</b> strontium 87.62	39 <b>Y</b> yttrium 88.906	40 <b>Zr</b> zirconium 91.224(2)	41 <b>Nb</b> niobium 92.905	42 <b>Mo</b> molybdenum 95.95	43 <b>Tc</b> technetium	44 <b>Ru</b> ruthenium 101.07(2)	45 <b>Rh</b> rhodium 102.91	46 <b>Pd</b> palladium 106.42	47 <b>Ag</b> silver 107.87	48 <b>Cd</b> cadmium 112.41	49 <b>In</b> indium 114.82	50 <b>Sn</b> tin 118.71	51 <b>Sb</b> antimony 121.76	52 <b>Te</b> tellurium 127.60(3)	53 <b>I</b> iodine 126.90	54 <b>Xe</b> xenon 131.29			
55 <b>Cs</b> caesium 132.91	56 <b>Ba</b> barium 137.33	57-71 lanthanoids	72 <b>Hf</b> hafnium 178.49(2)	73 <b>Ta</b> tantalum 180.95	74 <b>W</b> tungsten 183.84	75 <b>Re</b> rhenium 186.21	76 <b>Os</b> osmium 190.23(3)	77 <b>Ir</b> iridium 192.22	78 <b>Pt</b> platinum 195.08	79 <b>Au</b> gold 196.97	80 <b>Hg</b> mercury 200.59	81 <b>Tl</b> thallium 204.38 (204.38, 204.38)	82 <b>Pb</b> lead 207.2	83 <b>Bi</b> bismuth 208.98	84 <b>Po</b> polonium	85 <b>At</b> astatine	86 <b>Rn</b> radon			
87 <b>Fr</b> francium	88 <b>Ra</b> radium	89-103 actinoids	104 <b>Rf</b> rutherfordium	105 <b>Db</b> dubnium	106 <b>Sg</b> seaborgium	107 <b>Bh</b> bohrium	108 <b>Hs</b> hassium	109 <b>Mt</b> meitnerium	110 <b>Ds</b> darmstadtium	111 <b>Rg</b> roentgenium	112 <b>Cn</b> copernicium	113 <b>Nh</b> nihonium	114 <b>Fl</b> flerovium	115 <b>Mc</b> moscovium	116 <b>Lv</b> livermorium	117 <b>Ts</b> tennessine	118 <b>Og</b> oganeson			

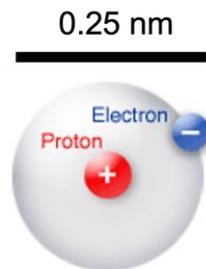


57 <b>La</b> lanthanum 138.91	58 <b>Ce</b> cerium 140.12	59 <b>Pr</b> praseodymium 140.91	60 <b>Nd</b> neodymium 144.24	61 <b>Pm</b> promethium	62 <b>Sm</b> samarium 150.36(2)	63 <b>Eu</b> europium 151.96	64 <b>Gd</b> gadolinium 157.25(3)	65 <b>Tb</b> terbium 158.93	66 <b>Dy</b> dysprosium 162.50	67 <b>Ho</b> holmium 164.93	68 <b>Er</b> erbium 167.26	69 <b>Tm</b> thulium 168.93	70 <b>Yb</b> ytterbium 173.05	71 <b>Lu</b> lutetium 174.97
89 <b>Ac</b> actinium 227.04	90 <b>Th</b> thorium 232.04	91 <b>Pa</b> protactinium 231.04	92 <b>U</b> uranium 238.03	93 <b>Np</b> neptunium	94 <b>Pu</b> plutonium	95 <b>Am</b> americium	96 <b>Cm</b> curium	97 <b>Bk</b> berkelium	98 <b>Cf</b> californium	99 <b>Es</b> einsteinium	100 <b>Fm</b> fermium	101 <b>Md</b> mendelevium	102 <b>No</b> nobelium	103 <b>Lr</b> lawrencium

For notes and updates to this table, see [www.iupac.org](http://www.iupac.org). This version is dated 1 December 2018.  
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# Universal Occurrence

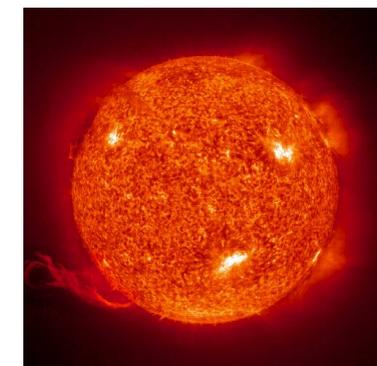
- Consisting of the simplest, smallest and lightest of all atoms, hydrogen ...



- ... 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

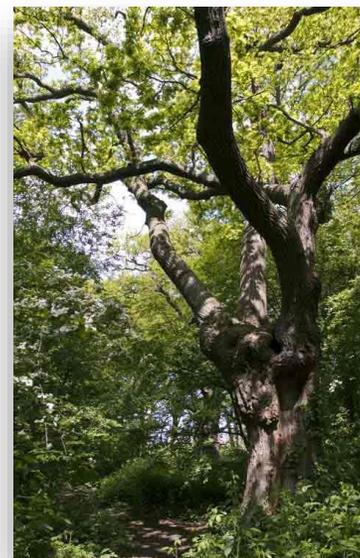
- Hydrogen is the third commonest element on the Earth's surface but almost all of it is contained in chemical compounds



water  
( $\text{H}_2\text{O}$ )  
 $\sim 10^{21}$  kg

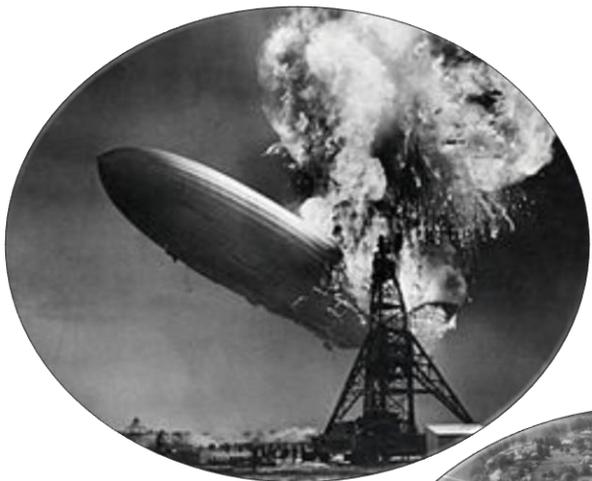


fossil  
fuels ( $-\text{CH}_x$ )

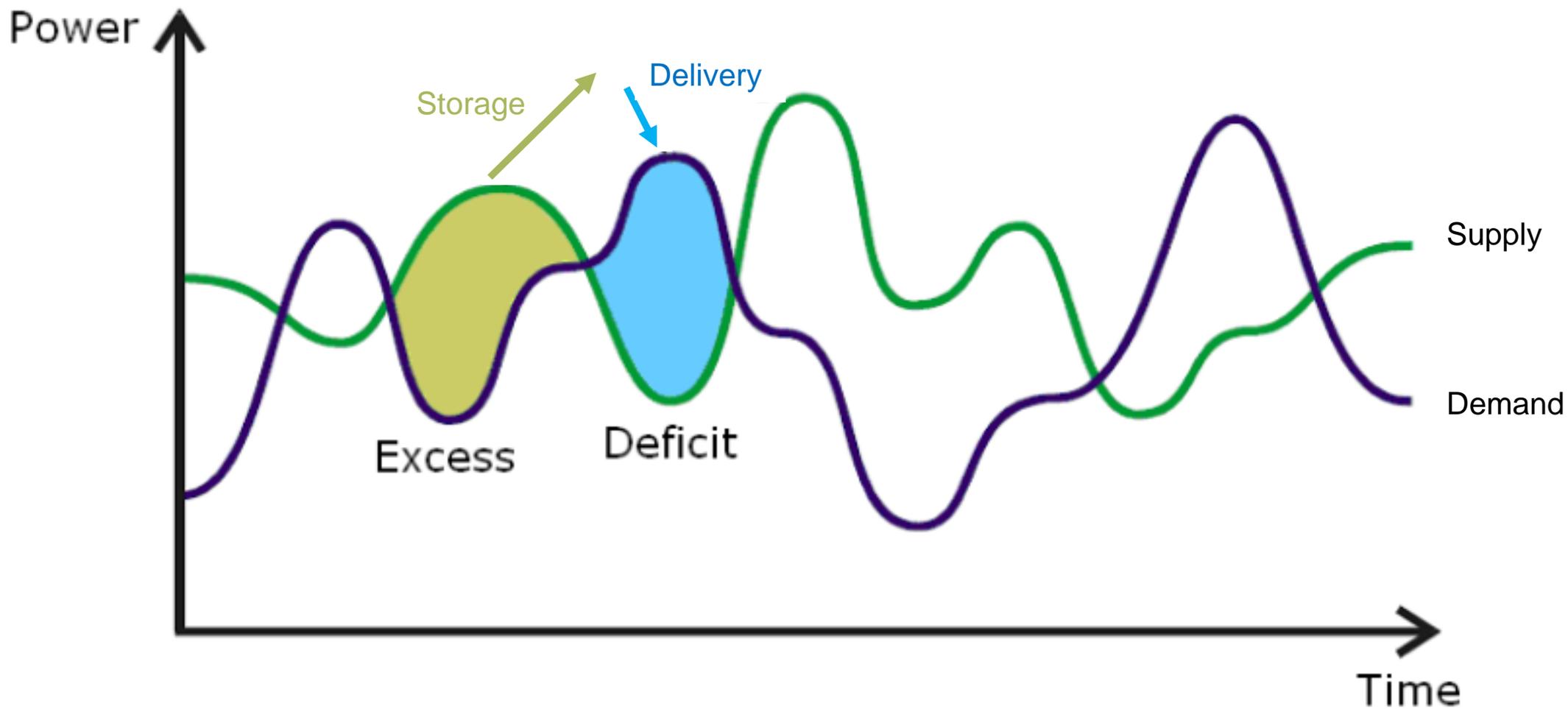


biomass ( $-\text{CH}_{2x}\text{O}_x$ )  
 $\sim 10^{15}$  kg (dry)

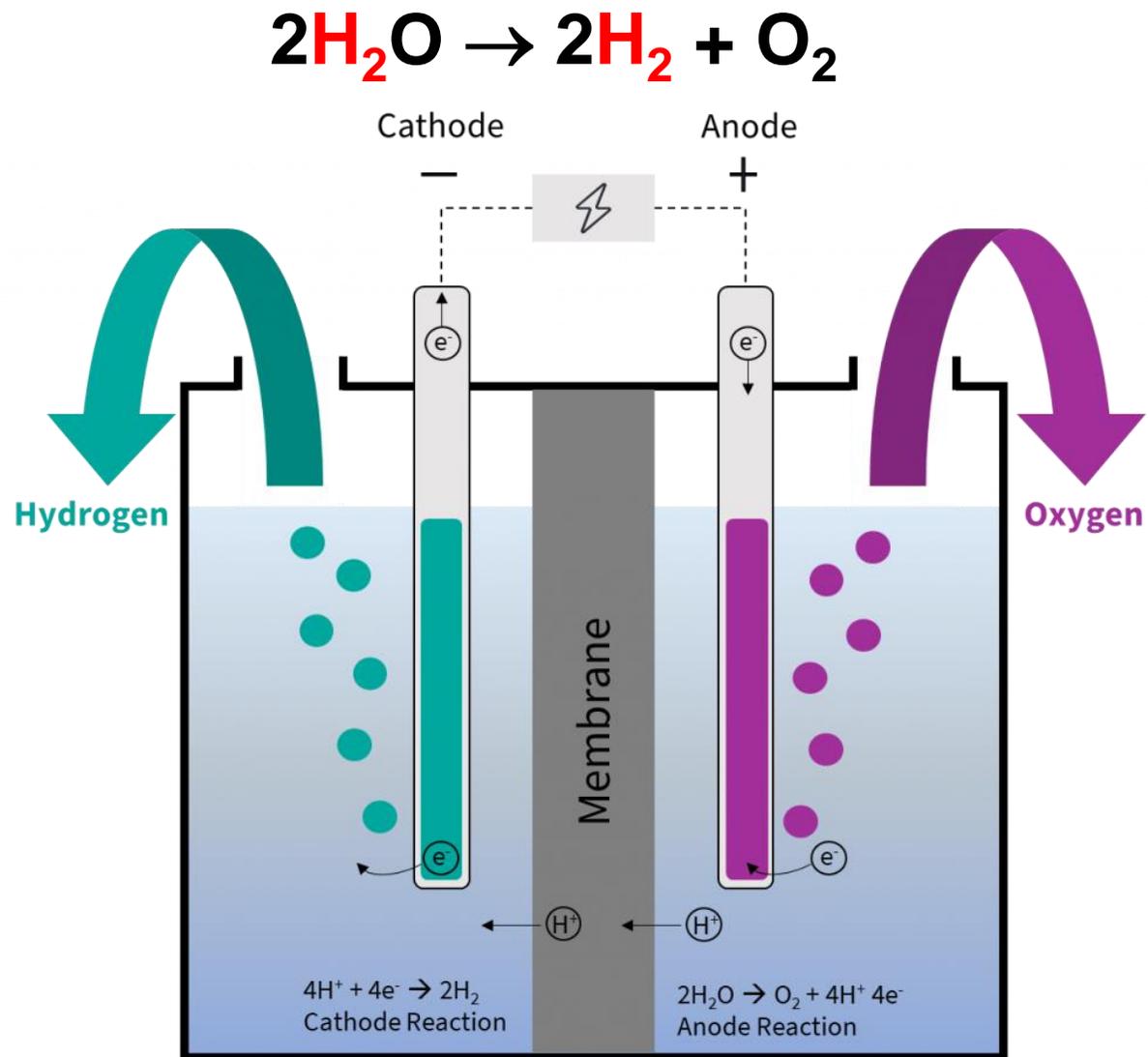
# Hydrogen in Real Life



# Buffering Intermittent Renewables



# Electrolytic Water Splitting



# Hydrogen Colours

Colour	Fuel	Process	Products/Emissions
	Coal	Steam reforming or gasification	$H_2 + CO_2$ (released)
	N/A	Naturally occurring	$H_2$
	Natural Gas	Steam reforming	$H_2 + CO_2$ (released)
	Natural Gas	Steam reforming	$H_2 + CO_2$ (% captured and stored)
	Natural Gas	Pyrolysis	$H_2 + C$ (solid)
	Nuclear Power	Catalytic splitting	$H_2 + O_2$
	Nuclear Power	Electrolysis	$H_2 + O_2$
	Solar Power	Electrolysis	$H_2 + O_2$
	Renewable Electricity	Electrolysis	$H_2 + O_2$

# Storage

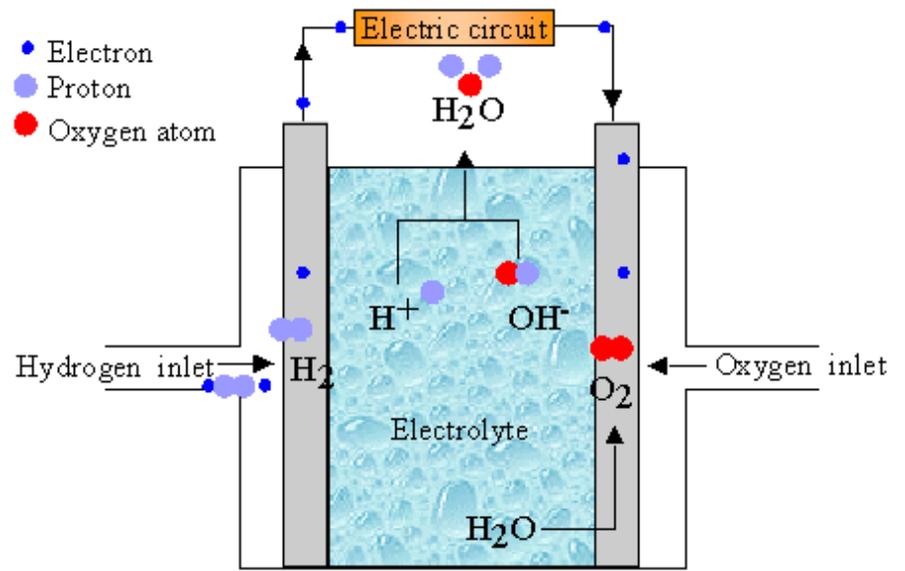


**storing molecules**  
easy

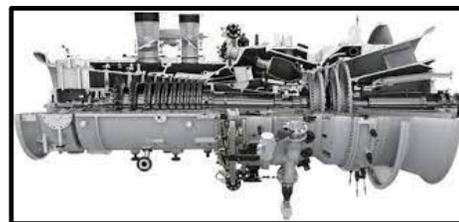


**storing electrons**  
not so easy

# Energy Harvesting from Hydrogen

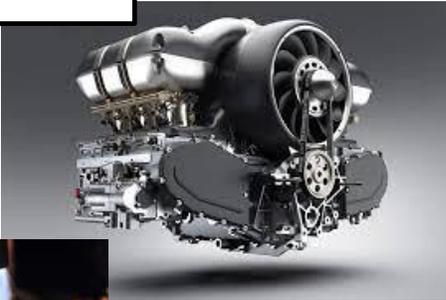


**Electrochemical  
(fuel cell)**



Gas turbine

Internal  
combustion  
engine



Flame burner

Boiler



Cooker

**Thermochemical  
(combustion)**

# Hydrogen Value Chain

Enable the renewable energy system → Decarbonize end uses

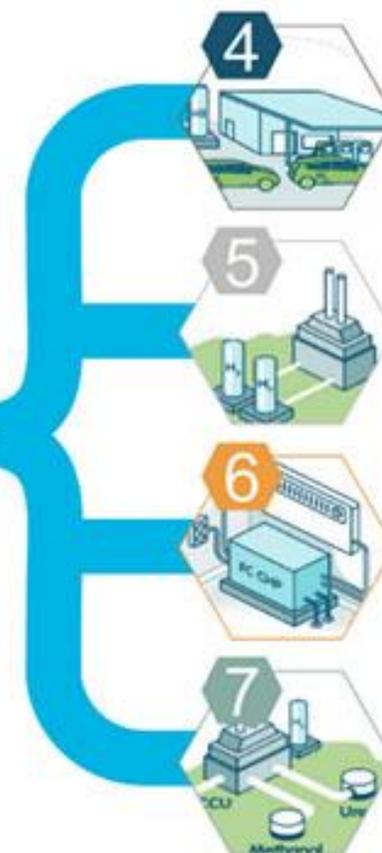
Enable large-scale renewables integration and power generation



Distribute energy across sectors and regions



Act as a **buffer** to increase system resilience



Help decarbonize **transportation**

Help decarbonize industrial energy use

Help decarbonize **building heat and power**

Serve as renewable **feedstock**

# 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 be 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

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19 February 2004 Volume 427 Issue no 6976

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## **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



# Research Overview

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- PhD, 2021 - 2025



**Mohamed Katish**  
PhD Researcher

“The aim of the project is to reduce **energy bills** and **carbon emissions** by reducing the large amount of **energy** used in **space heating & cooling**”.



**Veronica Ferrandiz-Mas**  
Lead supervisor



**Steve Allen**  
Co-supervisor



**Adam Squires**  
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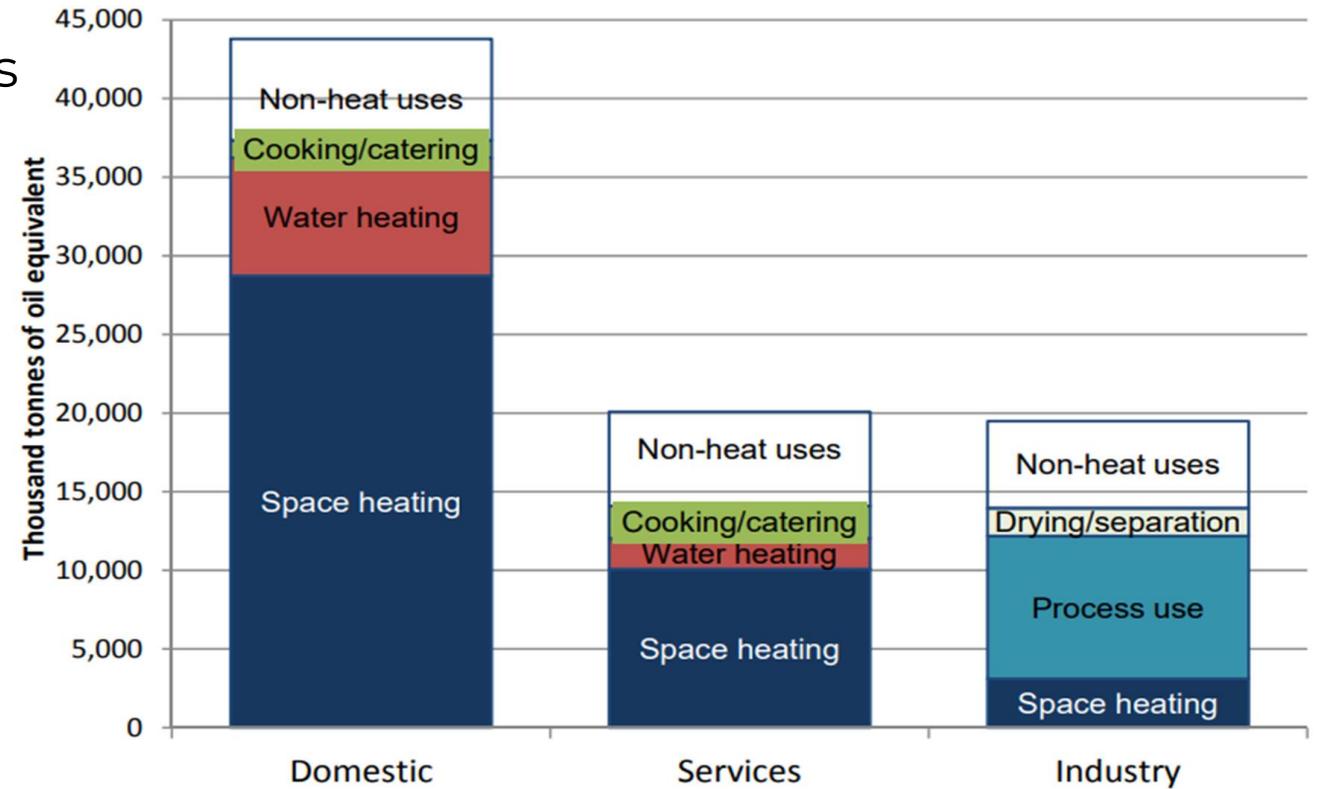


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# Research Overview

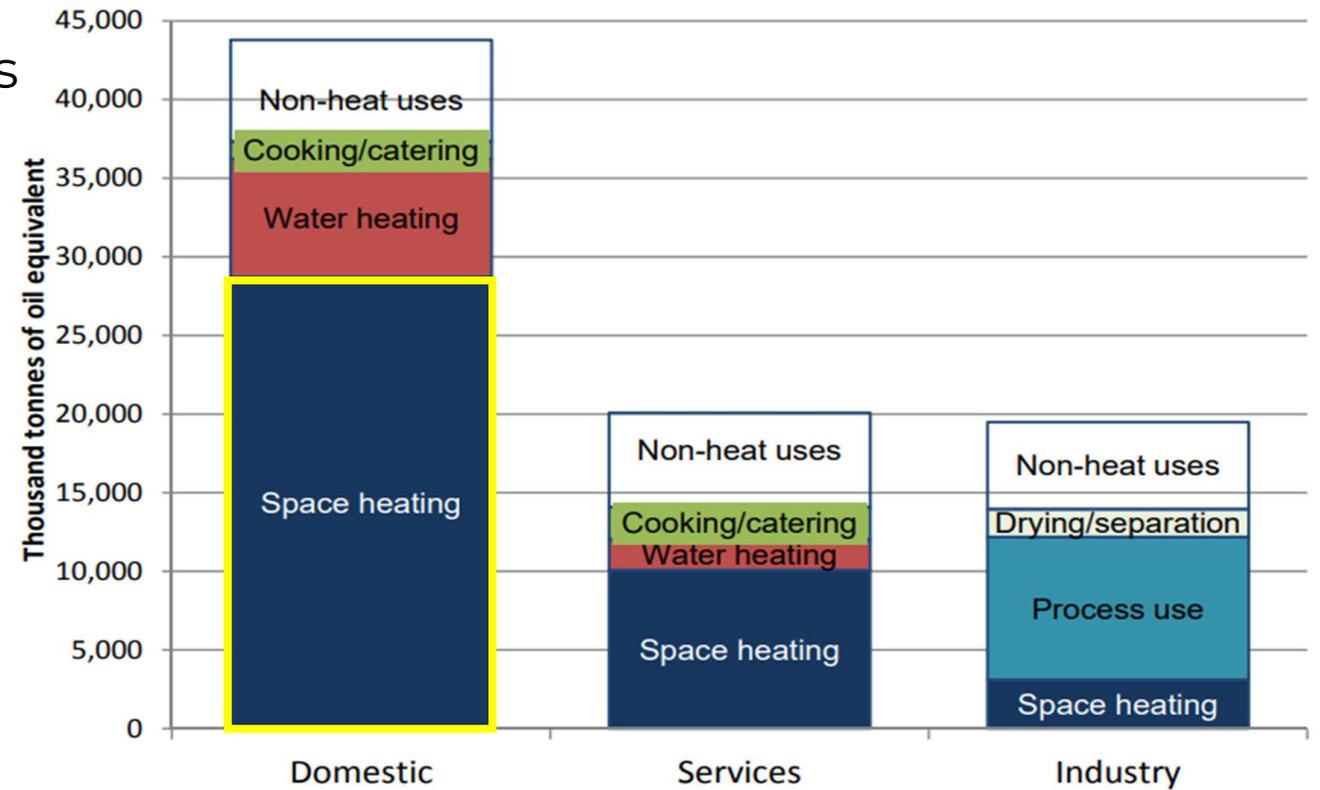
**70%** of the energy we use at home goes towards **Space Heating...**



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

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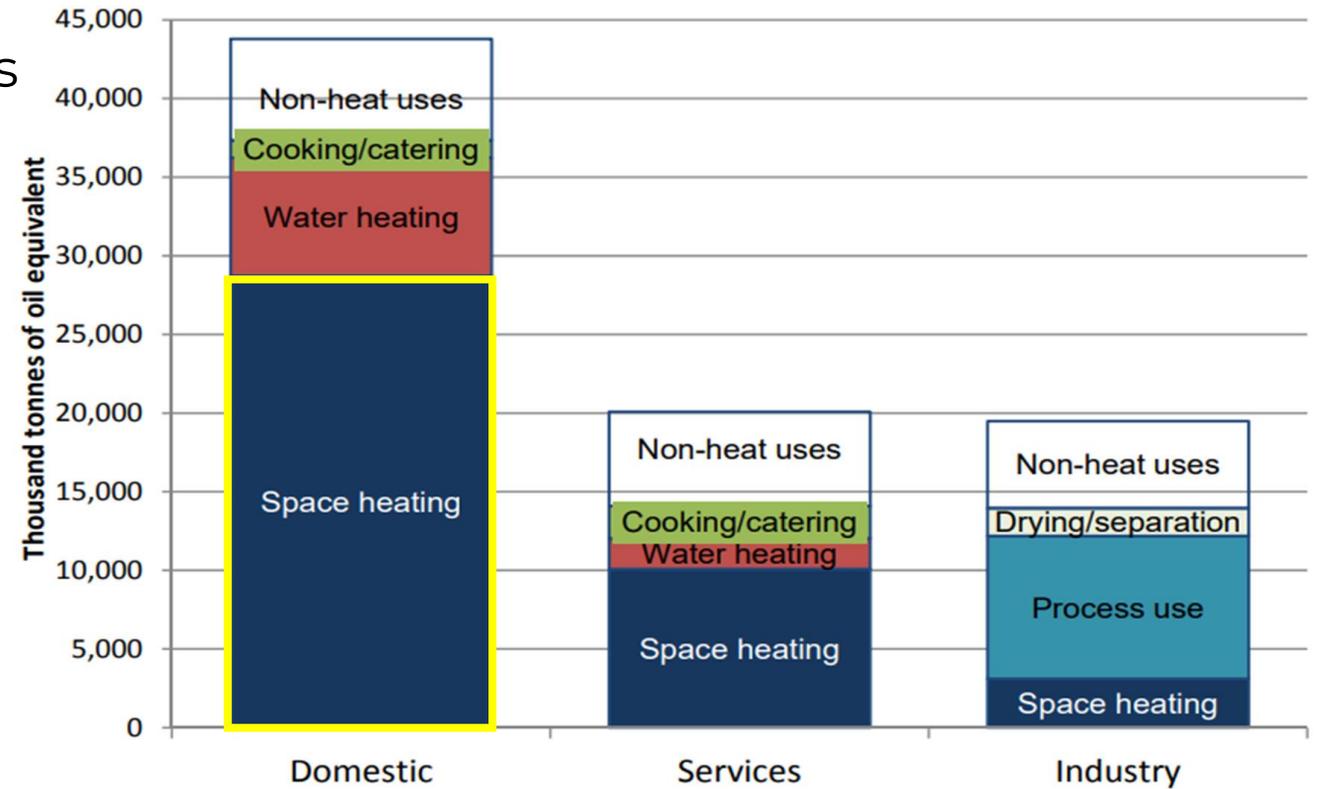
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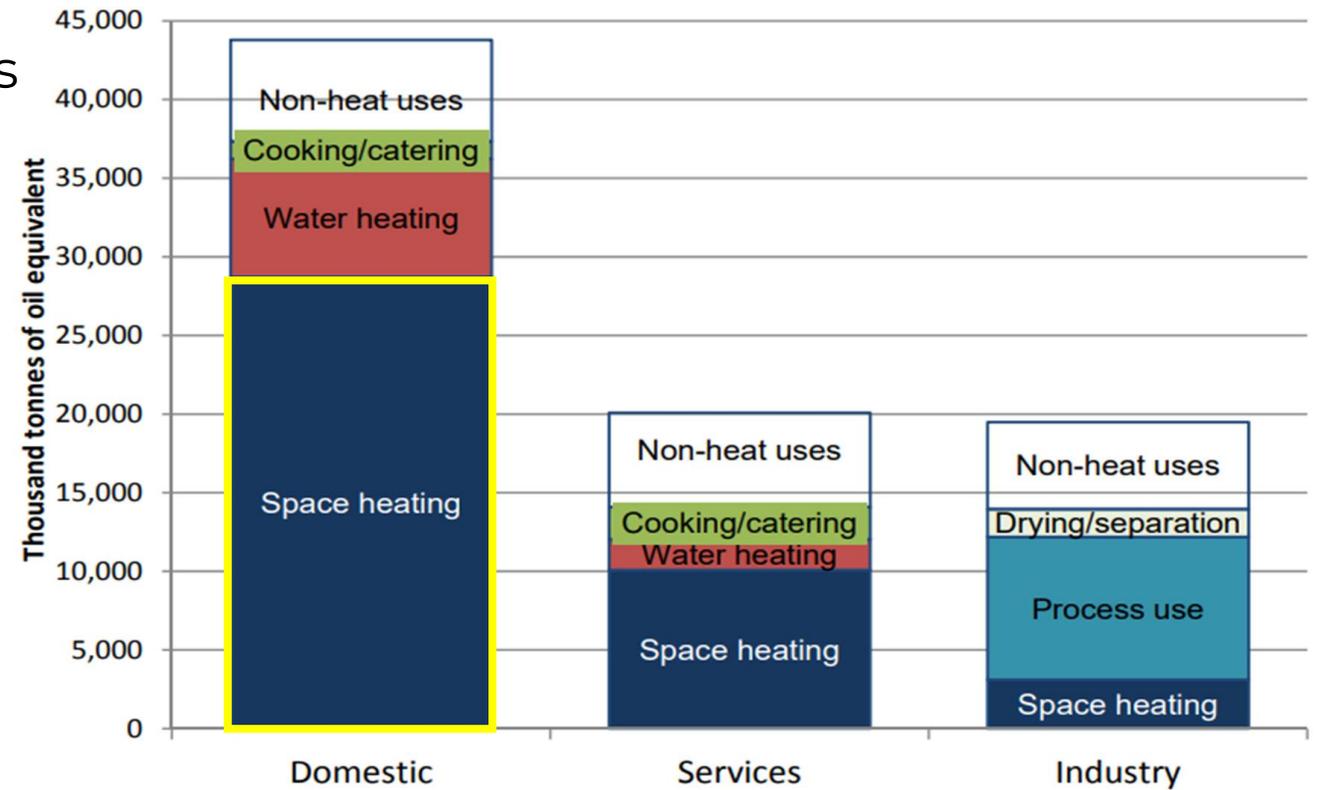
**£6.5 billion** were spent on space heating & cooling in 2022 UK...



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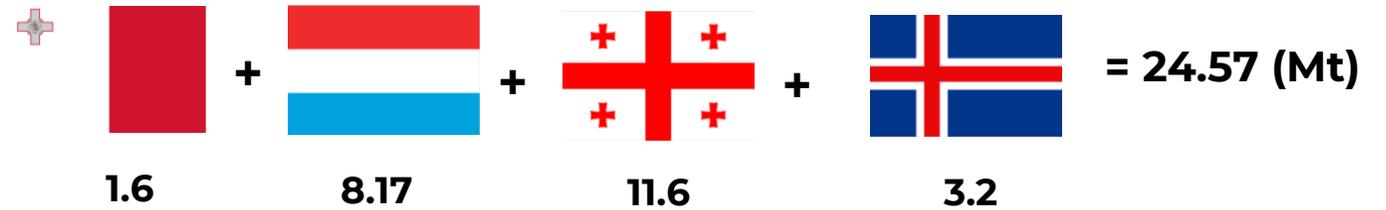
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# Research Overview

- Space heating and cooling in the UK was responsible for more than 16% of the UK's total CO<sub>2</sub>e.



**28 million tonnes (Mt) CO<sub>2</sub>e**

16% of the UK's total CO<sub>2</sub>e

1. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/1064923/2021-provisional-emissions-statistics-report.pdf](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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16% of the UK's total CO<sub>2</sub>e



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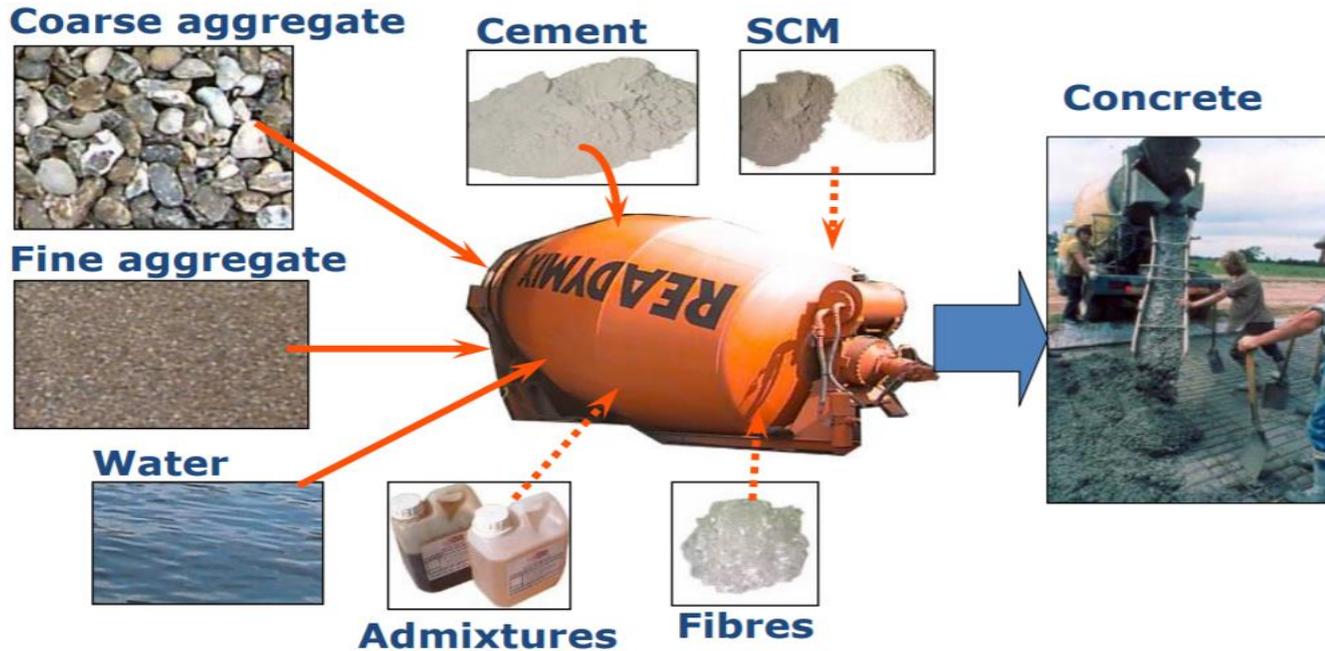
# Research Overview

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



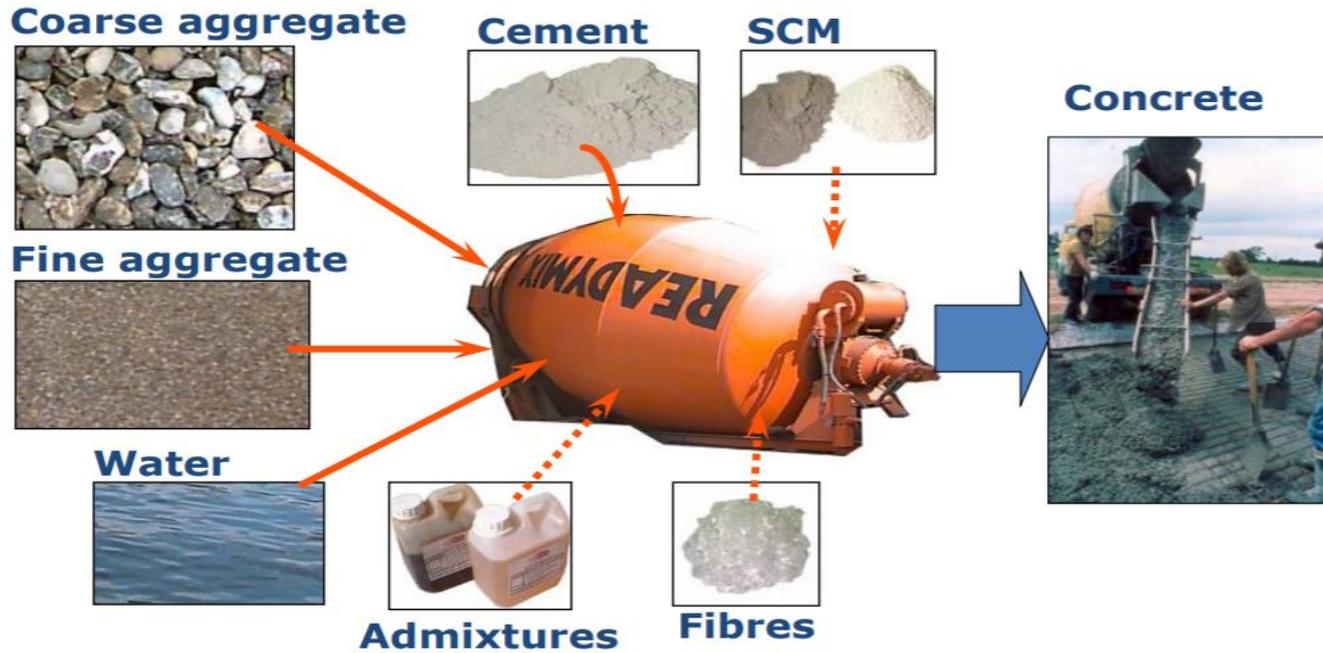
# Methodology

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



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**PCM: Phase Change Material**

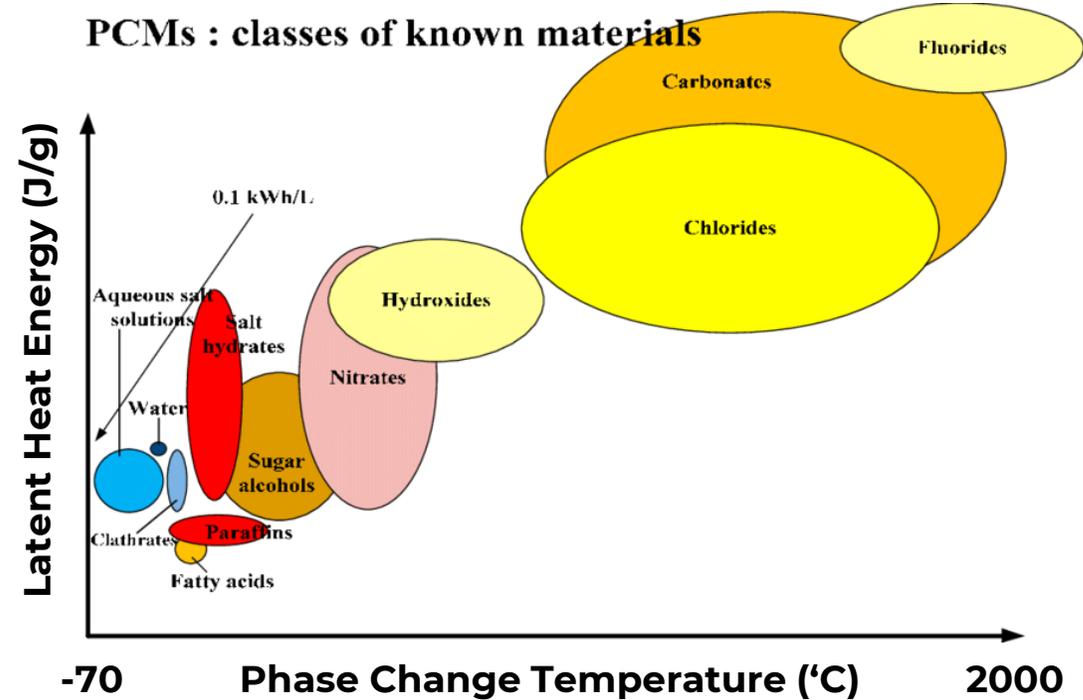
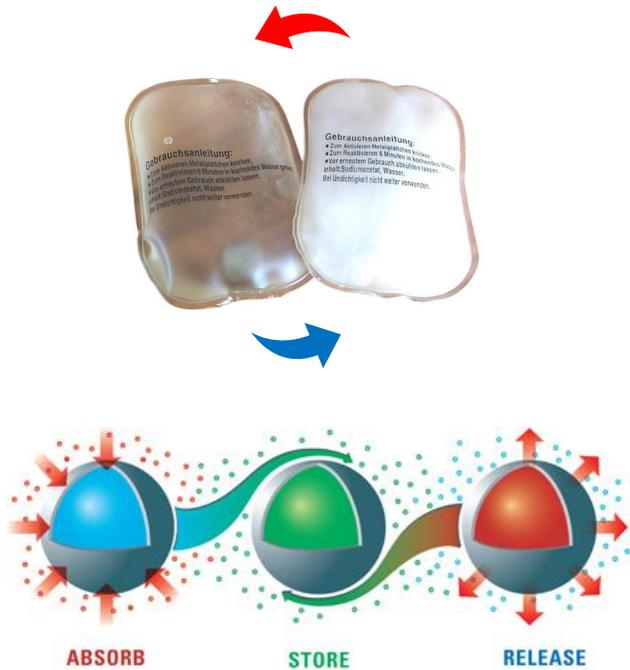
# Methodology

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



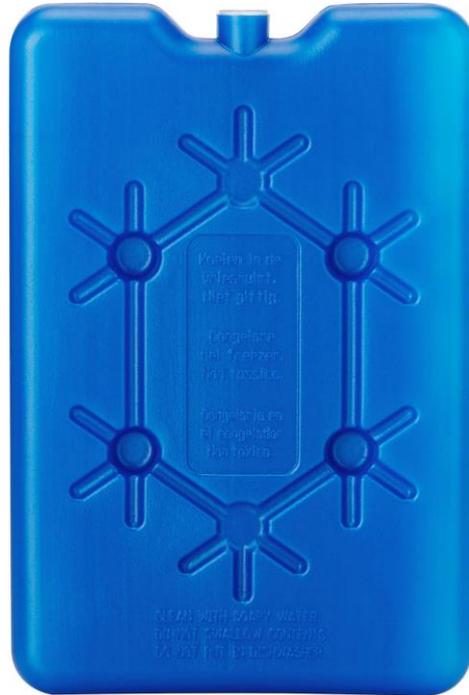
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Gaberoun - Oasis in Libya

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Mount Everest



Gaberoun - Oasis in Libya

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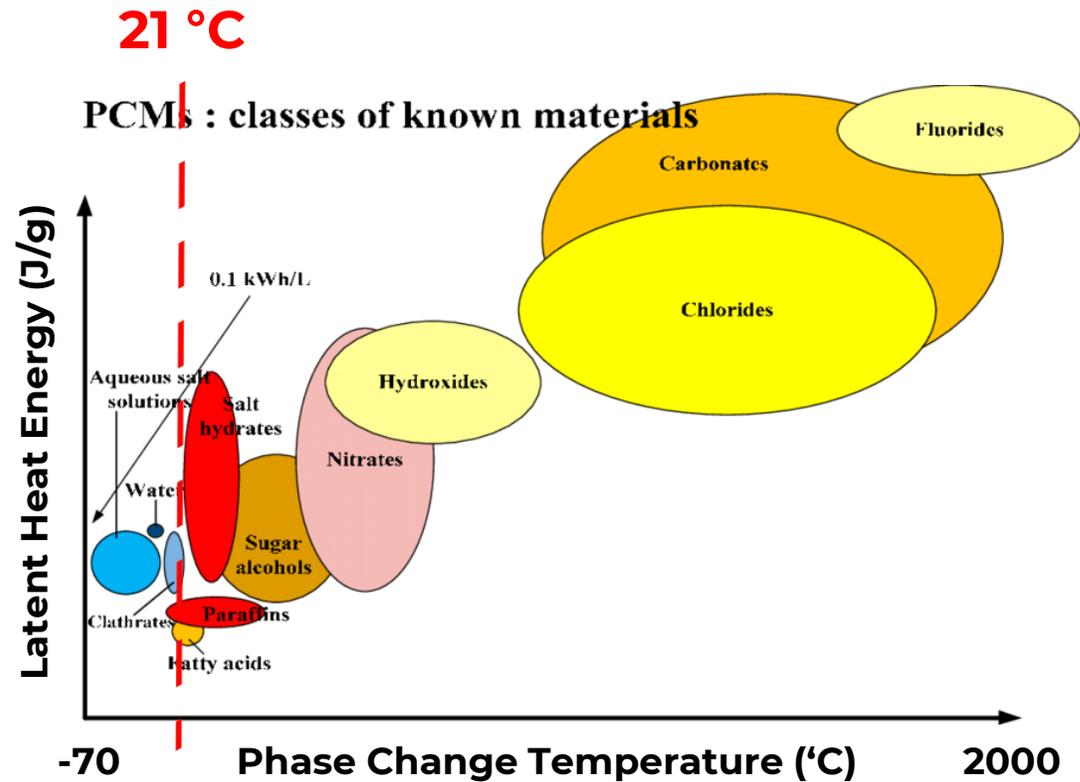
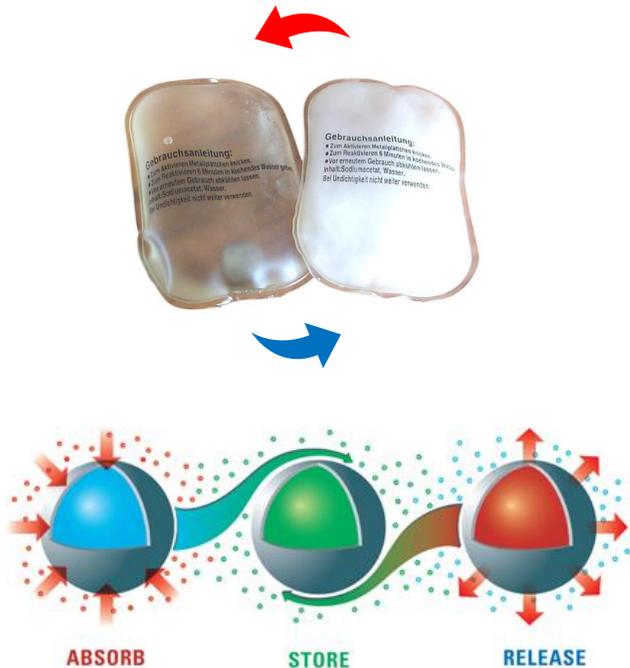
Mount Everest



Gaberoun - Oasis in Libya

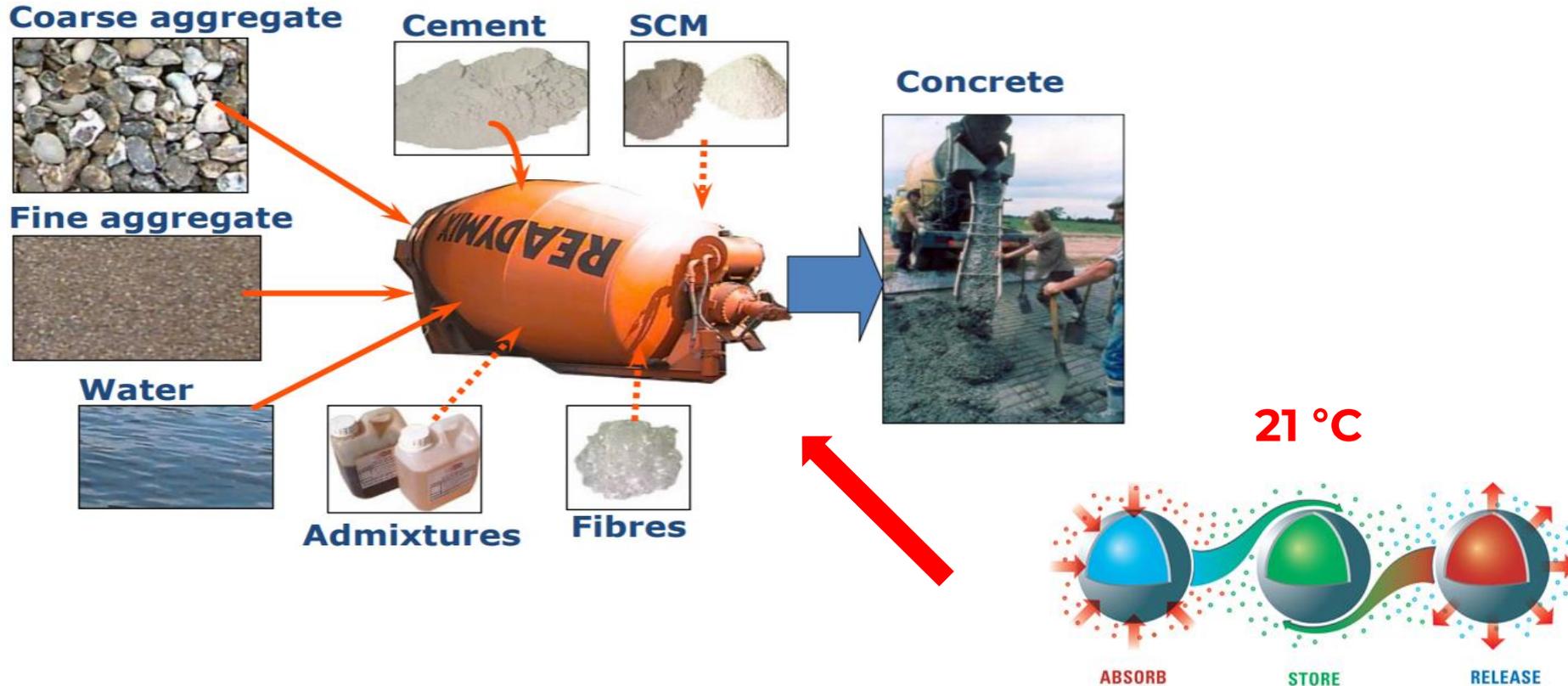
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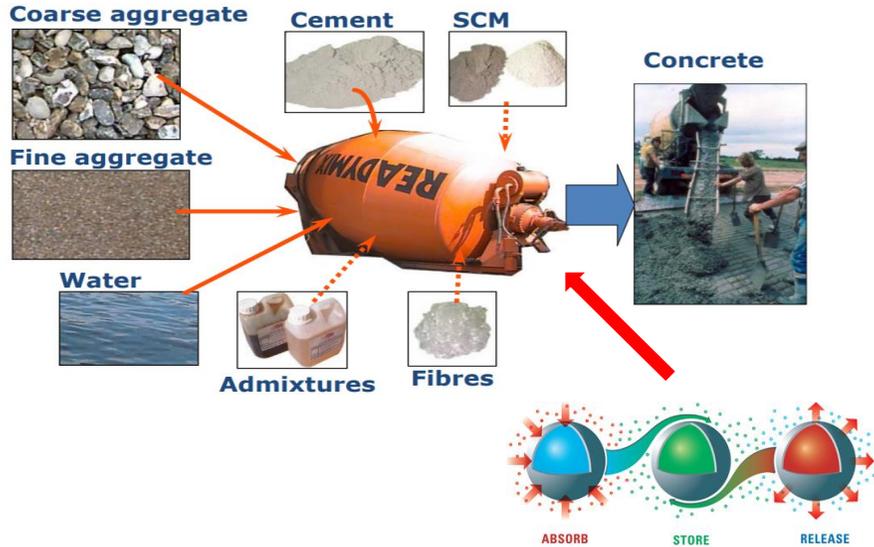
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- Altering the composition of building materials to make buildings which **regulate their own temperature**.



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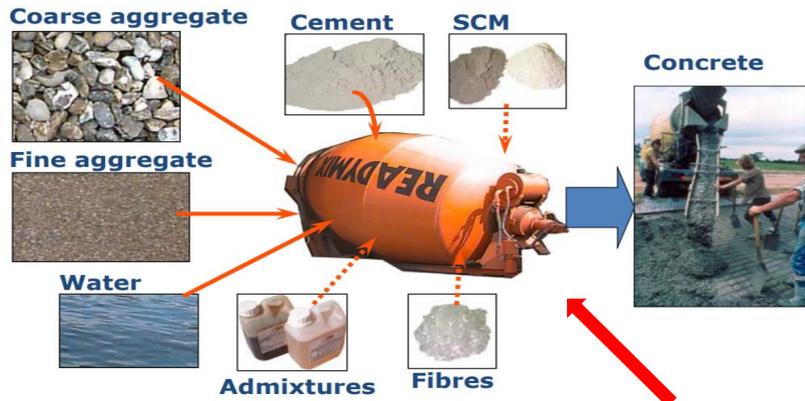
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**Same principals...**

# Methodology

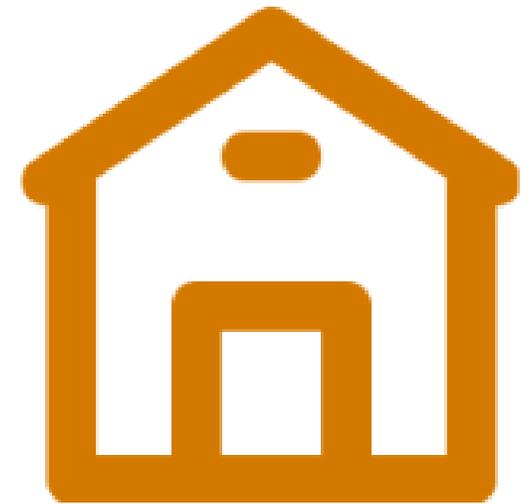
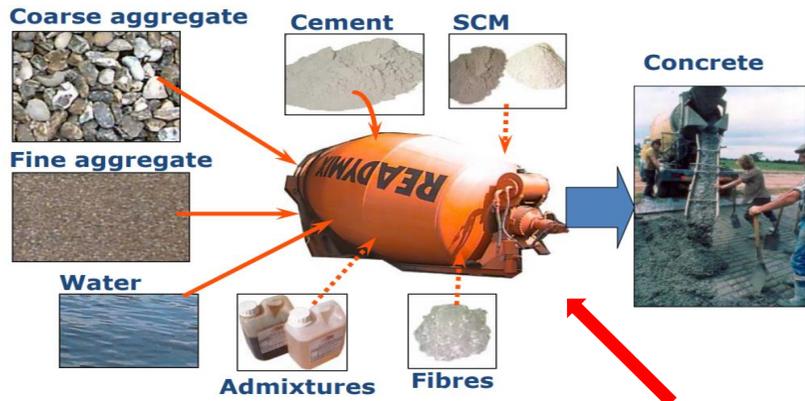
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**Same principals...**

# Methodology

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



**Same principals...**



# Methodology

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**Biochar**

# Methodology

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**Biochar**



**Scrap Wood**

# Methodology

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**Biochar**



**Sewage Sludge**



**Scrap Wood**

# Methodology

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**Biochar**



**Sewage Sludge**



**Food waste**

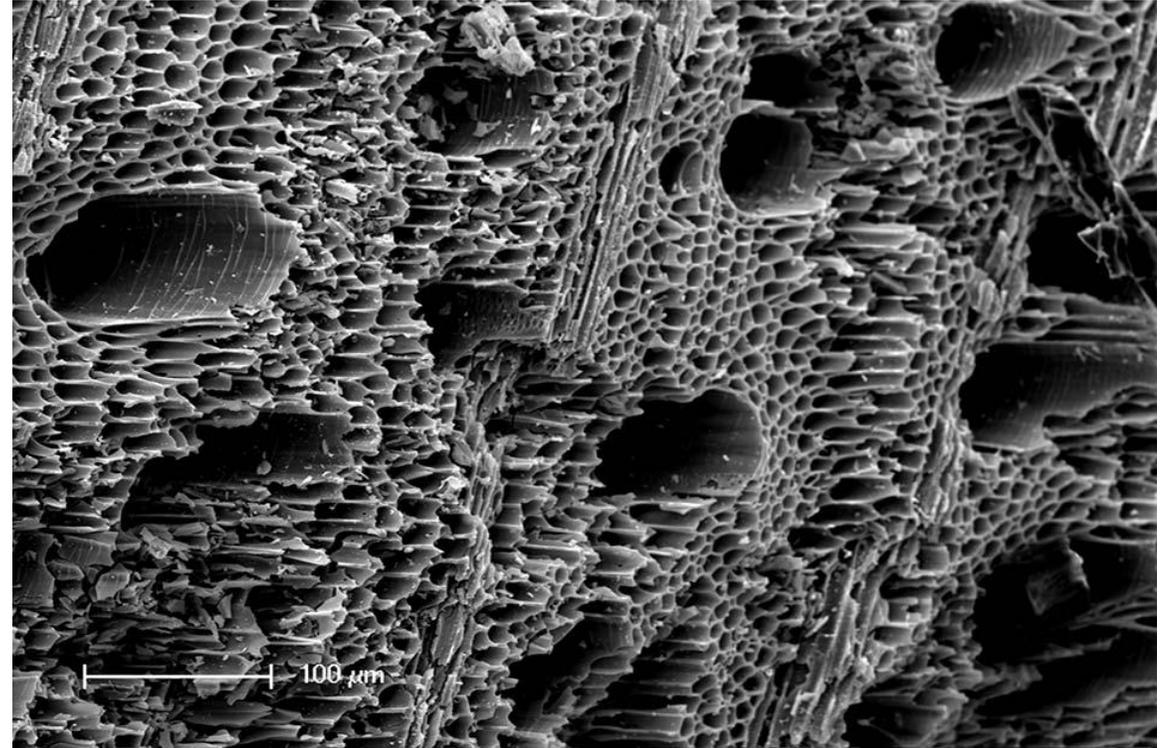


**Scrap Wood**

# Methodology



**Biochar**



**Biochar SEM**

Biochar is **83% Porous**

# Methodology



+



**Biochar**

**PCM**

Under very **specific reaction** conditions

# Methodology



**Biochar**

+



**PCM**



PCM-Biochar

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

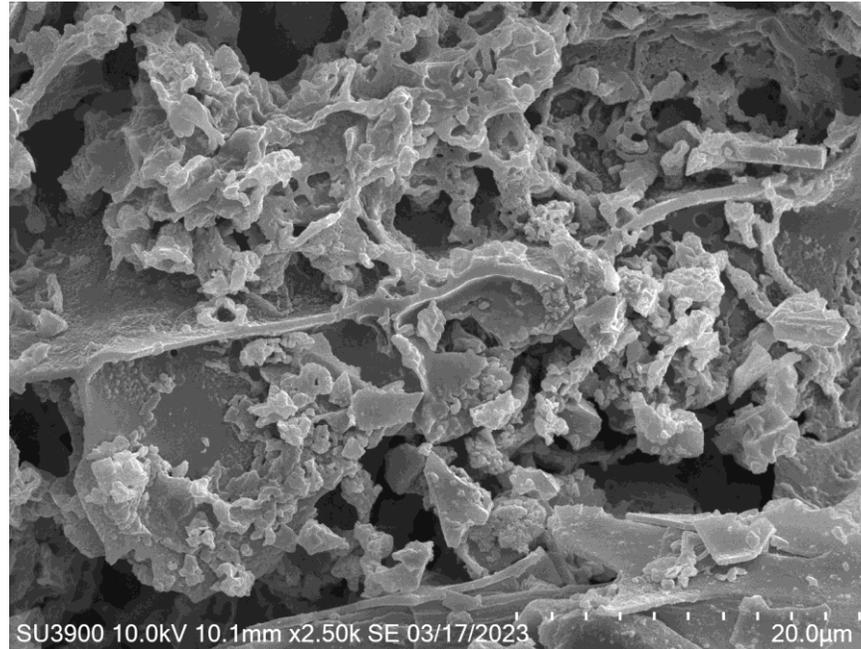
Under very **specific reaction** conditions

# Methodology

SEM of Biochar sample

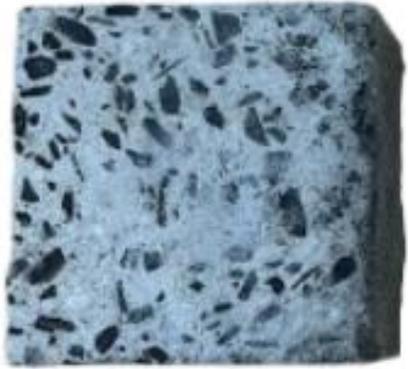


SEM of PCM-Biochar sample



PCM-Biochar

# Results



PCM-Mortar

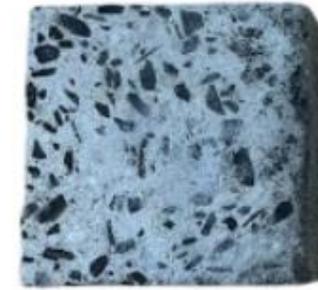
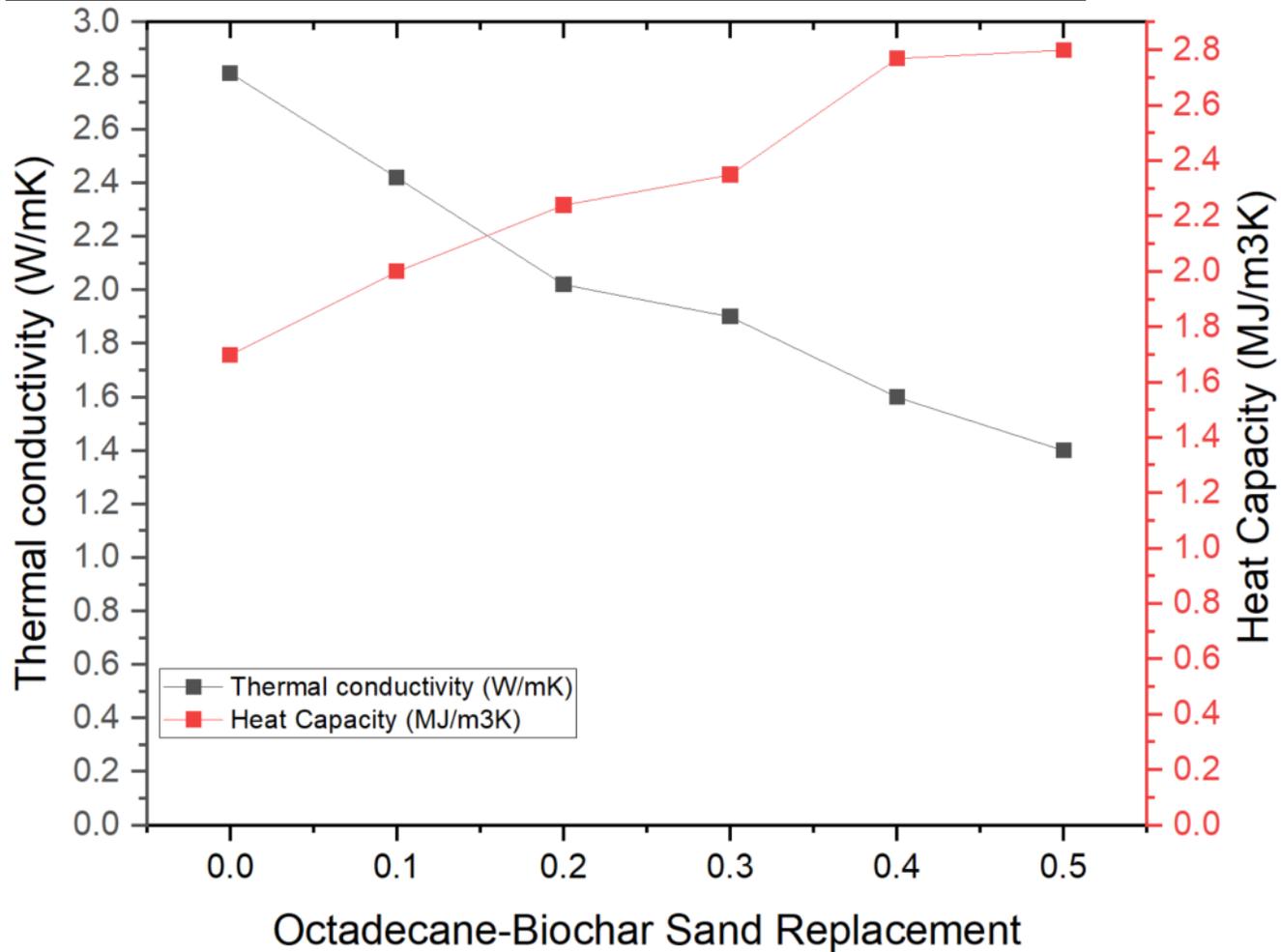


Mortar

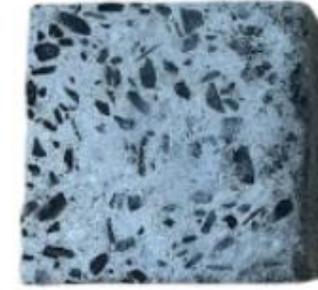
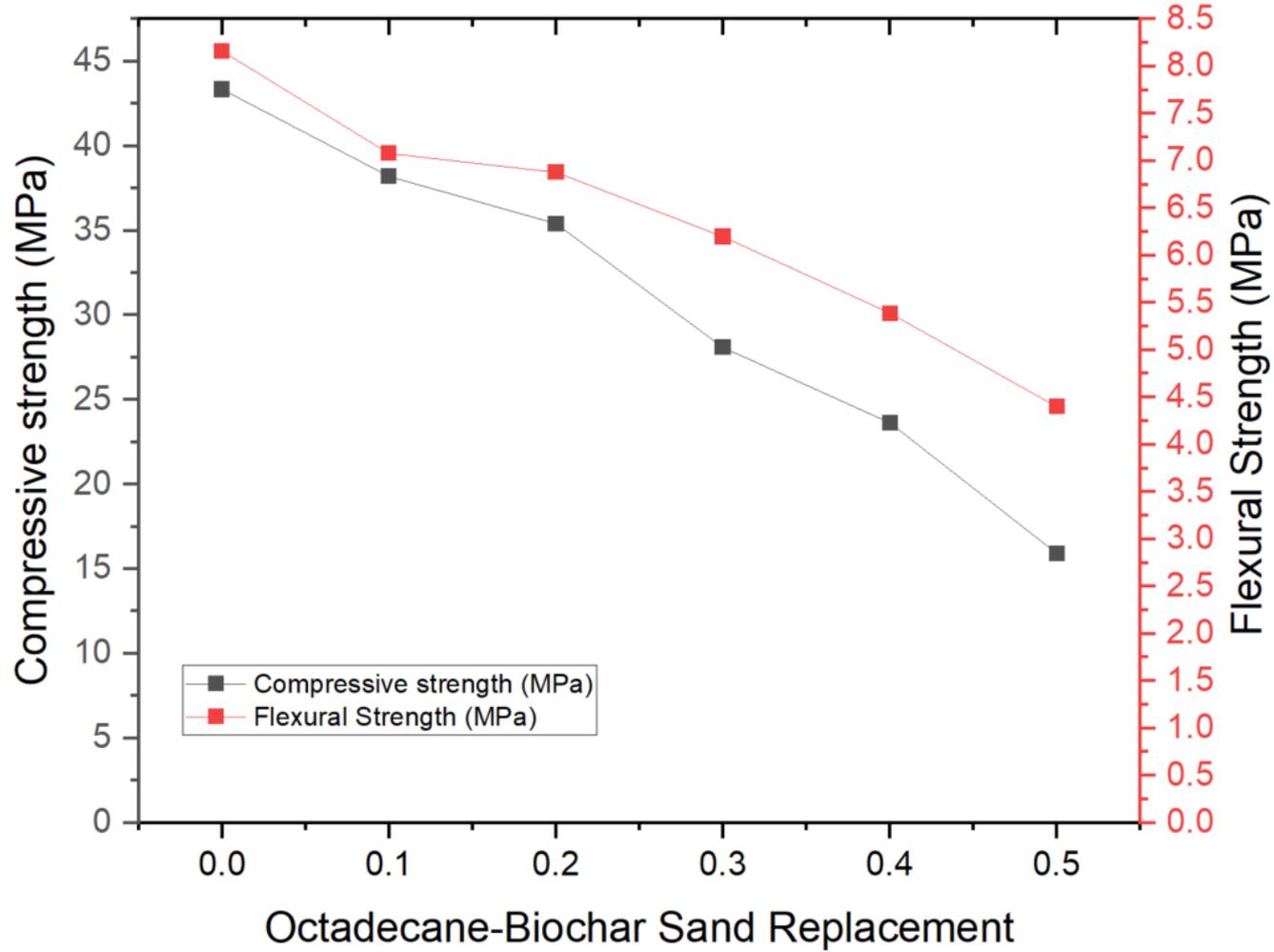


PCM Biochar Samples at different loading ratios

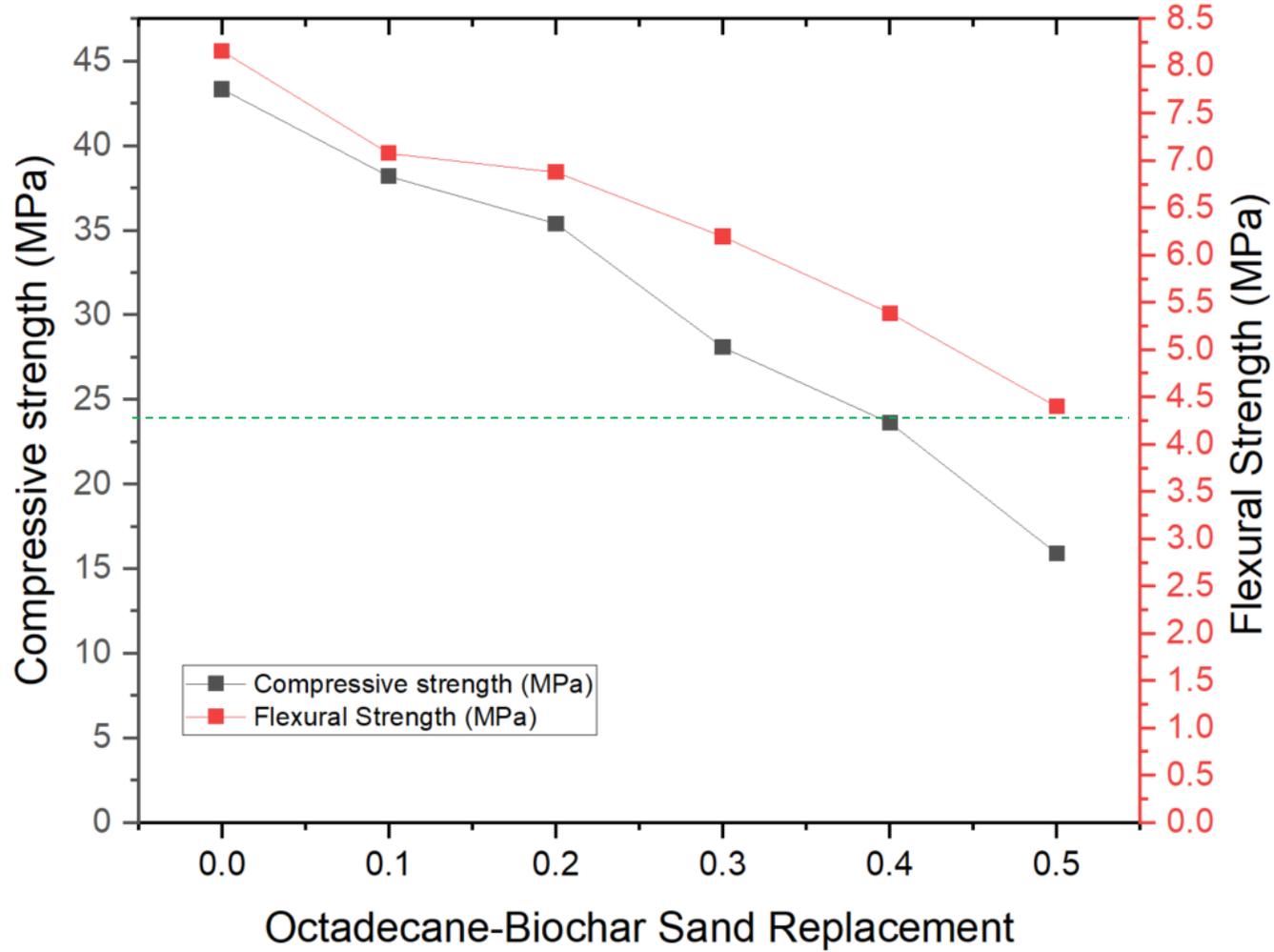
# Results



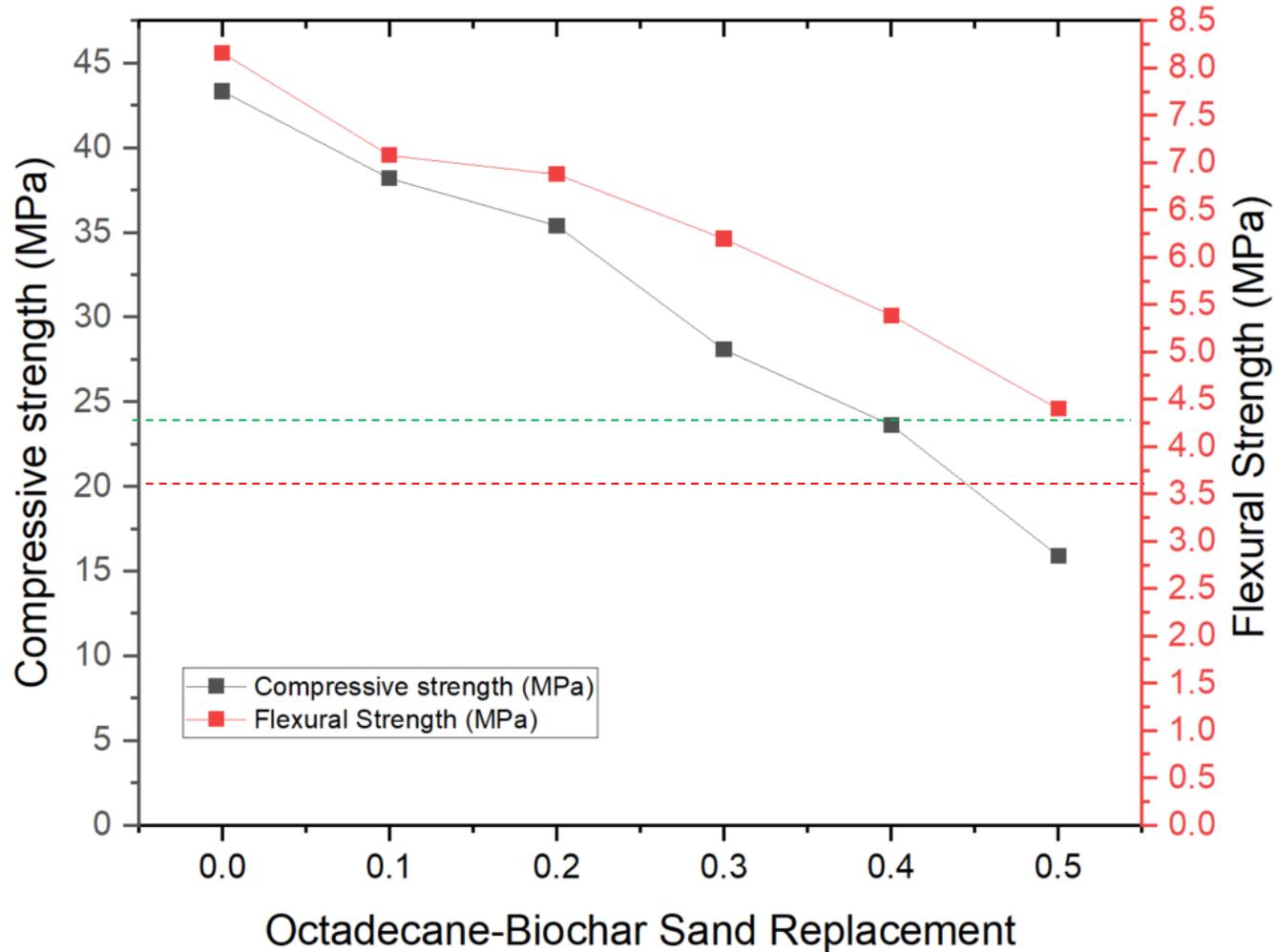
# Results



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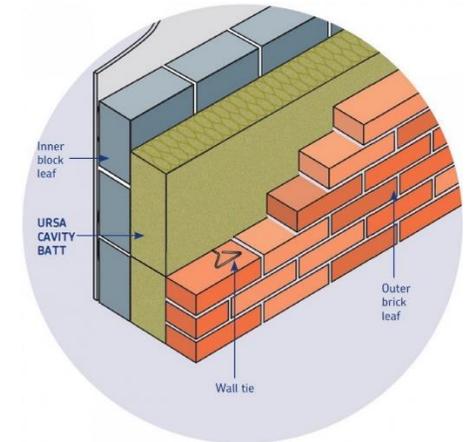
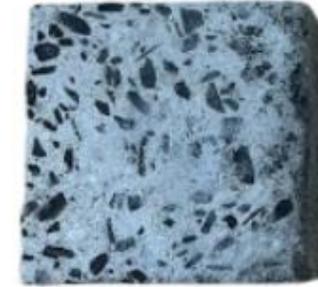


# Results



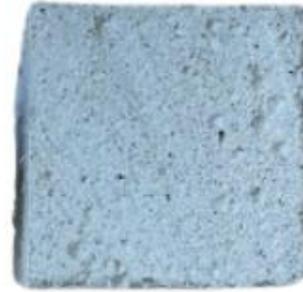
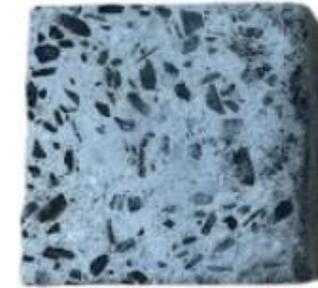
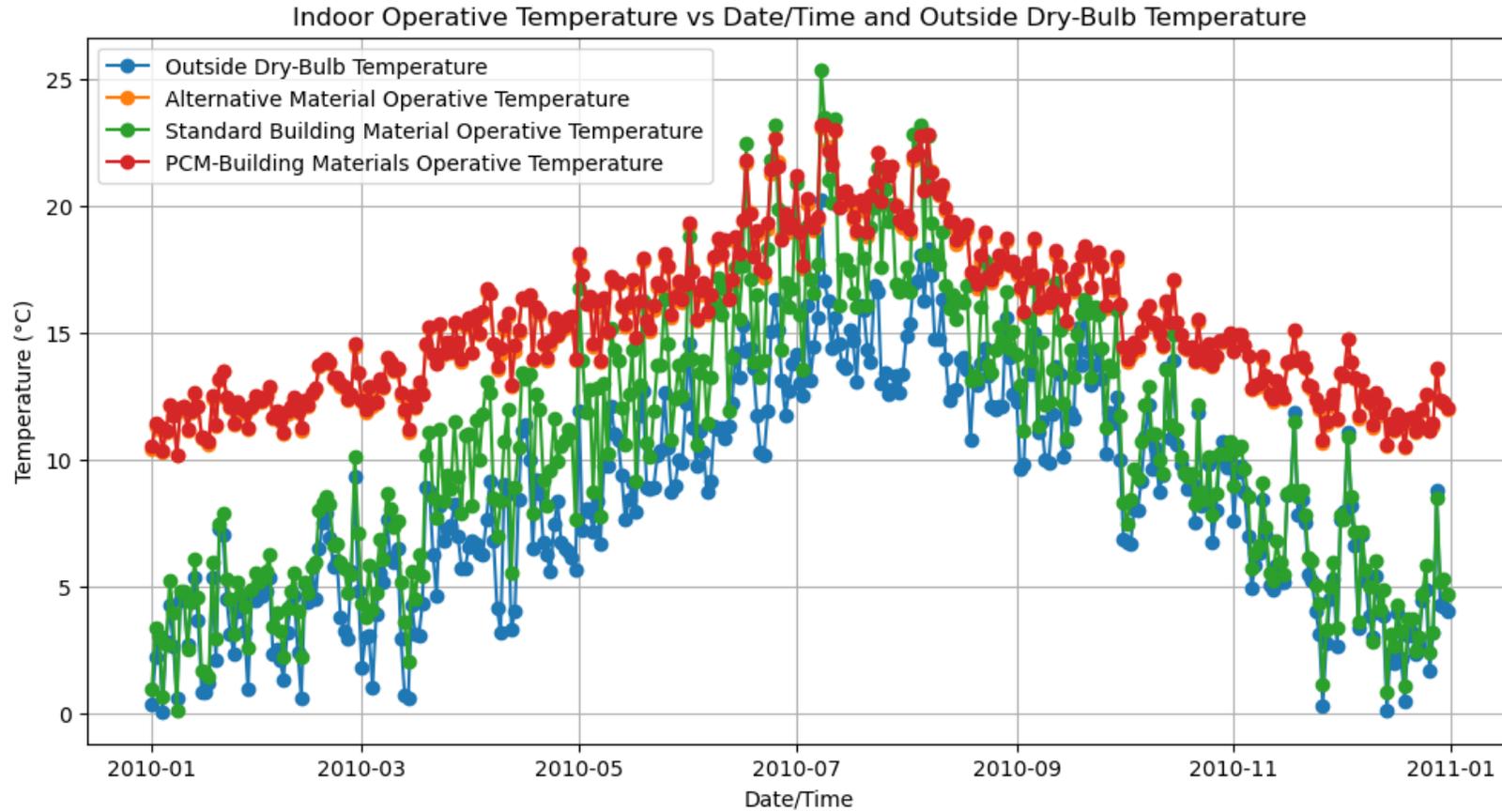
**BSI** 20 MPa for walls, columns, fireplaces and chimneys, footings, foundation walls, grade beams and piers.

# Results



DesignBuilder block of flats model located in Bristol.

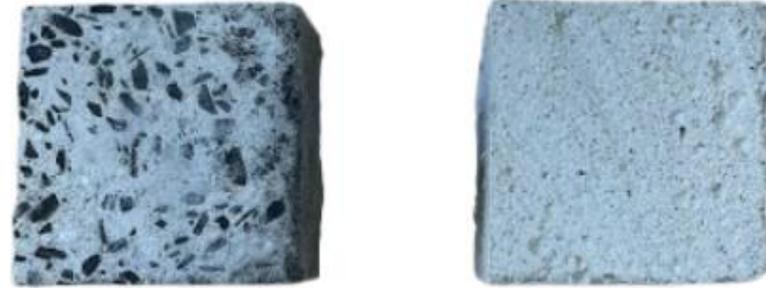
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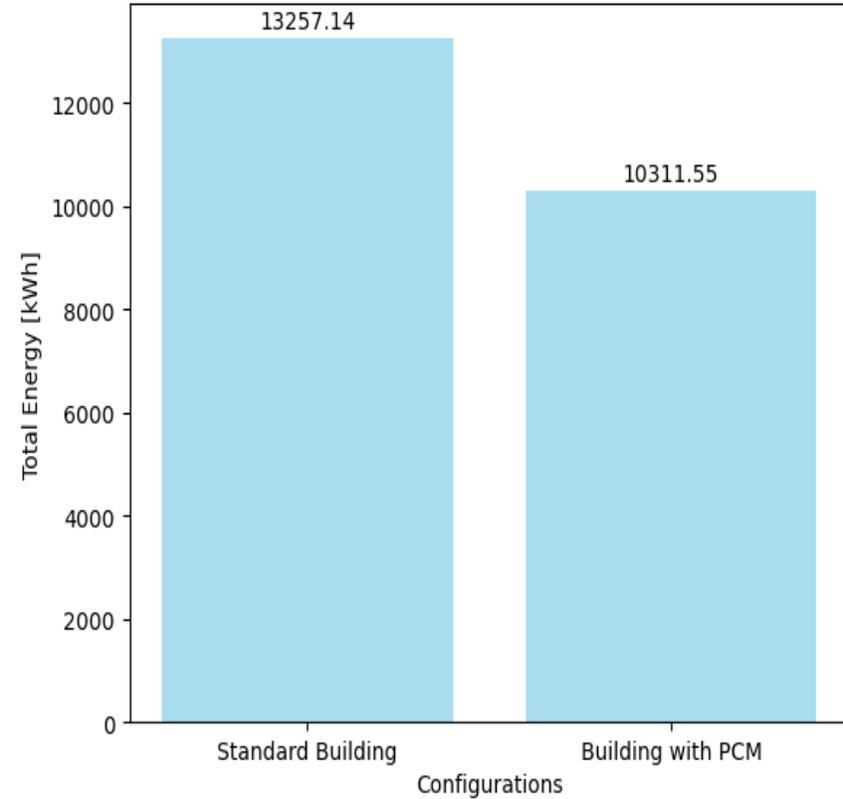
Simulation of indoor heat activity

# Results

Energy saving of **22.5%**



Total Energy Consumption

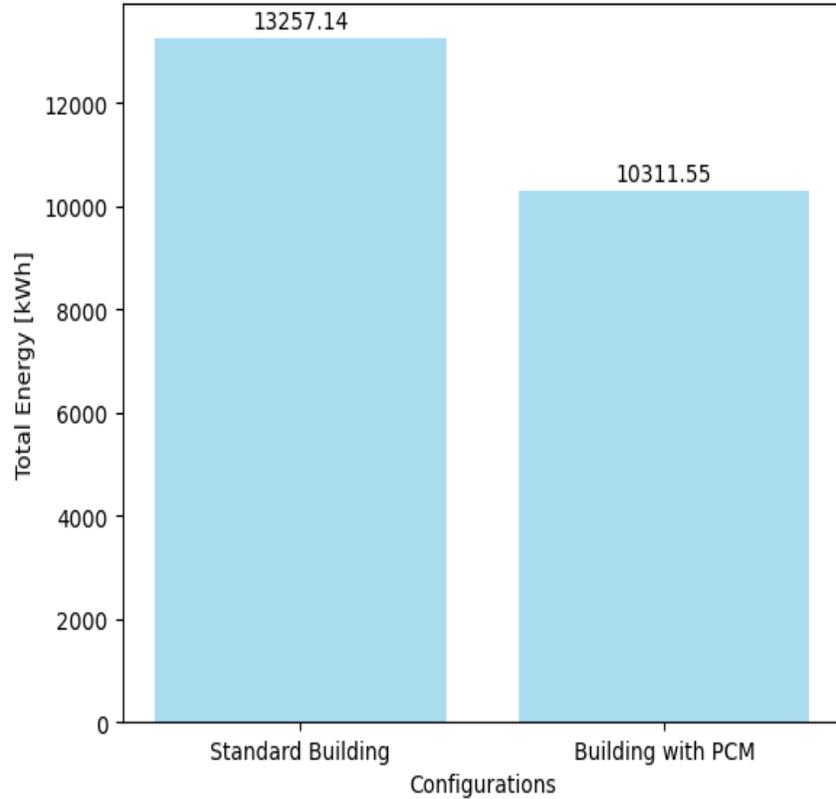


# Results

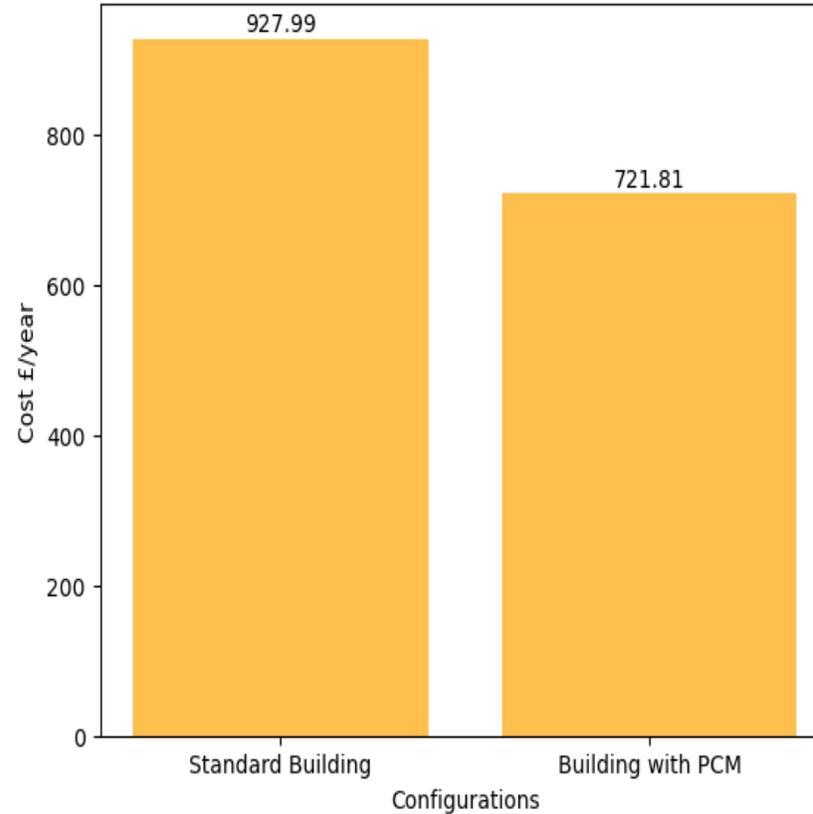
Energy saving of **22.5%**



Total Energy Consumption



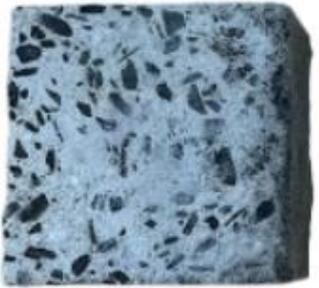
Cost per Year (7p/kWh)



# Conclusion/Future Work

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- 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

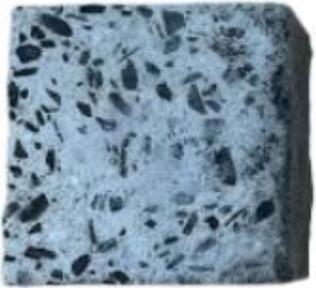


Mortar

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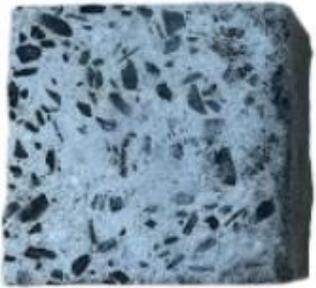


Mortar

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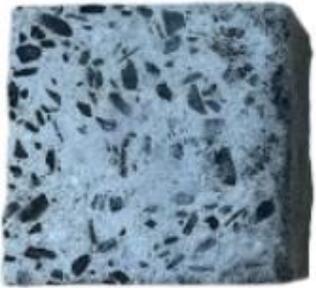


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PCM-Mortar



Mortar



Insulation Materials

# Acknowledgement

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**Veronica Ferrandiz-Mas**  
Lead supervisor



**Steve Allen**  
Co-supervisor



**Adam Squires**  
Co-supervisor

# Thank you!

