Bio, Energy and Storage -

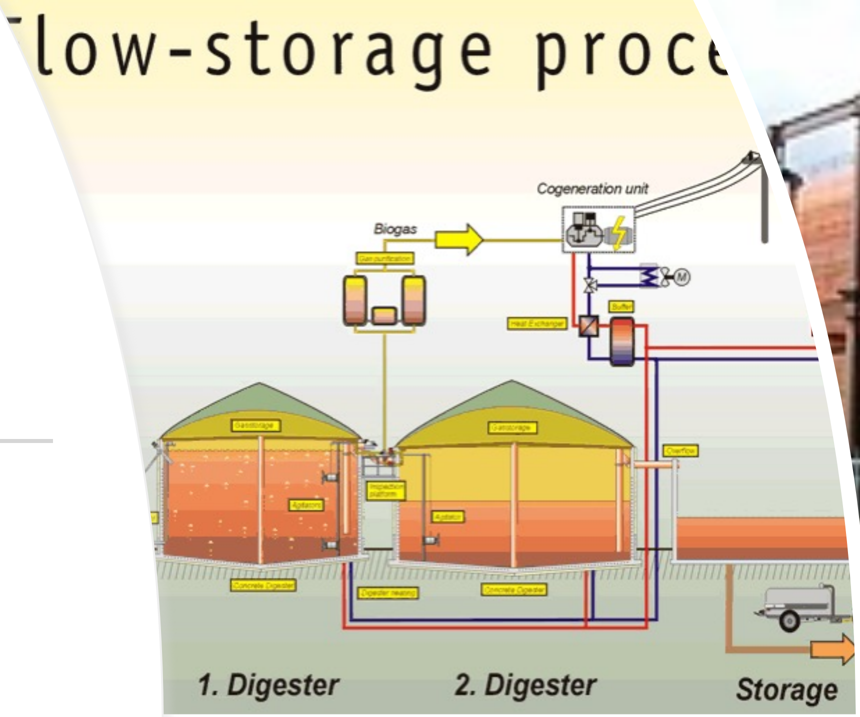
Where does it fit?

Horizons – Setting the Context

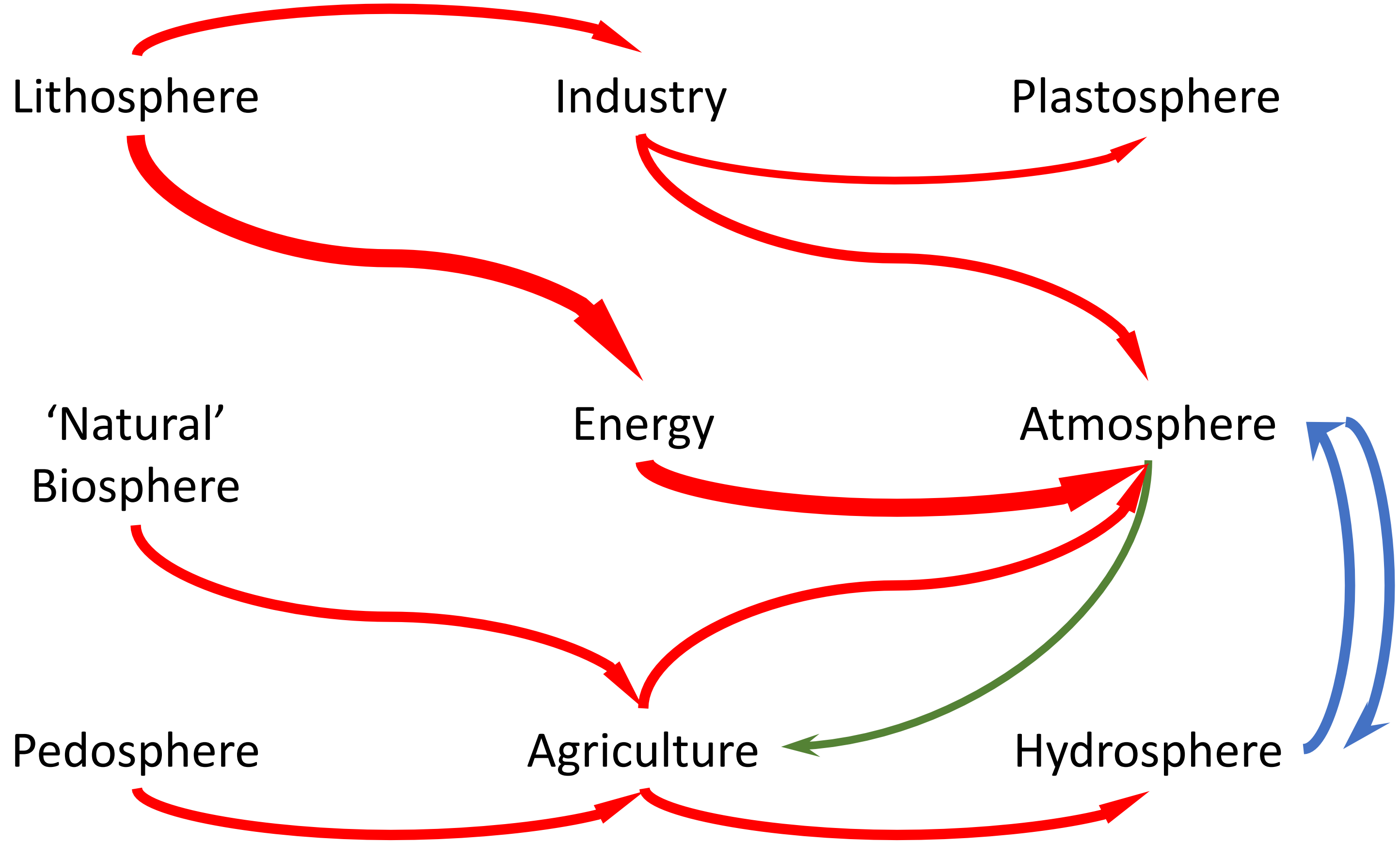
- England is a small part of a small archipelago of the West coast of a small peninsular of Asia.
- *‘I don’t skate to where the puck is, I skate to where the puck is going to be”. Wayne Gretsky – ice hockey star*

Key questions for bio-based energy storage

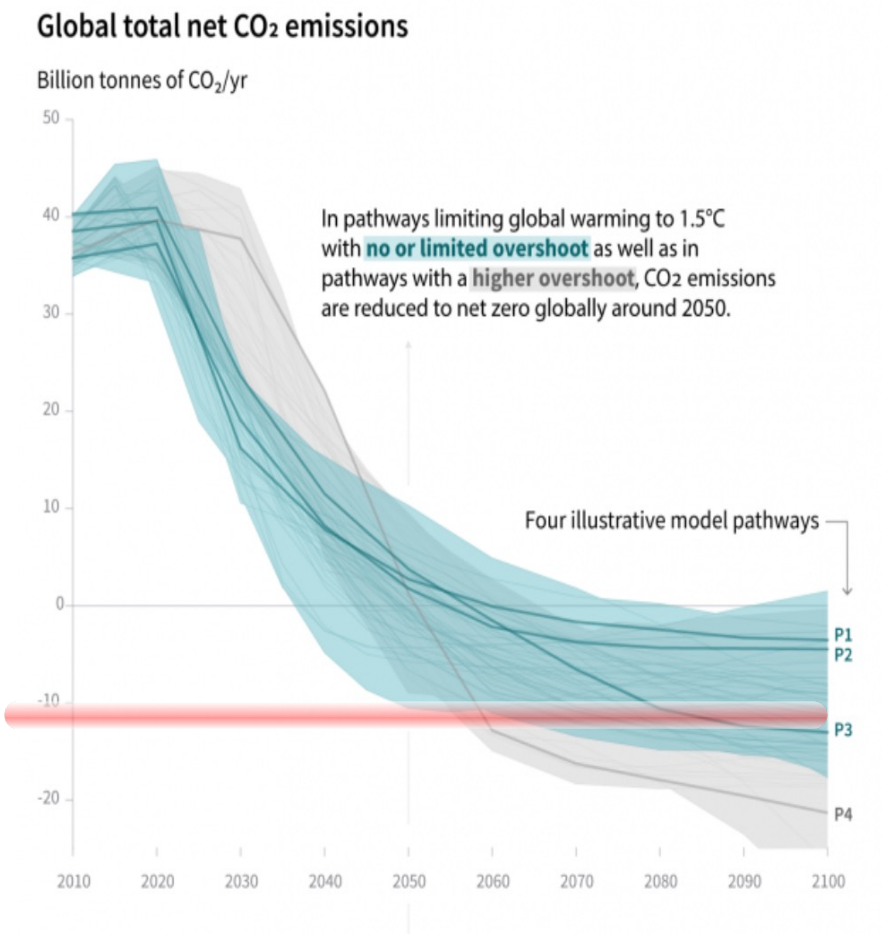
- What is bio-based storage better at than everything else?
- **Is it the best use of the carbon?**
- **Is there enough of it to make a difference?**



‘Bio’ means Carbon
Today’s Anthropogenic Carbon Flows

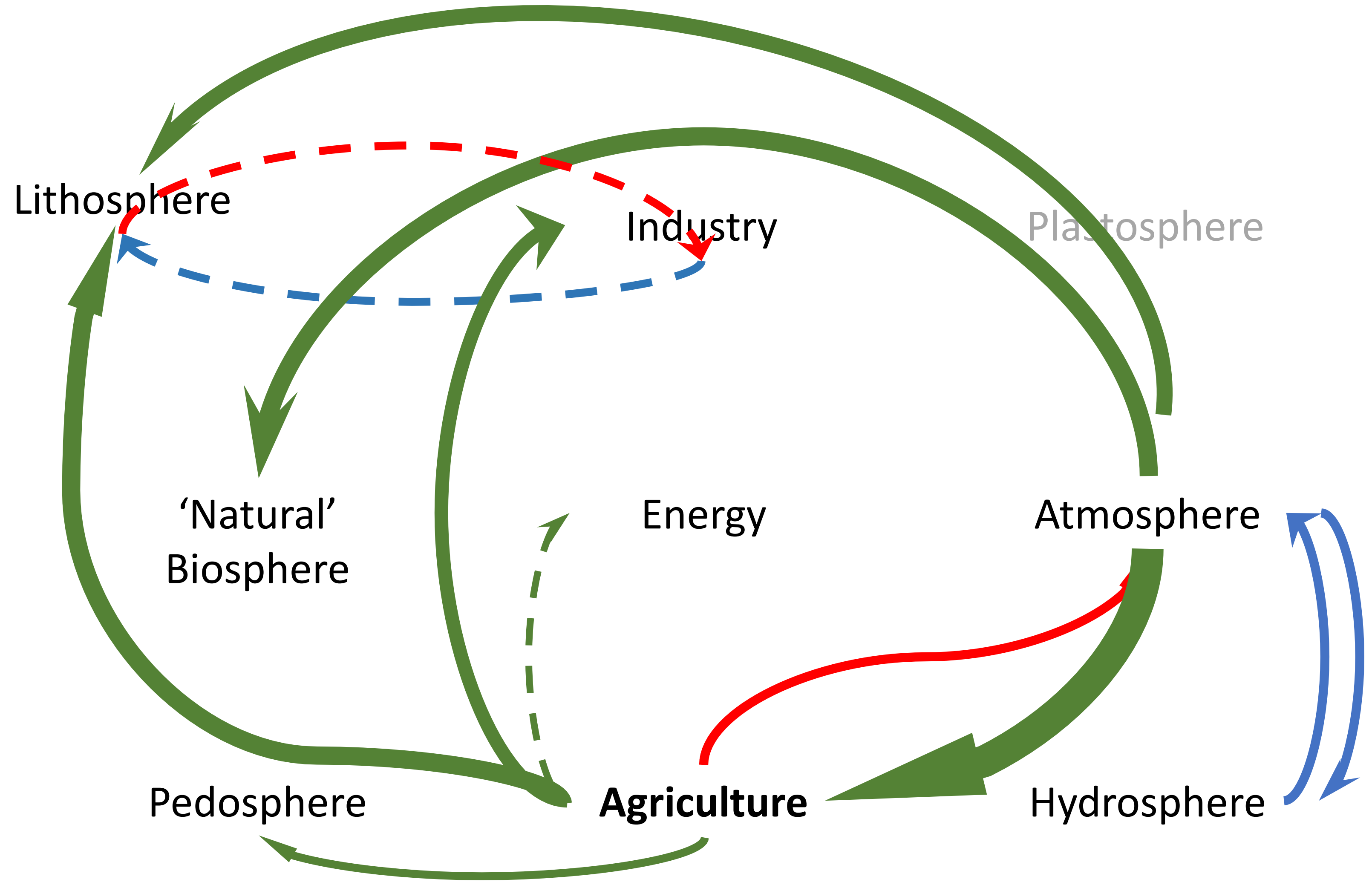


The Future of Carbon



	Carbon	CO2
Sequestration	2.7 Gt/y	10 Gt/y
Industry	1.2 Gt/y	4.5 Gt/y
TOTAL	**3.9 Gt/y**	**14.5 Gt/y**

Tomorrow's Carbon Flows



DAC - Energy Is The Big Issue

- By 2050 we will need >50PWh per year for carbon management and supply
- This is 30% of current global energy use, and twice current global electricity use
- In addition there is the steel needed, and other equipment
- **DAC could consume most of the world's resources by 2050**

Carbon for product (Smith School - Ox)	1.2E+09	tonnes/yr
CO2 for polymers etc	4.40E+09	tonnes/yr
CO2 drawdown needed (IPCC)	1.00E+10	tonnes/yr
CO2 capture energy (WRI)	7.20E+09	J/tonne
Energy needed to make Hydrogen	1.50E+11	J/tonne
H2 needed	6.00E+08	tonnes/yr
Energy needed to make Hydrogen	**9.00E+19**	**J/yr**
CO2 capture tonnage	1.44E+10	tonnes/yr
Energy needed	**1.04E+20**	**J/yr**
Total energy need	**1.94E+20**	**J/yr**
	53.80	PWh/yr
Global energy consumption today	160.00	PWh/yr

Carbon – A Changed Future

- Negative CO_2 and industrial carbon need to come from the air
- 14.5Gt/year using Direct Air Capture needs us to mechanically handle and chemically treat 1 million tonnes of air a second for a long time

Carbon Today

The **biggest source** of energy
Sourced from fossils
Dumped in the air

→

Carbon Tomorrow

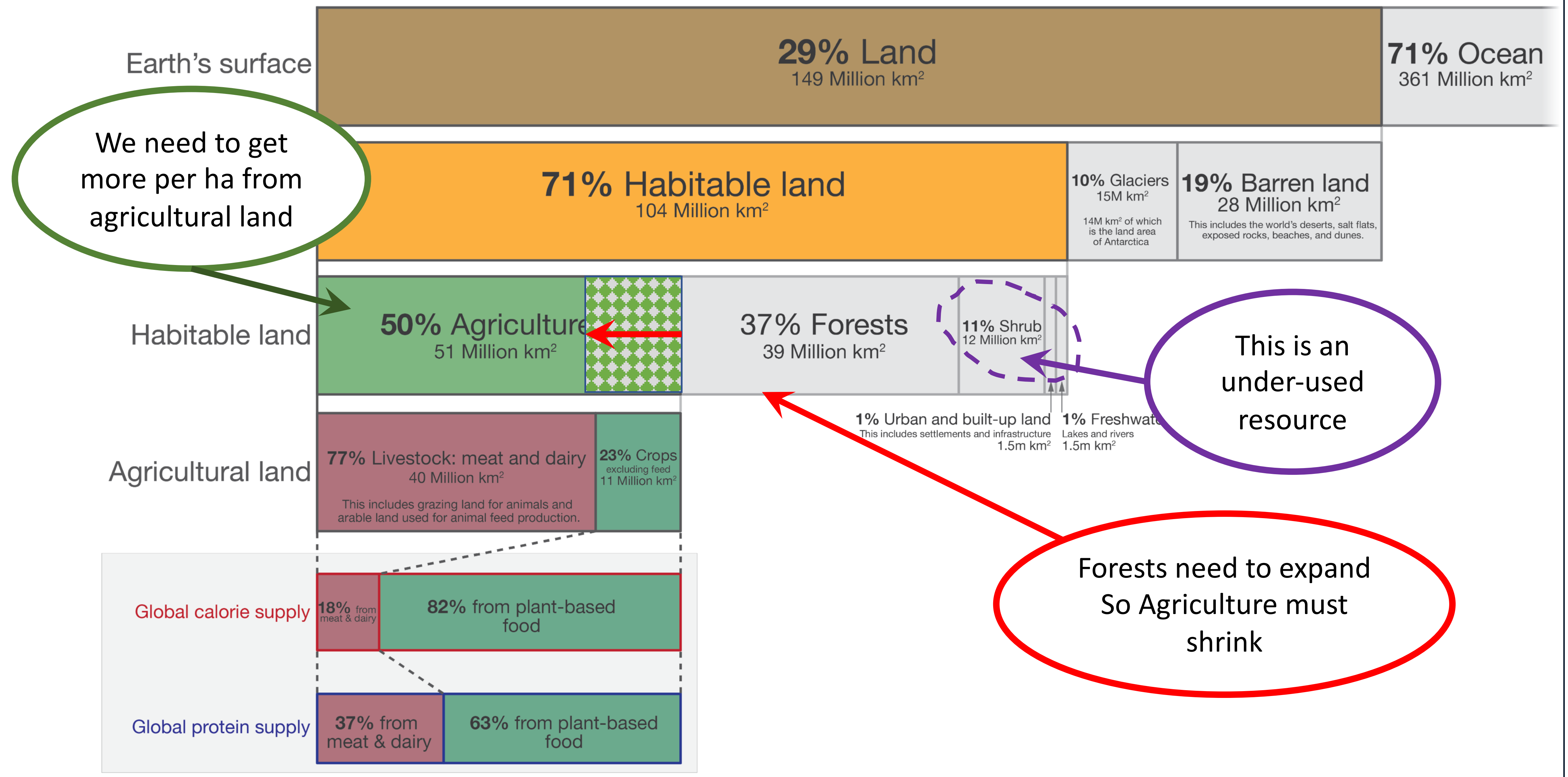
The **biggest user** of energy
Sourced from air
Buried in the ground or in forests

How Much Agricultural Carbon is There?

- Two major resources
  - Crop Wastes
  - CAM plants
- Conventional crop wastes can only deliver 33% of global carbon needs at maximum
  - but in reality at least half of that needs to go back to the fields
  - so there will be little conventional carbon spare for

	Total Residues (Mtpy)	Total Carbon (Mtpy)
Barley	210	90
Rice Straw	890	400
Wheat Straw	870	390
Corn Straw	600	270
Sugar Cane	310	140
Total		**1,290**

Global land use for food production



Data source: UN Food and Agriculture Organization (FAO)

OurWorldinData.org – Research and data to make progress against the world's largest problems.

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Leveraging that Carbon

Opportunity costs are dominant and rarely considered

Reforestation means displacing agriculture

RESEARCH LETTER

Table 1 | COCs and global PEMs of major crop and livestock products

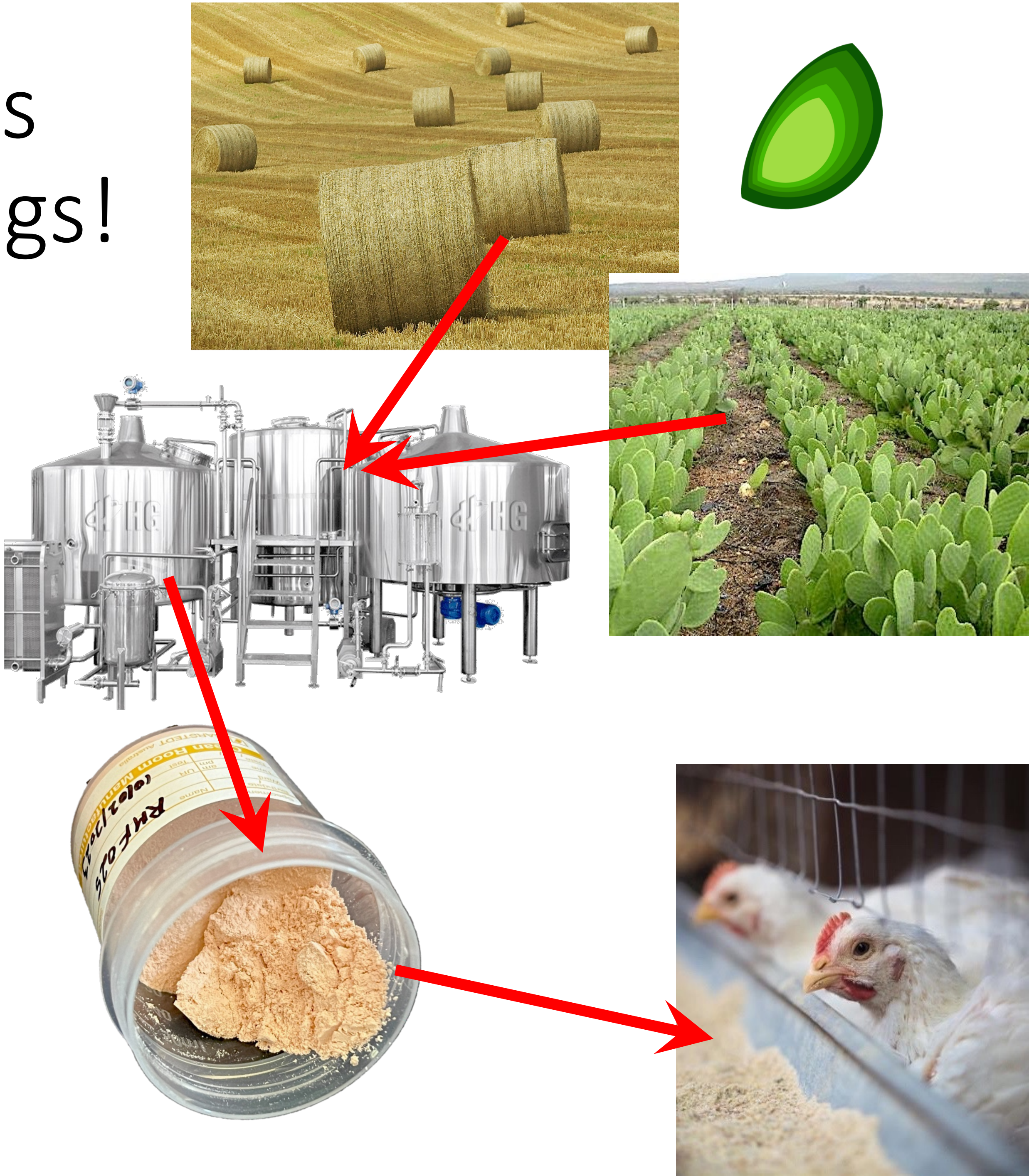
	COC[a] (kg CO_2 per kg fresh weight)	PEMs (kg CO_2e per kg fresh weight)	Total (kg CO_2e per kg fresh weight)	Total (g CO_2e per kcal[c])	Total (kg CO_2e per kg protein)
Maize	2.1	0.46	2.6	0.82	29
Rice (rough)	2.6	2.17	4.8	2.0	69
Wheat	1.9	0.69	2.6	0.9	23
Cassava	1.7	0.04	1.7	1.6	160
Potato	0.6	0.09	0.7	1.1	38
Soybeans	5.9	0.26	6.1	1.5	17
Pulses	10.5	0.55	11	3.1	47
Vegetable oils	9.7	1.3	11	1.2	Not applicable
Beef[b]	144	44	188	102	1,250
Cow milk	6.2	2.3	8.4	13.1	260
Pork	14	5.5	20	9.4	150
Poultry meat	11	3.7	14	8.4	110

Values are calculated using the carbon loss method and 4% time discounting.
[a]Includes peatland emissions.
[b]Average, including meat from dairy animals.
[c]1 kcal = 4,184 J.

Searchinger, Timothy D., Stefan Wirsenius, Tim Beringer, and Patrice Dumas. 2018. "Assessing the Efficiency of Changes in Land Use for Mitigating Climate Change." *Nature* 564 (7735): 249–53.

Finding Space for Forests
Replacing Crops with Bugs!

- Use unconventional carbon sources
  - Agricultural wastes like straw
  - CAM plants grown on semi-arid land
- Precision fermentation with micro-organisms to produce Protein and fat Rich Cells (PRCs)
- Use PRCs to replace 300 Mt/y of soy meal used as animal feed
- **Every tonne of PRC gains >8 tonnes of CO_2 from avoided deforestation or reforestation – 2.5Gt CO_2 potential**
- Other crops could also be replaced – R&D needed



CAM Plants – A Primer

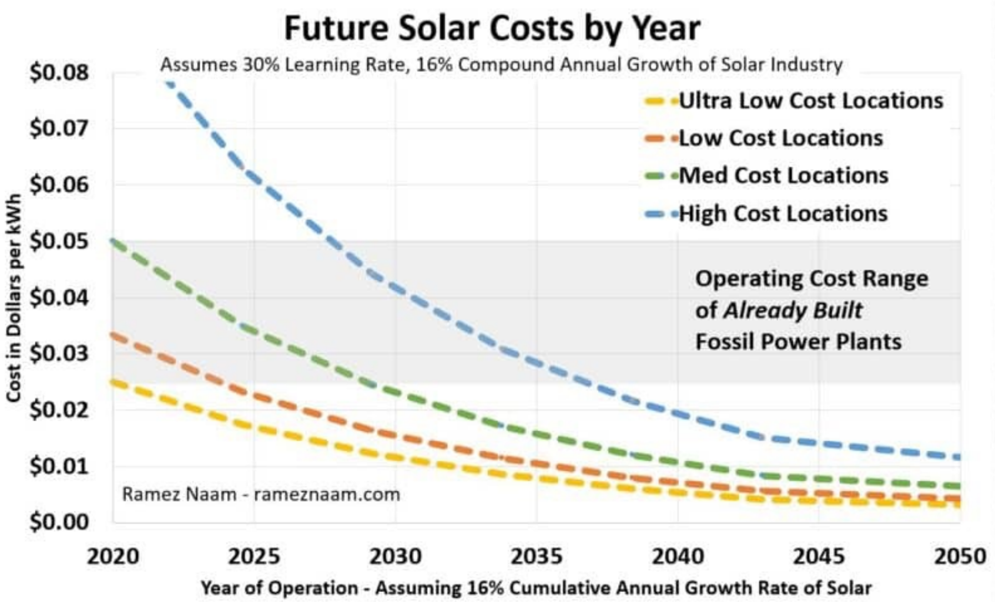
- Crassulacean Acid Metabolism (CAM)
  - CAM plants need 20% of water of normal plants
  - They are exceptionally efficient nutrient users
  - **Able to grow on semi-arid, often degraded lands**
  - Minimal competition with agriculture
- CAM plants like wheat 8,000 yrs ago
  - 16,000 species – but none as major crops
  - Little serious investigation or development
- CAM plants are unrecognised supercrops

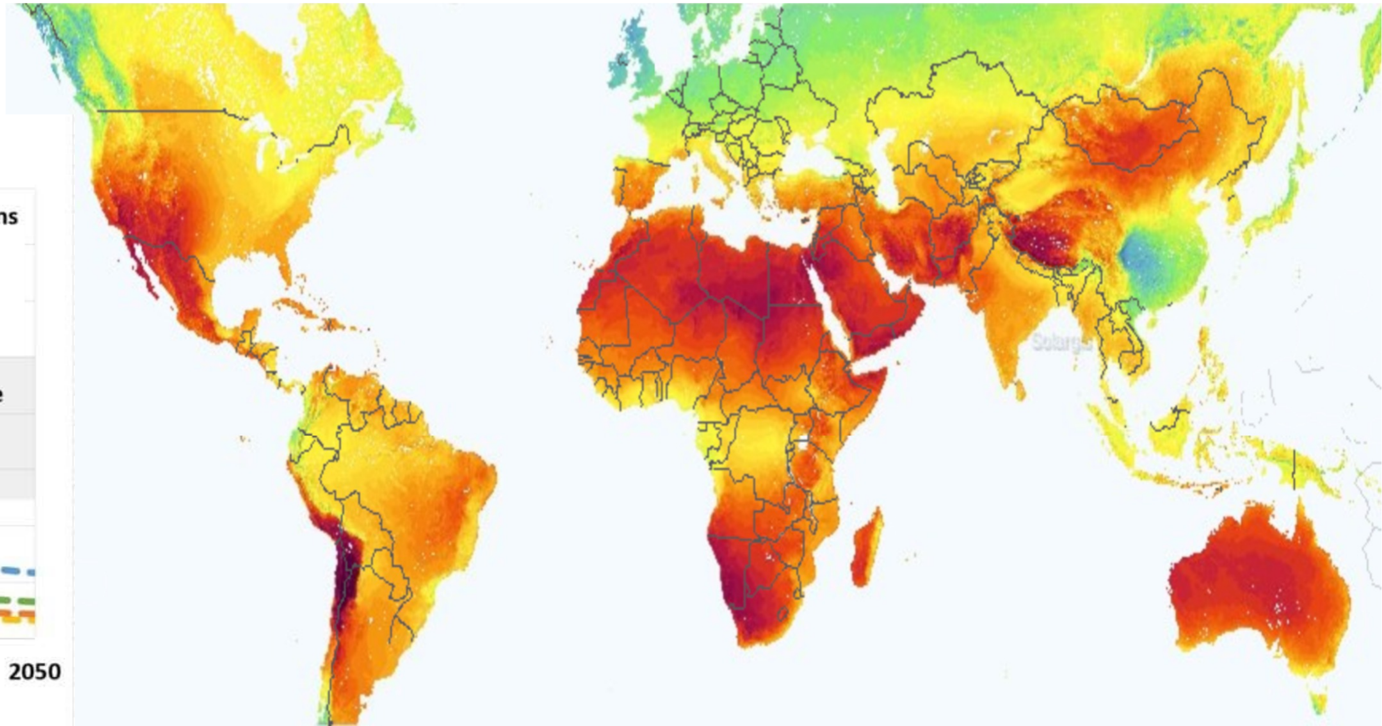
Using Biocarbon – the Need for Hydrogen

- Carbon is too precious to waste – so all carbon from a plant needs to be used productively or sequestered
- All biology used to process biomass produces CO2, so to make maximum use of carbon you need hydrogen to carry off the oxygen, or you need to sequester it.
- This makes any energy vector using all available carbon expensive unless it is done where there is very low cost electricity
- The lowest cost of electricity on the planet is, and will for a long time, be solar PV

CAM Plants and Solar Correlate Well

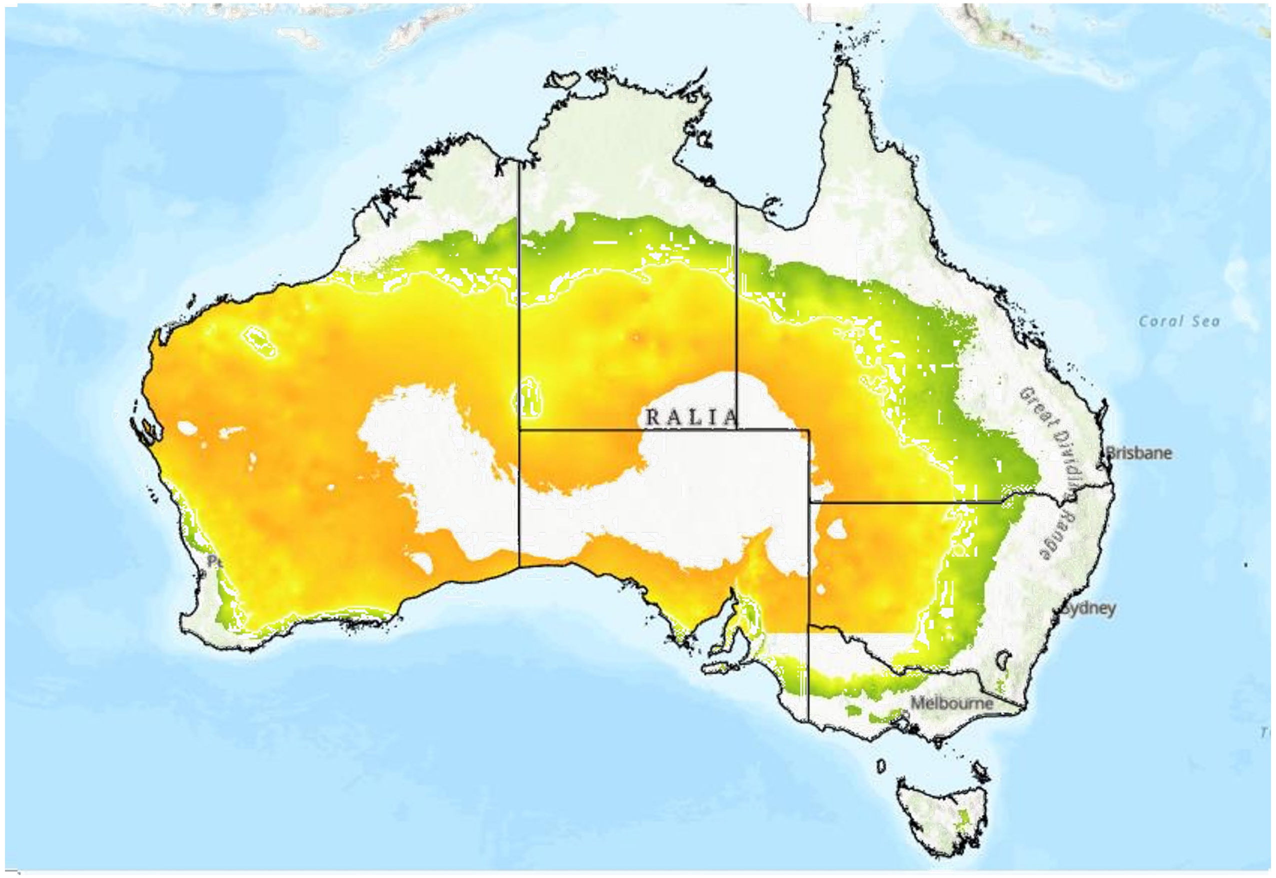
- With a few notable exceptions – most Solar and CAM plant potential is not where people live – it is too hot and dry.
- This argues for biocarbon being converted to <u>transportable</u> biofuels **once all food needs are met**





Australia – A CAM plant superpower

- Map of Australian pasture zone – 200-600mm irregular rainfall
- **Queensland alone** – 90M ha with 6Bn tonnes of CO_2 capture potential per year
- Australia could probably meet the entire global carbon needs



But Australia has Other Options

- Using biofuel results in CO2 which usually goes to atmosphere or has to be captured from a chimney – not a good plan!
- Ammonia could be the next global reserve fuel
  - No carbon losses
  - As cheap to make per GJ as biofuels
  - Easy to transport and looking easy to burn or use in fuel cells
  - Early work suggests we can do it very safely
- Australia will make massive quantities of ammonia – displacing the need for biofuels

NH_3 powered bus – Brussels 1943

Not just electricity!

Ammonia can tackle some of the difficult to decarbonize sectors

Bio, Energy and Storage?

Back to the question

Storage Problems to Solve
Moving energy in time and place

Power and Heat - Moving in Time

- Very long term (multi-decadal)
- Seasonal storage
- Short term - Intra-day to weekly

Mobile Energy – Moving in Place

- Shipping
- Heavy plant and equipment
- Cars
- Aviation

Storage Problems to Solve
Moving energy in time and place

Power and Heat – Moving in Time

Very long term (multi-decadal)	Hydrogen in geological storage, Ammonia shipped globally
Seasonal storage	Hydrogen and Ammonia
Short term - Intra-day to weekly	Batteries, liquid air, hydrogen, ammonia

Mobile Energy – Moving in Place

Shipping	Ammonia, **possibly some bio-derived fuels**
Heavy plant and equipment	Batteries, Ammonia, **possibly some bio-derived fuels**
Cars	Batteries
Aviation	Some Hydrogen, Ammonia, **bio-derived fuels**

To Summarise

- **Carbon is valuable** – we can't afford to waste a single atom
- **Forests are key to our survival** – using land to grow energy crops has HUGE carbon opportunity costs
- In any assessment of the carbon benefits of bio-energy and storage the **carbon opportunity costs will dominate**
- **CAM plants** could allow better use of marginal and degraded lands, and provide an opportunity for bioenergy stores
- **Stored bioenergy will almost certainly be high value transportable liquids**
- The competition will be **Ammonia**

Thank you

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