
UNDO
PUTTING CARBON IN ITS PLACE

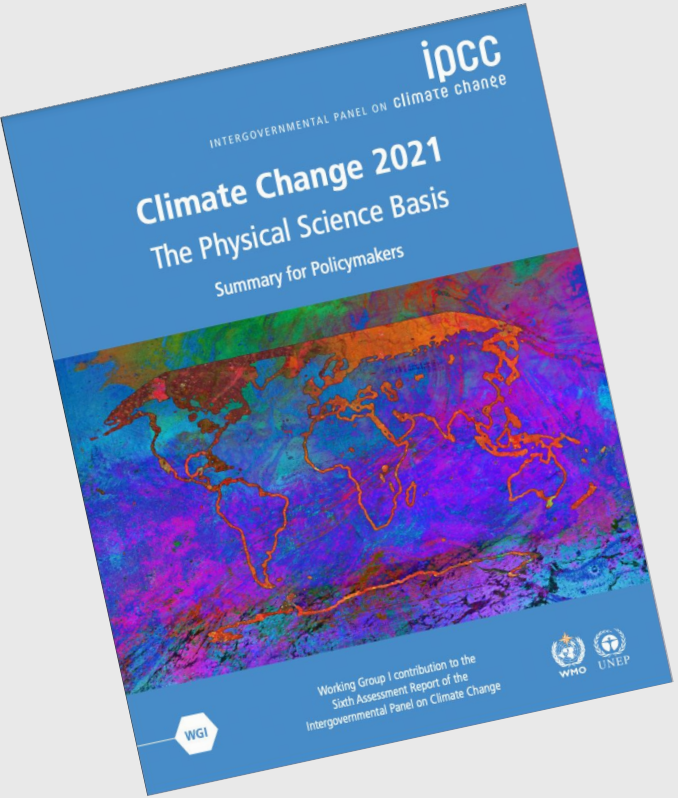
Background: *Liverpool UG/Masters/PhD (Muon g-2) / Postdoc (LZ)*

Why did I leave academia? *There is an urgent need to build a carbon removal industry, who should build it?*

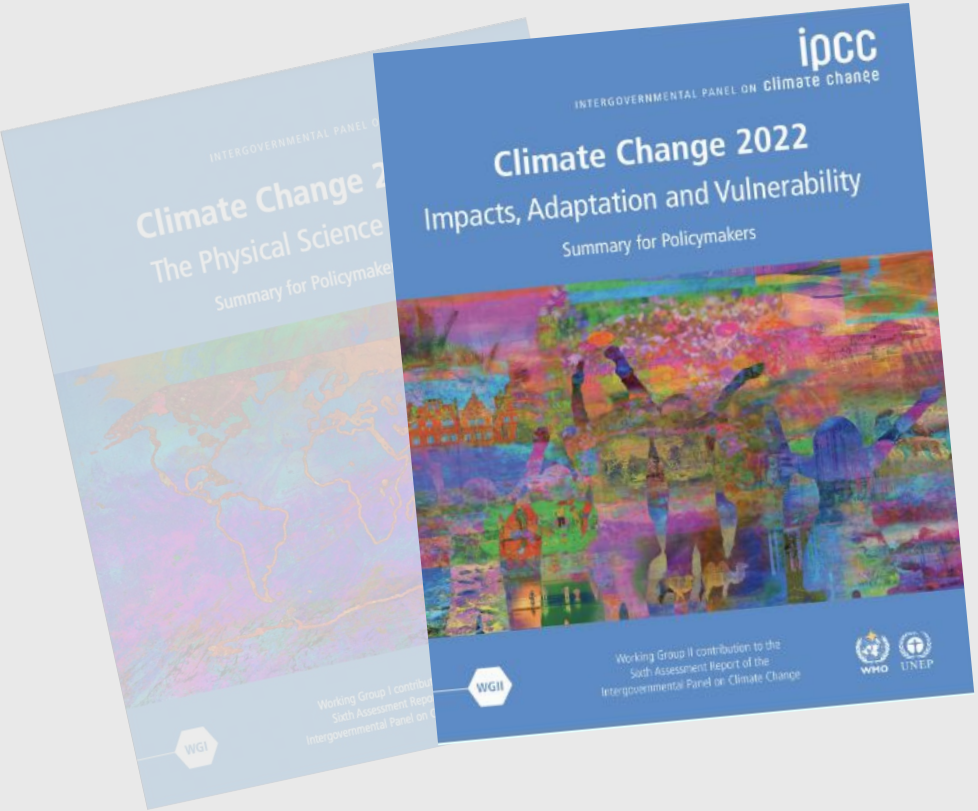
What is it like working for a startup? *Much like small physics experiments, you work out what needs to be done, learn how to do it, and then do it.*

Is my aim to try and convince you to leave academia and join a company in the climate space? *No, just to show you the areas where your skills are in high demand.*

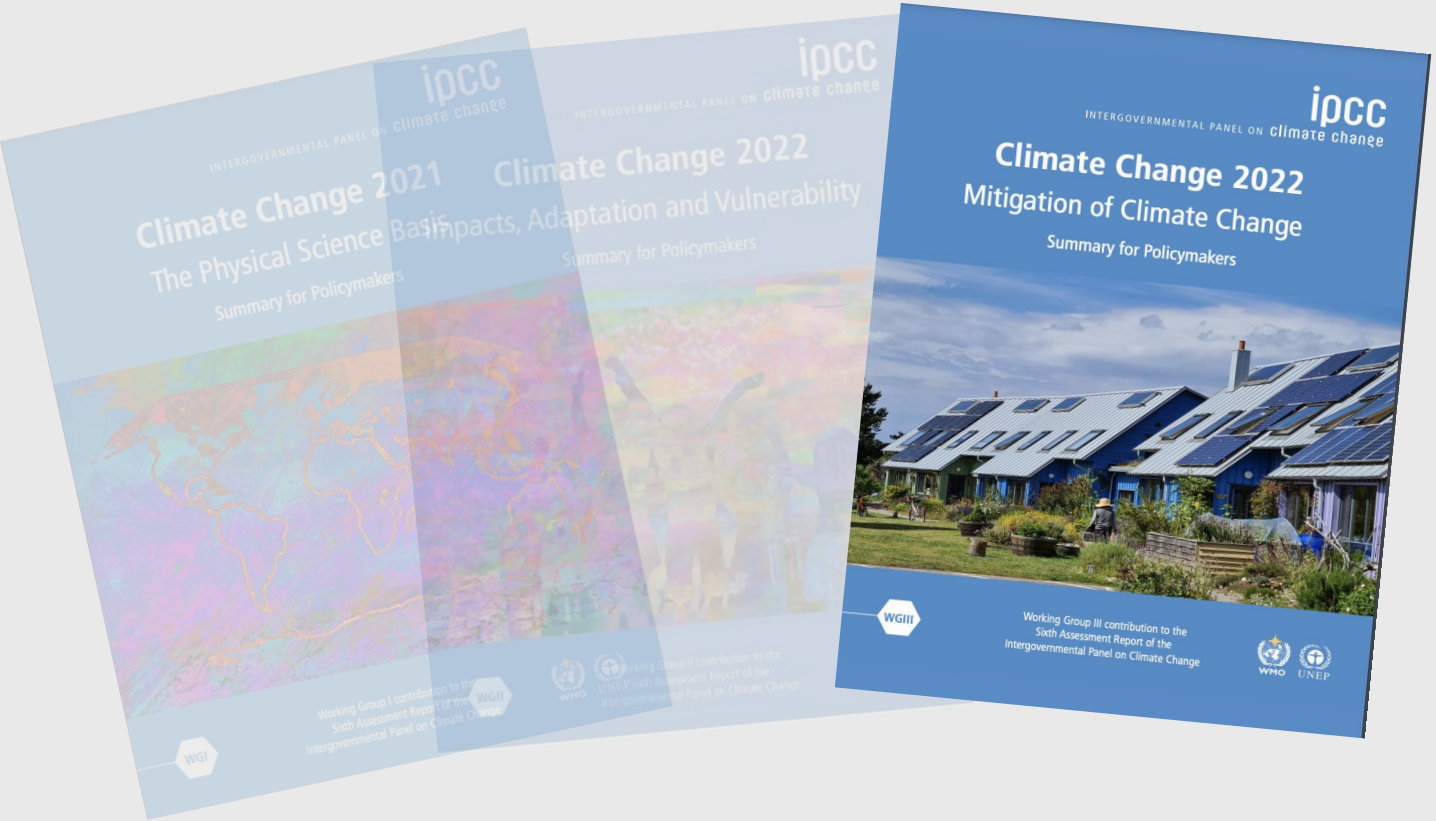
“Climate change is widespread, rapid, and intensifying and a result of human-induced greenhouse gas emissions”



“All life on earth, from ecosystems to human civilisations, is vulnerable to a changing climate”



“The deployment of carbon dioxide removal (CDR) to counterbalance hard-to-abate residual emissions is unavoidable to achieve net zero”



“There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all.”

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Paris Agreement Goal - 1.5°C

Achieving the Paris Agreement goal of keeping global warming to within 1.5°C above pre-industrial levels by 2100 **requires rapid decarbonisation.**

If countries *only* meet their current nationally determined contributions (NDCs) for 2030, it is likely (with high confidence) that **warming will exceed 1.5°C** during the 21st century.

There is a large gap between 2030 commitments, and the magnitude of emissions reductions needed to limit warming to less than 1.5°C above pre-industrial levels by 2100.

There is a need to remove **10 billion tonnes of CO2 a year by 2050** in order to stay within the Science Based Target (SBTI) goals and achieve net zero by 2050.

Reducing emissions alone is no longer enough.

Can we carbon offset our way out of this problem? *No.*

Do we urgently need to remove carbon from the atmosphere at the same time as rapid decarbonisation? *Yes.*

What is the business model? *We remove carbon dioxide from the atmosphere and forward looking companies (who have already made suitable steps towards net zero) pay us for the carbon credits, ~$300/tCO2 sequestered over 10yrs.*

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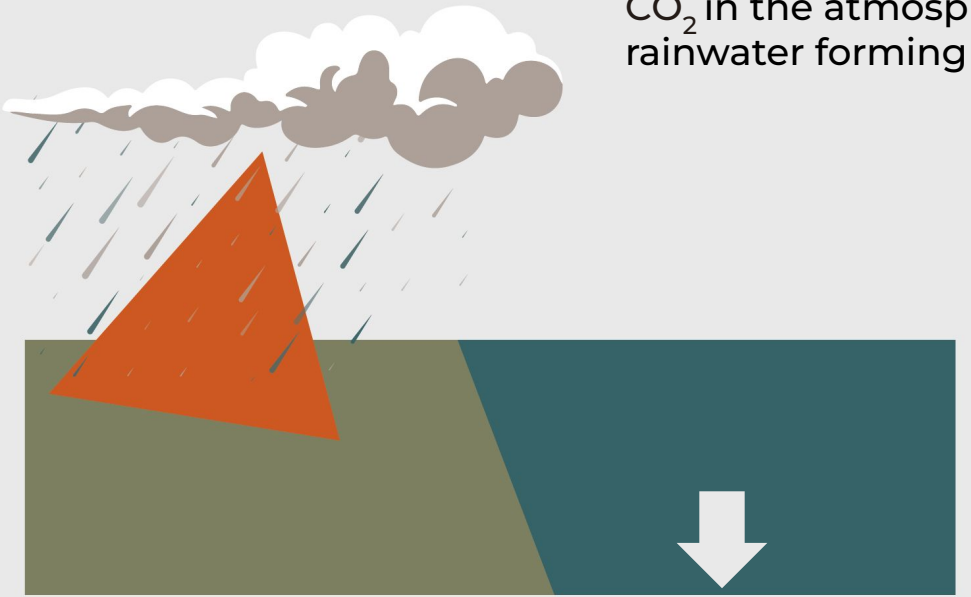
EARTH'S NATURAL CO_2 REMOVAL MECHANISM - ROCK WEATHERING

CO_2 in the atmosphere dissolves in rainwater forming carbonic acid.

Rain (*with the weak carbonic acid*) falls on rocks which then undergo a chemical reaction sequestering CO_2 in the process.



Bicarbonate are transported to the ocean via waterways where they are stable for thousands of years

$$2CO_2 + 3H_2O + CaAl_2Si_2O_3 \rightarrow Al_2Si_2O_5(OH)_4 + Ca^{2+} + 2HCO_3^-$$

Carbon dioxide + water + plagioclase → Amorphous clay + calcium + bicarbonate

We accelerate this natural process by increasing the surface area exposed for the reaction to occur.

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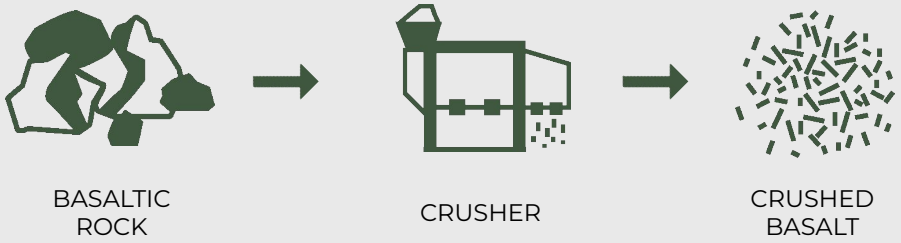
ENHANCED ROCK WEATHERING



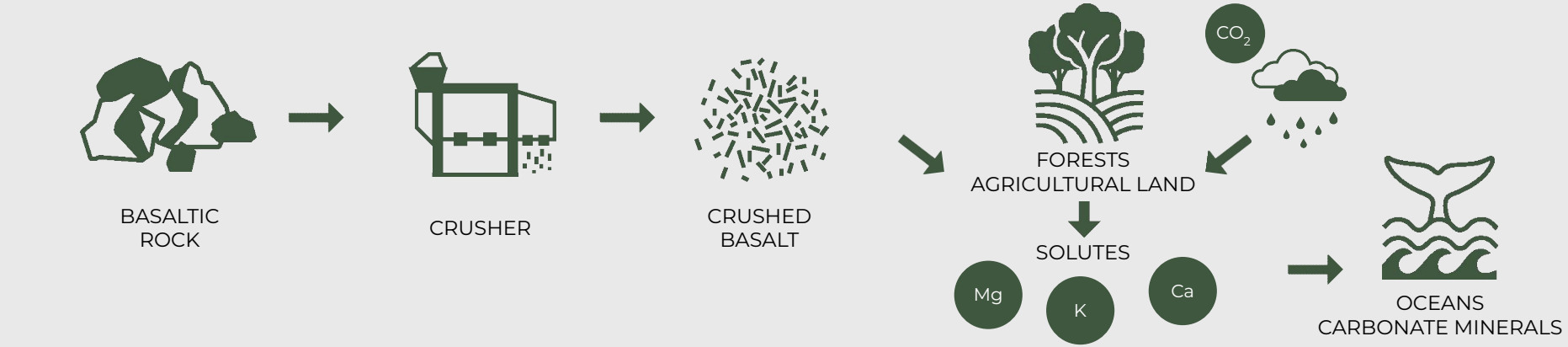
The aggregate industry around the world is already quarrying and crushing basalt.

During the crushing process they produce a fine dust which can not be used.

Usually left to sit in big piles at the quarry.

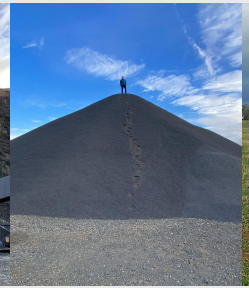
Basalt | Quarry operations | Aggregate by-product

ENHANCED ROCK WEATHERING



Basalt

Quarry operations



Aggregate by-product

Arable Land

White Cliffs of Dover

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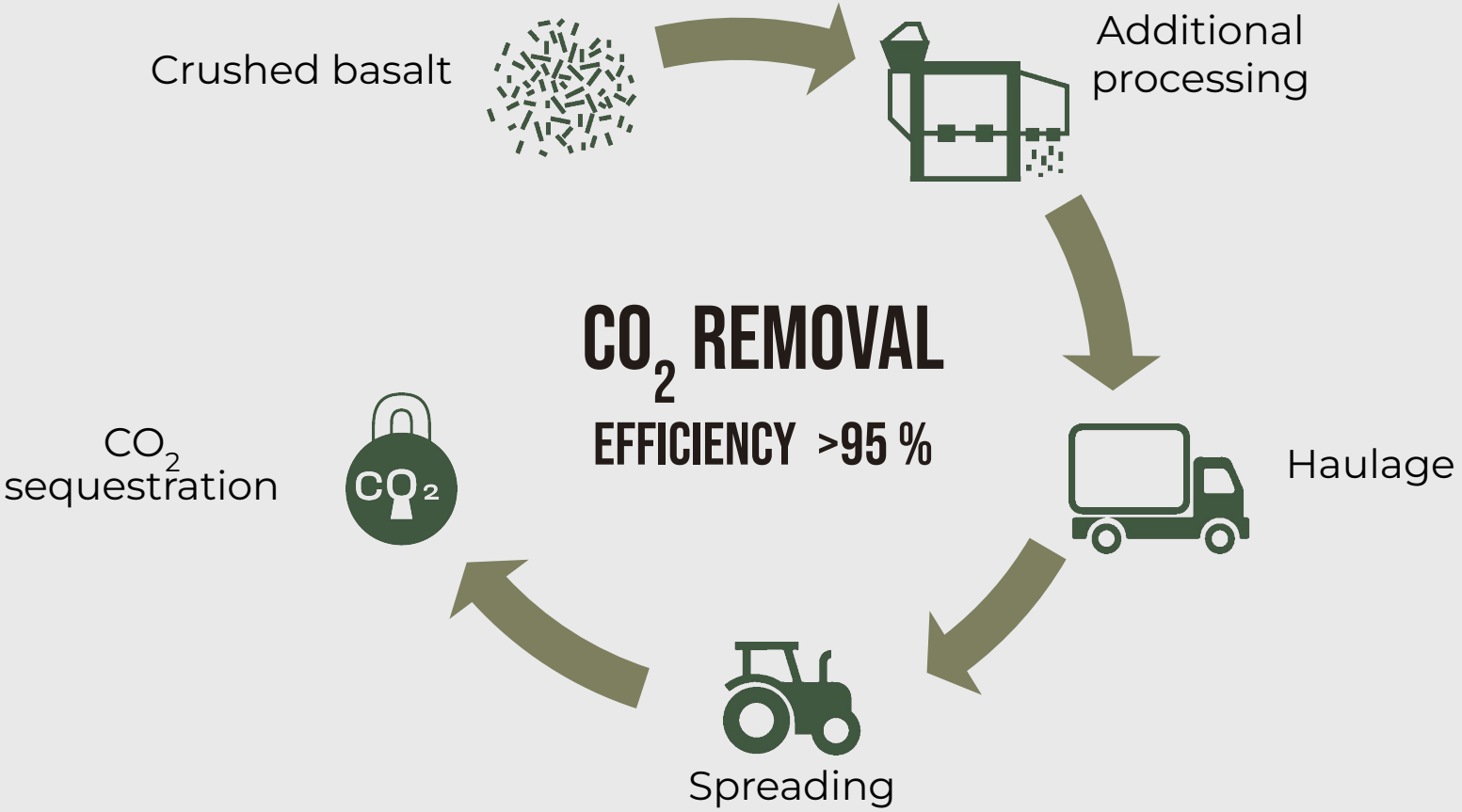
FACTORING IN THE LCA



PROVE YOU DID ANYTHING...

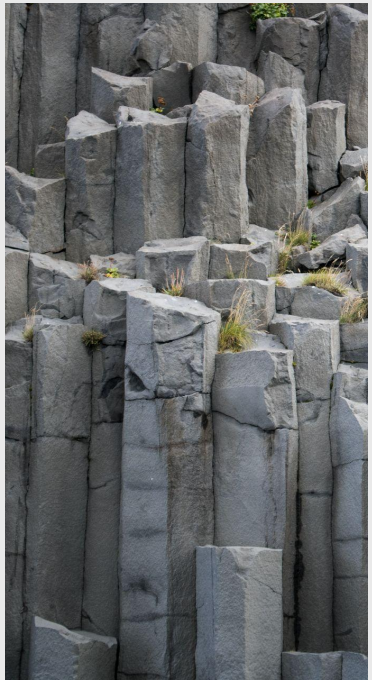
PERMANENT

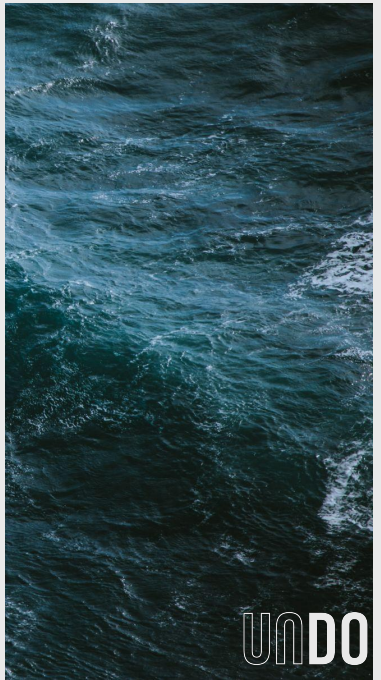
SCALABLE

EXISTING INFRASTRUCTURE

CO-BENEFITS

DATA AND SCIENCE DRIVEN

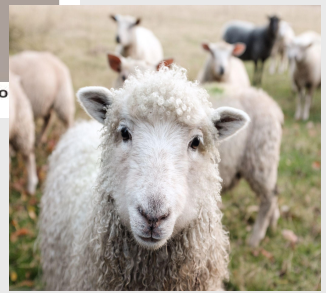


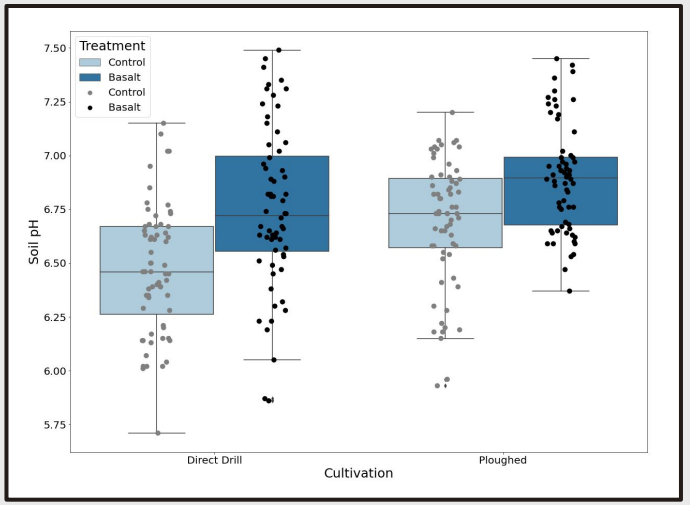


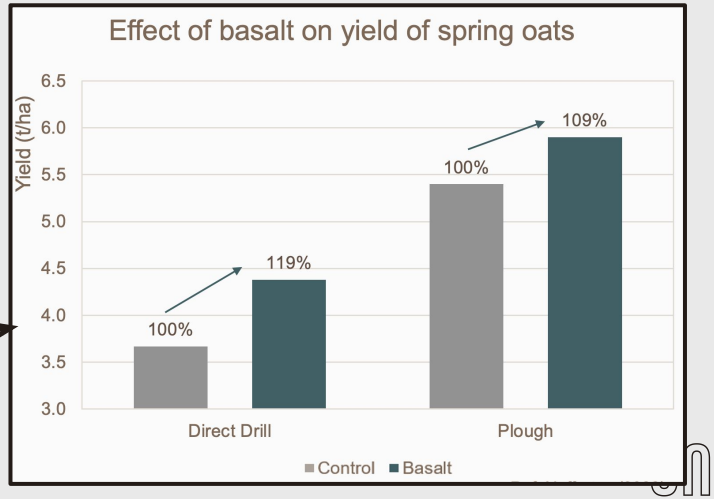
CARBON REMOVAL... WITH BENEFITS...

	NUTRIENT	SYMBOL	CONTENT %	AMOUNT KG/HA*
Macronutrients	Phosphorus	P	0.13	25
		P_2O_5	0.29	57
	Potassium	K	0.9	180
		K_2O	1.089	218
Major Nutrients	Magnesium	Mg	3.49	698
		MgO	5.76	1,152
	Calcium	Ca	5.78	1,156
	Sulphur	S	0.14	28
Micronutrients	Copper	Cu	0.0063	1.26
	Iron	Fe	9.17	1,834
	Molybdenum	Mo	0.0001	0.02
	Manganese	Mn	0.139	27.80
	Zinc	Zn	0.0124	2.48
Other Nutrients	Silicon	Si	23.46	4,692
	Sodium	Na	1.8	360
	Cobalt	Co	0.004	0.80
	Selenium	Se	0.00002	0.004

* Amount applied based on 20 tonnes/hectare applicatio







This should not come as a surprise, the land around volcanoes is often very fertile.

UNDO OUR GEOCHEMICAL MODEL SO FAR (After Kelland et al. *Glob Chang Biol*., 2020)

Four key categories of variables used by model:

1. BASALT

- Mineralogy (olivine, plagioclase, pyroxene)
- Mineral dissolution rates
- Particle size and surface area
- Application density

2. CLIMATE

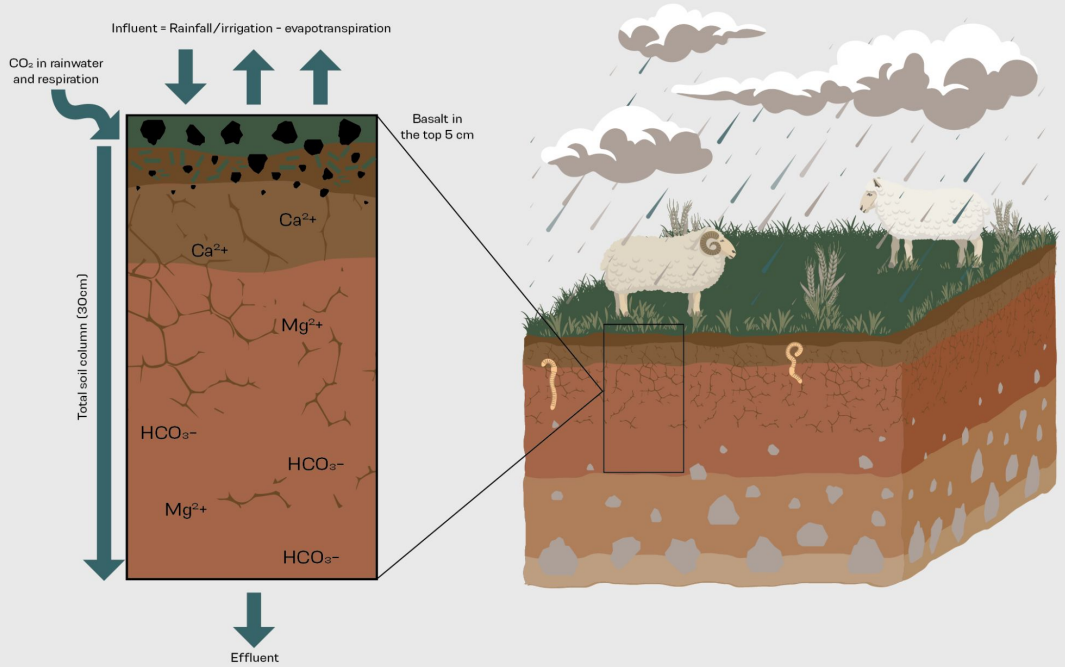
- Temperature
- Precipitation ± irrigation

3. SOIL (PHYSICAL & CHEMICAL) PARAMETERS

- pH
- Texture
- CEC (Cation Exchange Capacity)
- SOC (Soil Organic Carbon)
- Bulk density
- Water filled porosity

4. ATMOSPHERE

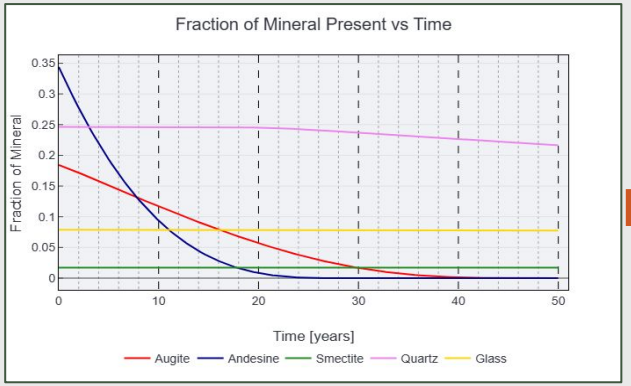
- Atmospheric CO_2
- Soil CO_2 partial pressure



Above: From model paper: carbon sequestration is modelled using PHREEQC (Parkhurst and Appelo, 2013), using published experimentally derived kinetic and thermodynamic data (Palandri and Karaka, 2004)

UNDO THREE STEPS TO MODELLING CDR

Model **rock weathering** rates



Model results of varying weathering rates across rock phases: augite, andesine, smectite, quartz and glass.

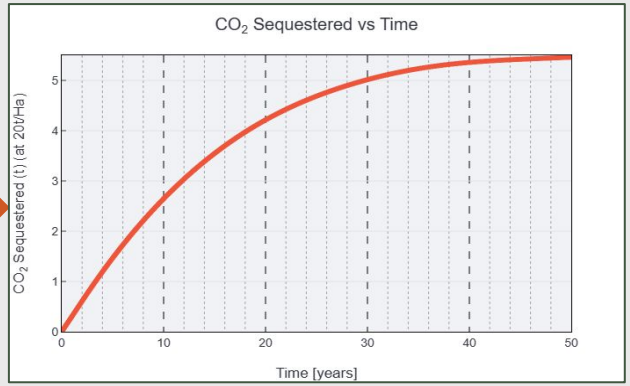
Calculate a **charge balance**

Concentration of Bicarbonate =

2*(Ca+Mg)+Na+K

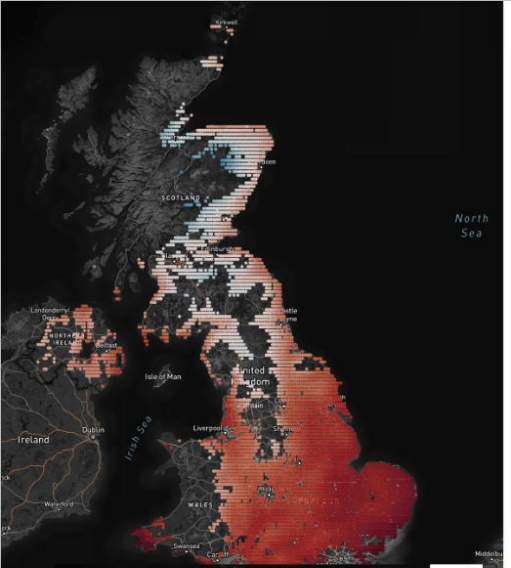
Calculate CDR based on rock phases weathering over time

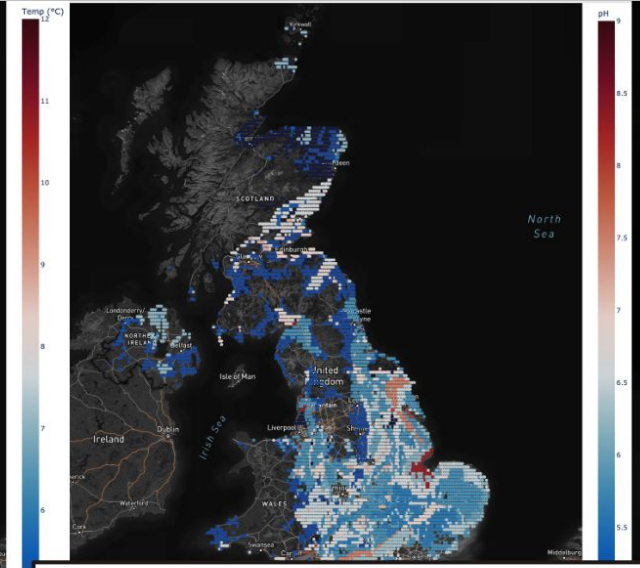
Convert mol/L to **tonnes of CO_2 per ha**



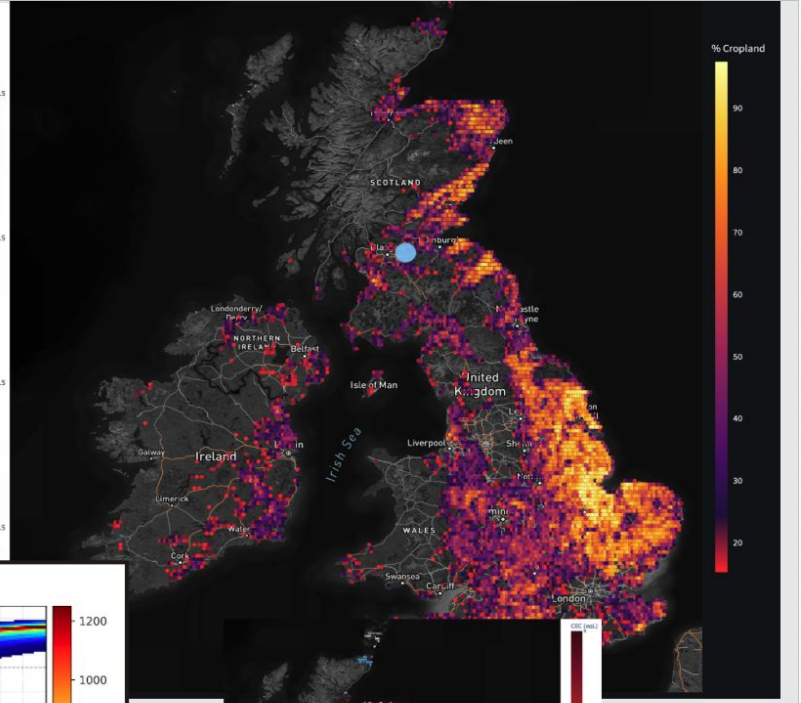
Model output of calculated tCO_2 sequestration per hectare over 50 year time horizon

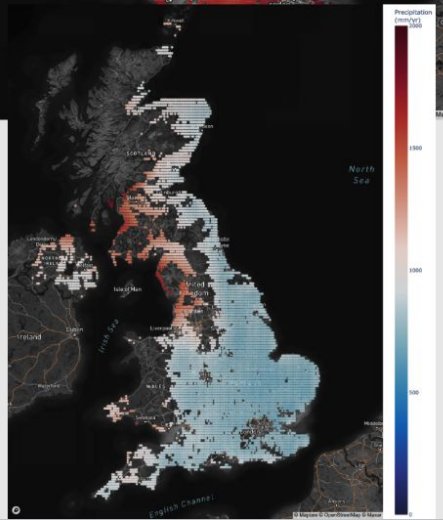
Research on laptop -> Production in the cloud.

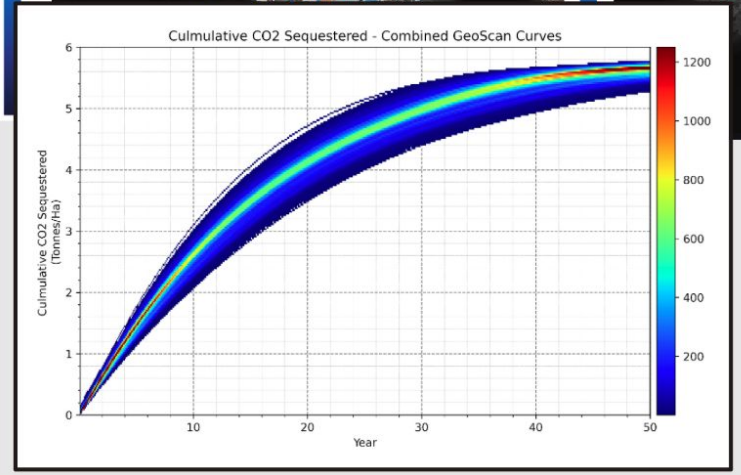

North Sea
Irish Sea
Ireland
SCOTLAND
WALES

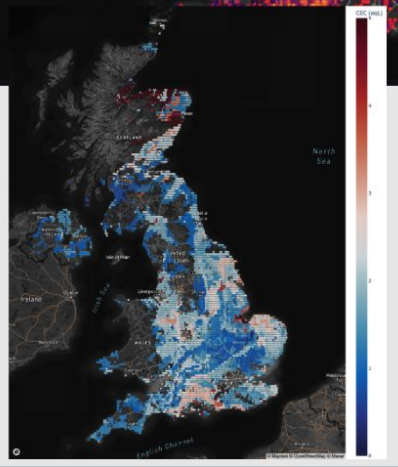

Temp (°C)
12
11
10
9
8
7
6
North Sea
Irish Sea
Ireland
SCOTLAND
WALES

pH
9
8.5
8
7.5
7
6.5
6
5.5
North Sea
Irish Sea
Ireland
SCOTLAND
WALES


% Cropland
90
80
70
60
50
40
30
20
SCOTLAND
Irish Sea
Ireland
WALES


Precipitation (mm/yr)
1500
1000
500
North Sea
Irish Sea
Ireland
English Channel

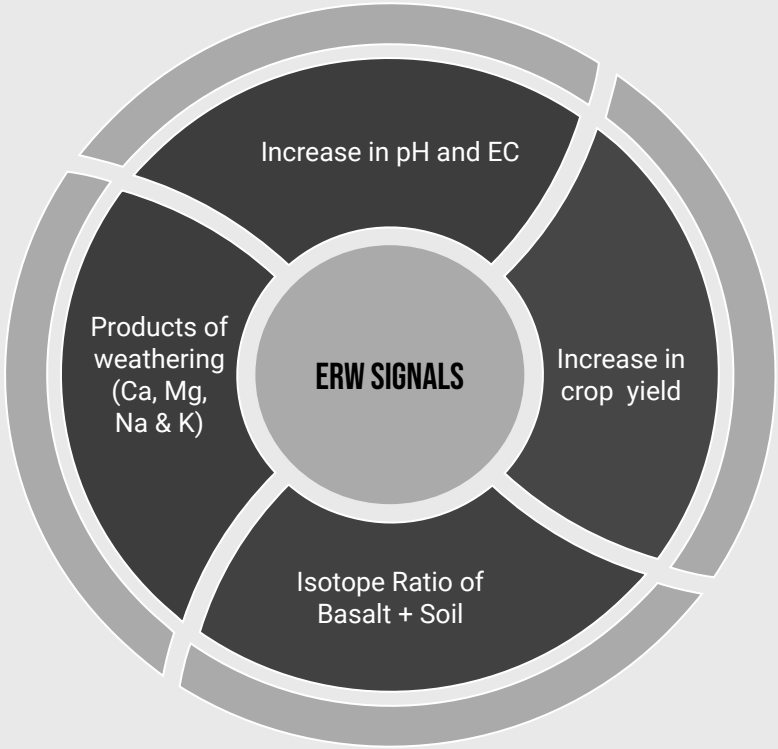

Culmulative CO2 Sequestered - Combined GeoScan Curves
Culmulative CO2 Sequestered (Tonnes/Ha)
Year
0
1
2
3
4
5
6
10
20
30
40
50
1200
1000
800
600
400
200


North Sea
Irish Sea
Ireland
English Channel

UNDO MRV: MODEL & MEASURE APPROACH

To date, no single method has proven accurate in quantifying the amount of CO_2 sequestered, but, rather, are indications that weathering is taking place. Hence the need for a model and measure approach.

We use all known approaches in our field and mesocosm trials, combined with exploring new techniques to **measure indicators** predicted by the model.



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HOW WE MEASURE

We measure weathering indicators multiple ways, primary through our **mesocosm experiments** and **field trials** in selected regions of interest representative of climate and soil conditions (e.g. Scotland).

Indicators measured:

- **In-situ sensors** measure depth- and time-integrated changes in proxy weathering signals (pH, soil moisture, electrical conductivity)
- **Soil sampling** measure soil inorganic carbon (SIC) and exchangeable cations
- **Soil pore water sampling** measure pH, alkalinity (HCO_3^-), EC, major cations, anions
- **Sample biomass** for uptake of cations

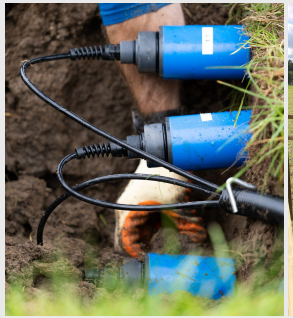
MESOCOSMS EXPERIMENTS

Soil mesocosms incorporate the complexity of field conditions with added ability to take a wider range of measurements on a higher frequency. More controlled basalt application for ground truthing of the model.



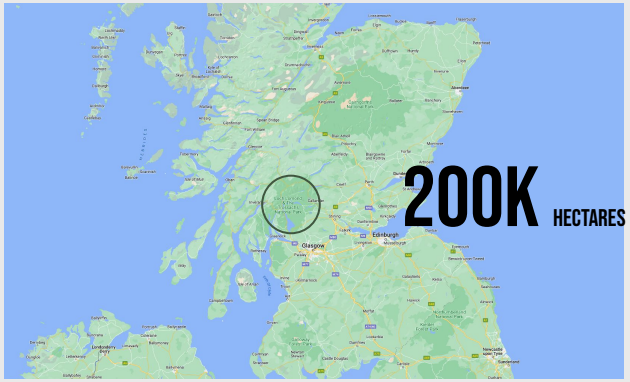
FIELD TRIALS

Combination of small plot trials with high number of replicates combined with large scale operational field trials and agronomy co-benefits trials.

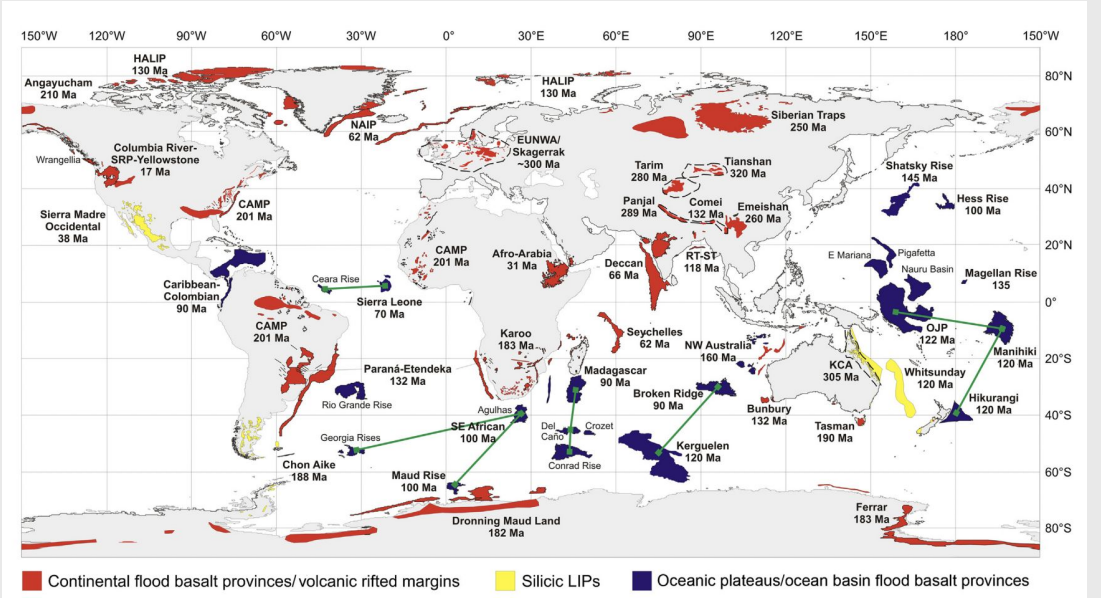




POTENTIAL FOR SCALE - 2025

4MT Rock



1 Mt CO_2



BILLIONS OF TONNES OF BASALT GLOBALLY (Self et al. 2015)

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RECOGNITION

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Science & Environment

Can ‘enhanced rock weathering’ help combat climate change?

21 May

Climate change

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ENVIRONMENT

Microsoft funds UK climate experiment to spread crushed rock on fields

Tech giant backs ‘enhanced weathering’ test in effort to pull carbon dioxide out of the air

Rhys Blakely, Science Correspondent

Thursday April 13 2023, 12.00am, The Times

Microsoft will pay Undo, a Scottish company, to spread … England

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The Climate Show with Tom Heap: How to lock away carbon and throw away the key

Carbon dioxide is the big villain of global warming, but can we imprison it?

Saturday 27 May 2023 08:38, UK

Climate Crisis

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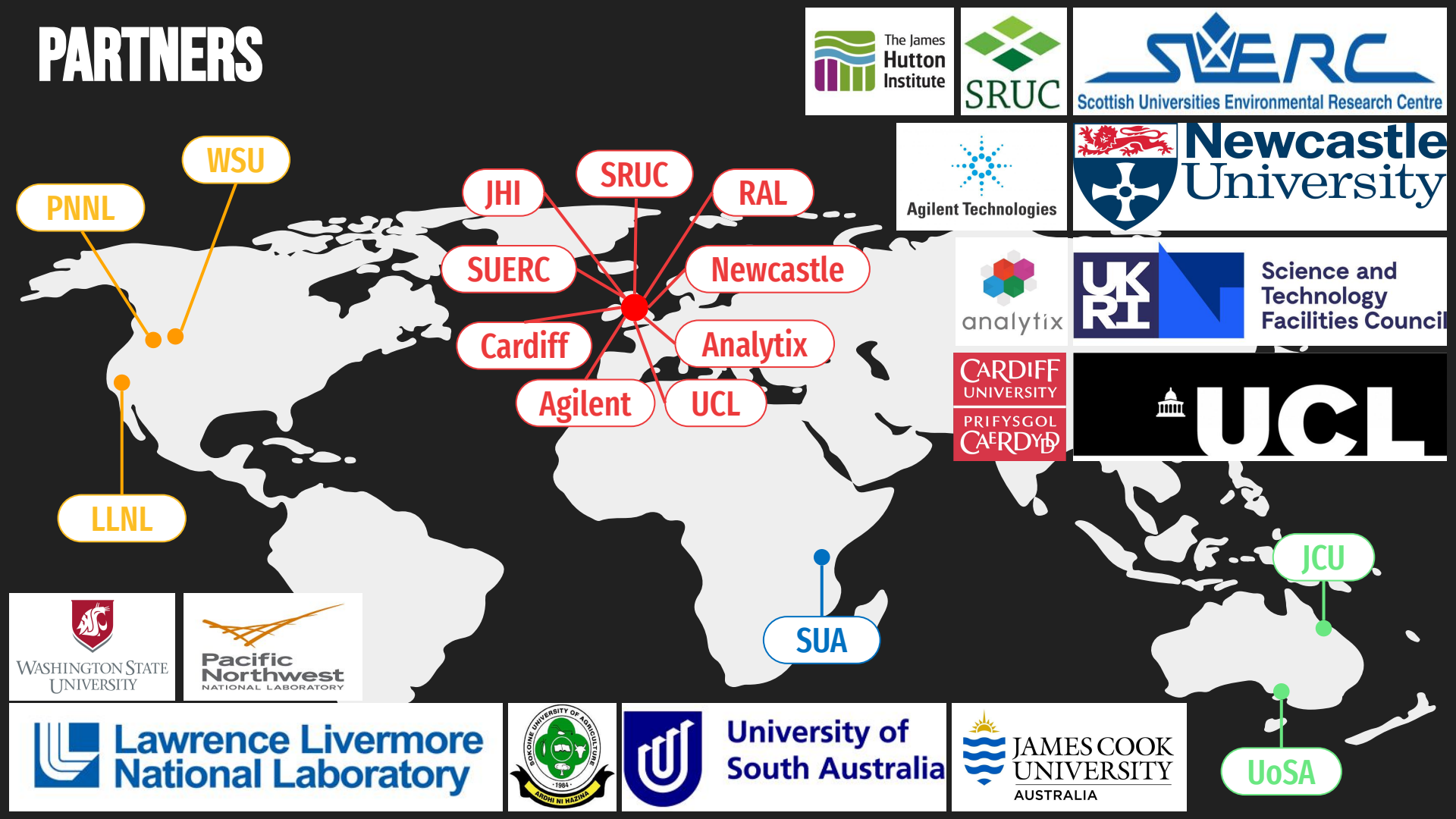
PARTNERS


WSU
PNNL
LLNL
JHI
SRUC
RAL
SUERC
Newcastle
Cardiff
Analytix
Agilent
UCL
SUA
JCU
UoSA
The James Hutton Institute
SRUC
SWERC
Scottish Universities Environmental Research Centre
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UKRI
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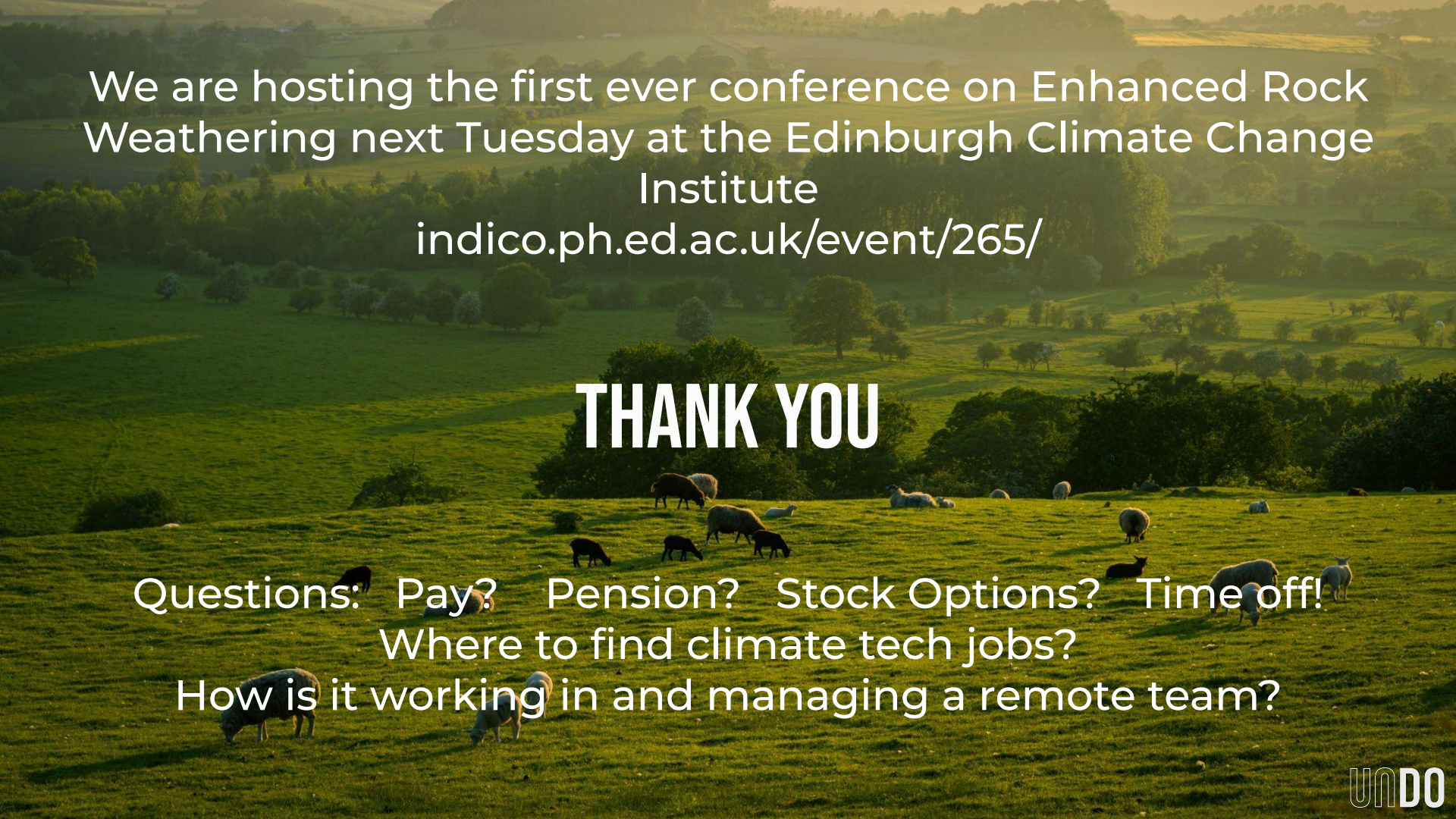
We are hosting the first ever conference on Enhanced Rock Weathering next Tuesday at the Edinburgh Climate Change Institute
indico.ph.ed.ac.uk/event/265/
THANK YOU
Questions: Pay? Pension? Stock Options? Time off!
Where to find climate tech jobs?
How is it working in and managing a remote team?
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