SEATA
Deconstructing the world's problems into profitable carbon-negative solutions

Carbon *Negative* Hydrogen:

Pathways to Net Zero -

Hydrogen <u>with</u> Carbon Sequestration and Co-Benefits

New H2 Industry Forum

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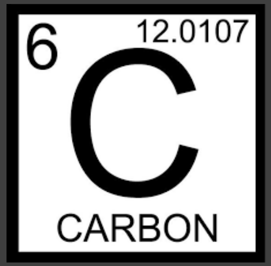
Presentation Outline

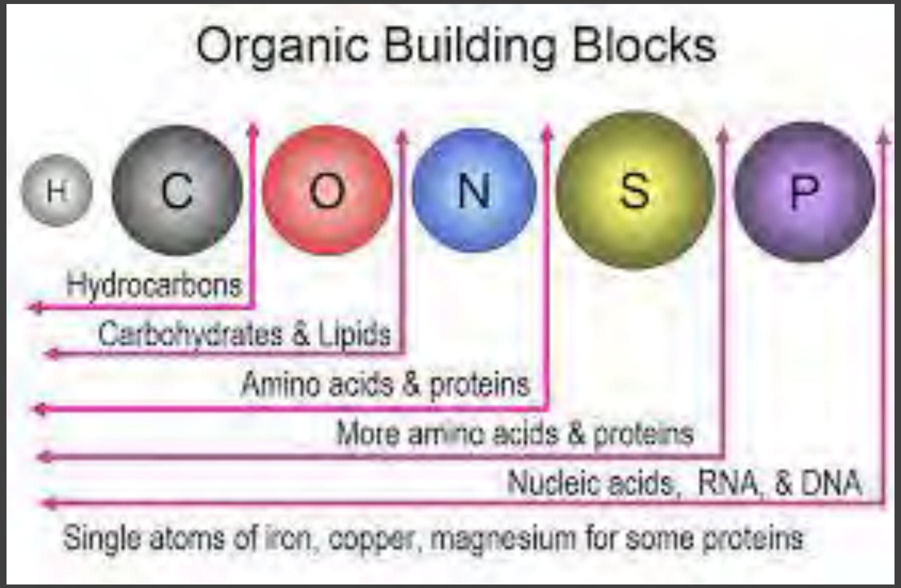
- **Carbon is Good (normally)**
- **Taking The Blanket Off the Planet** – The Need for Carbon *Removal* in addition to Emissions Reduction / Avoidance
- **Carbon *Negative* Hydrogen -** Hydrogen with carbon sequestration & Co-Benefits
  - Advancements in Thermal Treatment from Linear to Circular
  - Carbon + Hydrogen Products (Commodities)
  - Applications (‘Carbontech’, Industrial, Agricultural)
  - Carbon Credits
- **SEATA Technology**
  - Hydrogen AND Carbon “Drawdown”
  - Key Points of Difference
- **Complementary Aspects to Assist ‘Conventional’ Green and Blue Hydrogen**
- **Development Pathway**
  - Piloting toward Commercial scale systems
  - SEATA R&D Centre, Glen Innes REZ, NSW
- **Lessons Learned To Date**
- **Questions**

> *“ If your house is on fire, you don’t tell the fireman to just let it simmer, you want to put the fire **out** ..we need carbon **removal** that actually **keeps the carbon out afterwards** ”*
>
> *Albert Bates, Co-author of ‘Burn: Using Fire to Cool the Earth’*

Normally, carbon is good…it's the building block of all Life



- 4th most abundant element on Earth
- Found in all living things
- Basis of cellular functions keeping things alive (DNA, proteins, sugars).
- The heart of healthy soils for plants, forests and food production.



Chemistryland.com

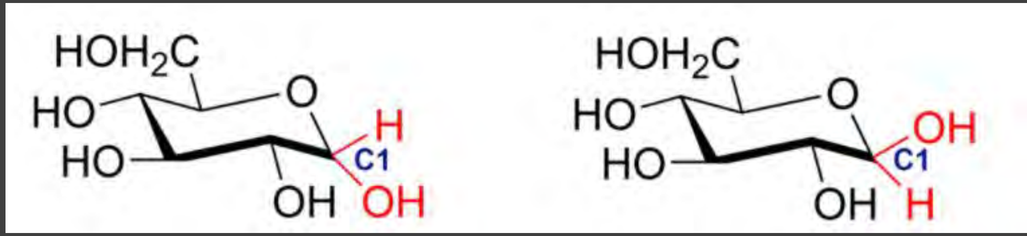
- **Chemical building block** of many important **materials** (including carbon fibre, graphite and graphene)
- Binds with almost anything due to atomic structure.

➔ *…we just don't want excess in the sky, we need it back down in our soils and in materials*

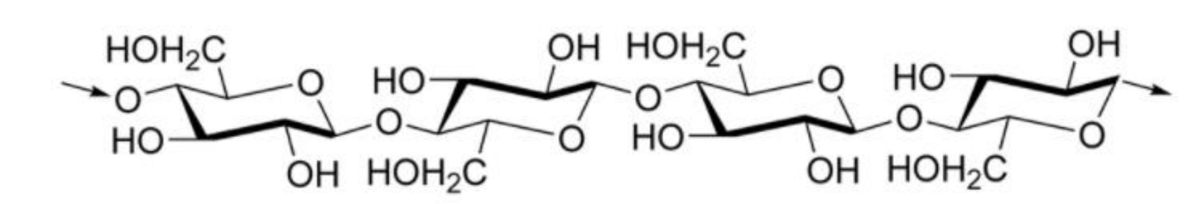
"Green carbon" is the basis of the *new carbon economy*

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

- *Photosynthesis*



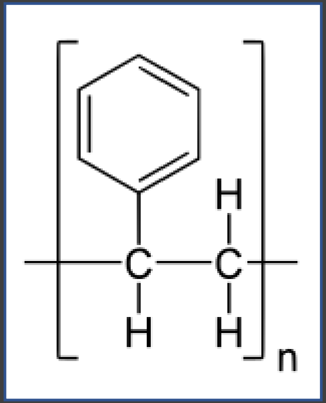
- Glucose



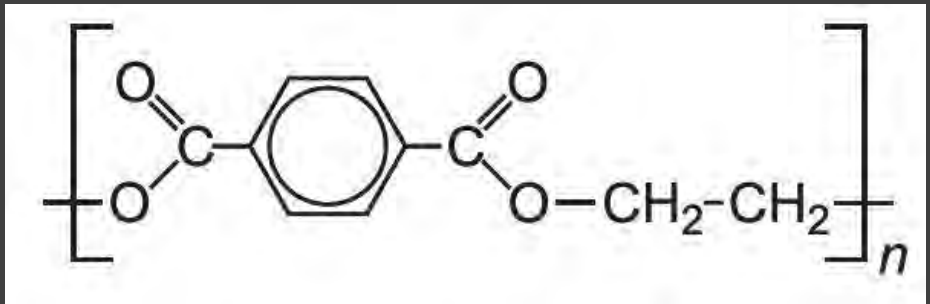
- Cellulose

Carbon is Carbon

(it's just in different forms)



- Polystyrene



- Polyester

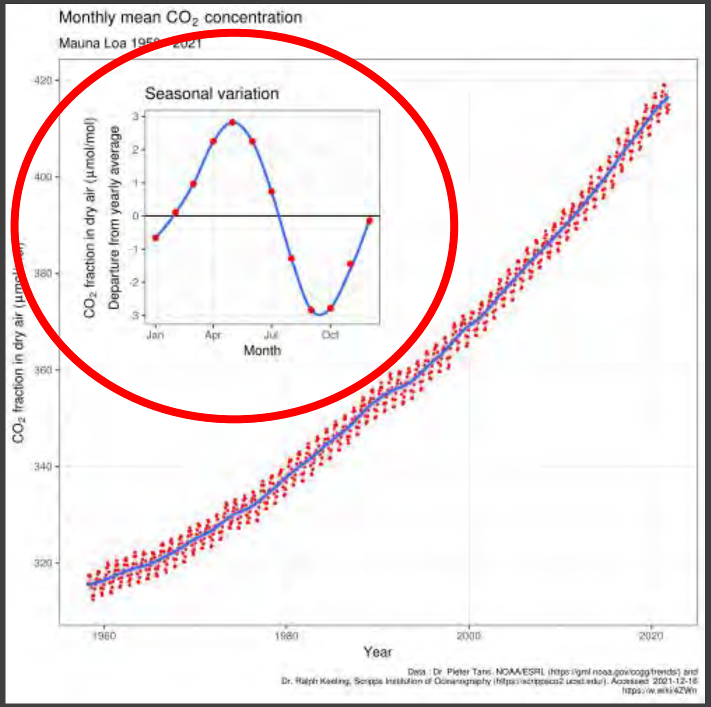
The Need for Carbon *Removal*

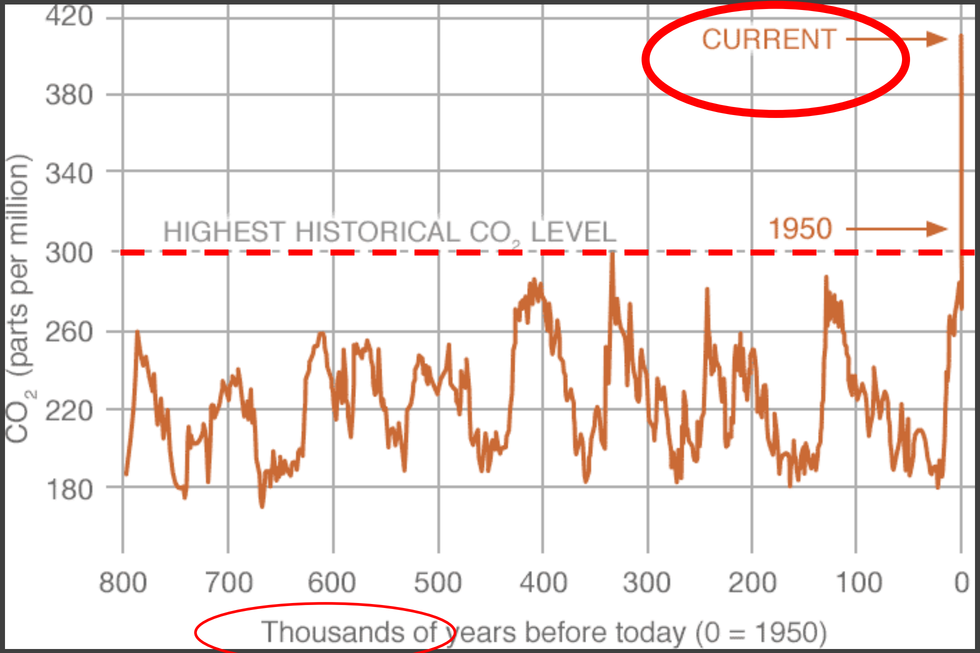
- Anthropogenic CO_2 added to the atmosphere lasts between **300 to 1000 years**
- Even if **<u>all</u> emissions stopped** immediately, the earth is expected to continue to heat for decades, and would take **thousands of years to cool to pre-industrial levels**. *(Source: Royal Society, March [2020](2020))*
- Target limit 1.5 degrees by 2100 via Net Zero 2050, with **<u>half the reductions required by 2030</u>**

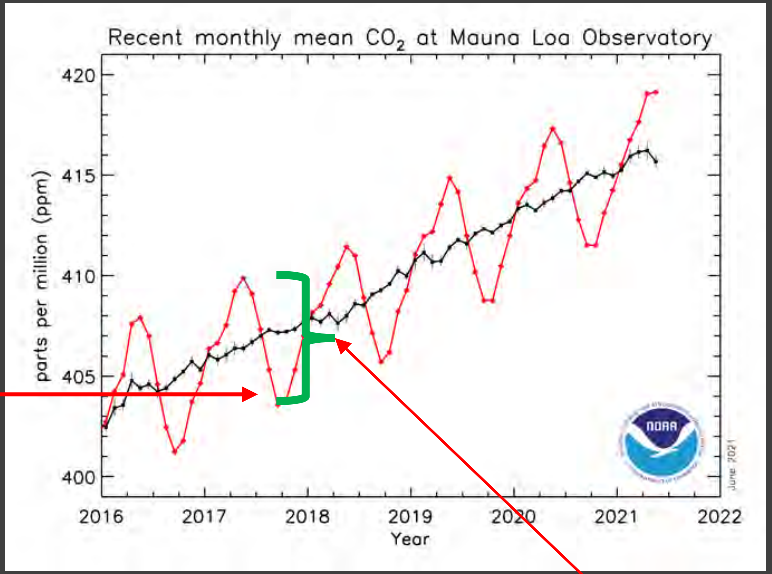
BUT we're **currently tracking <u>well above worst case modelling</u>, toward 3.2 degrees**

➔ Carbon *removal* is urgently needed in addition to emissions reduction

➔ Nature's existing carbon sinks need "turbo-charging" – *nature already indicates ways to do it*

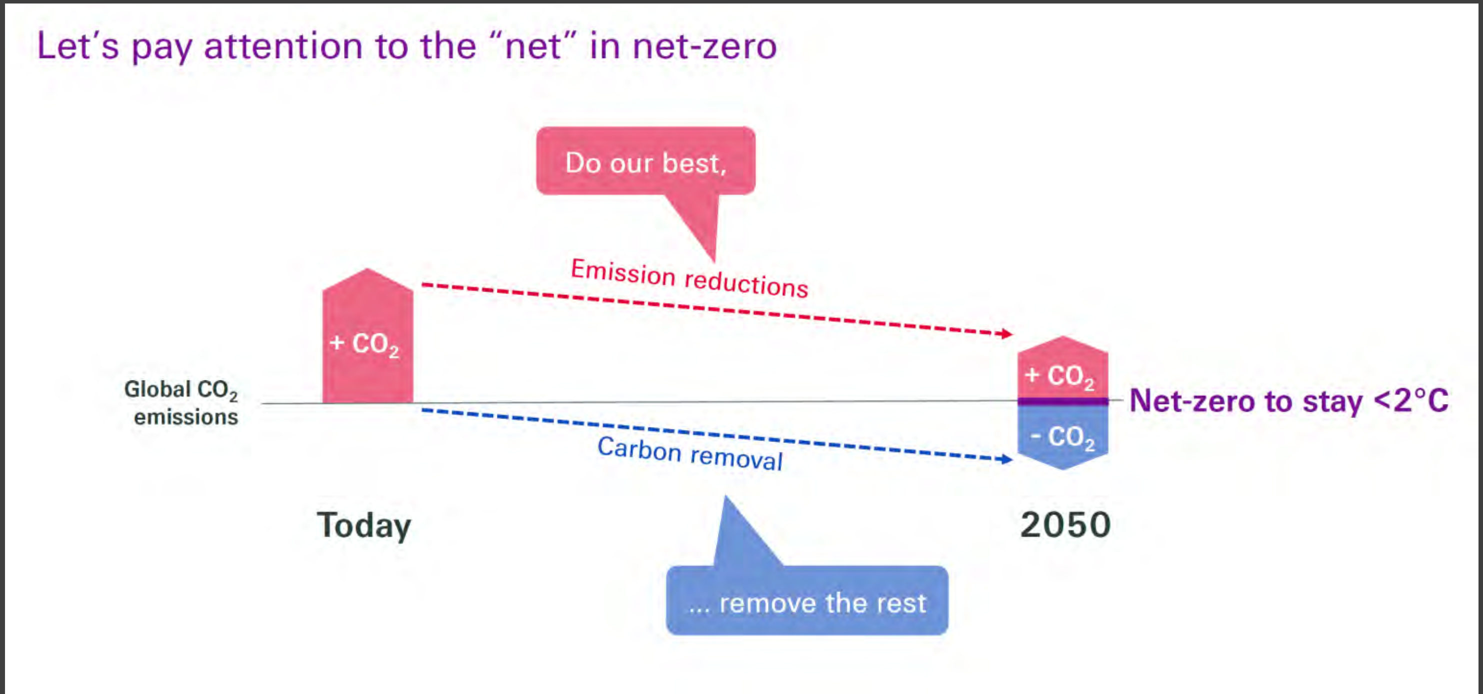


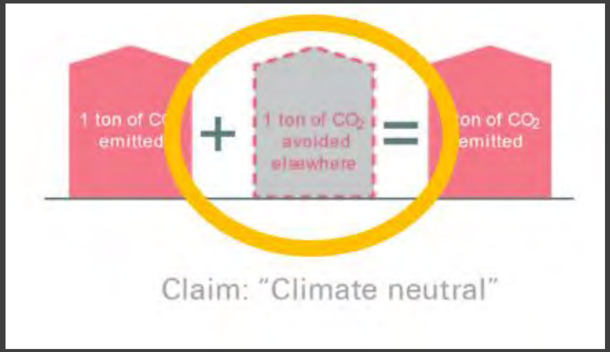


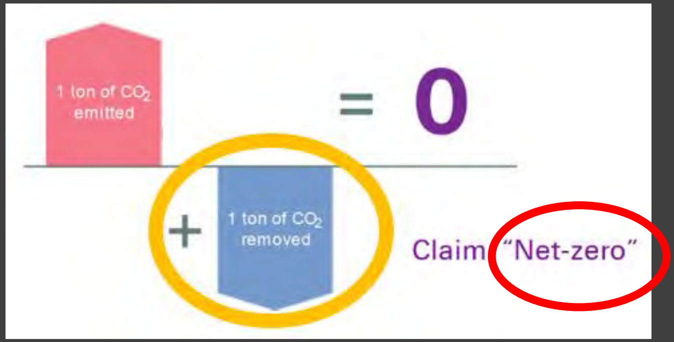


Annual *cyclic variations are due to seasonal* ***<u>Photosynthesis</u>***

Carbon *Removal* – *Beyond* Net Zero Vs Climate Neutral







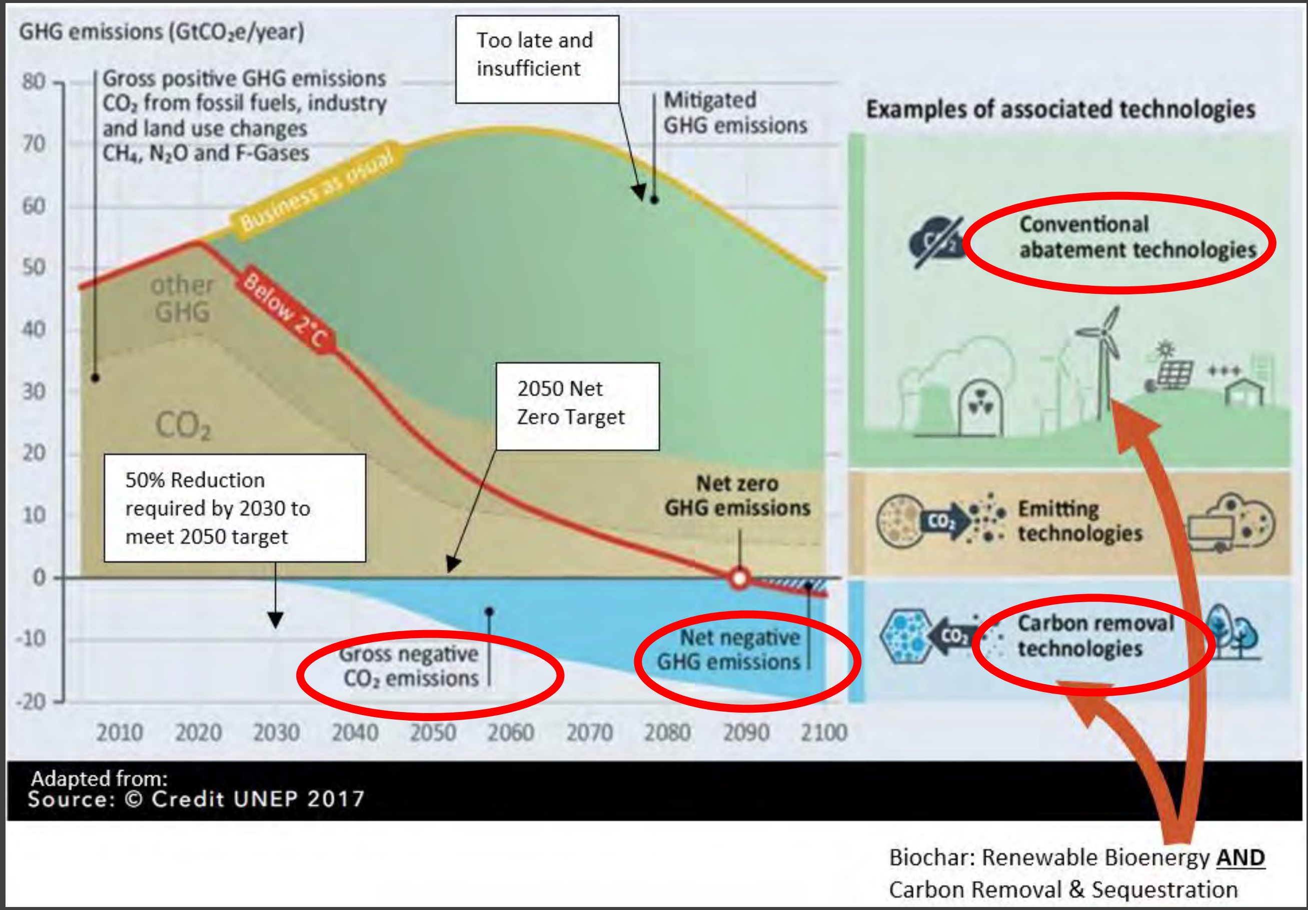
- Credit: Swiss Re, 2021

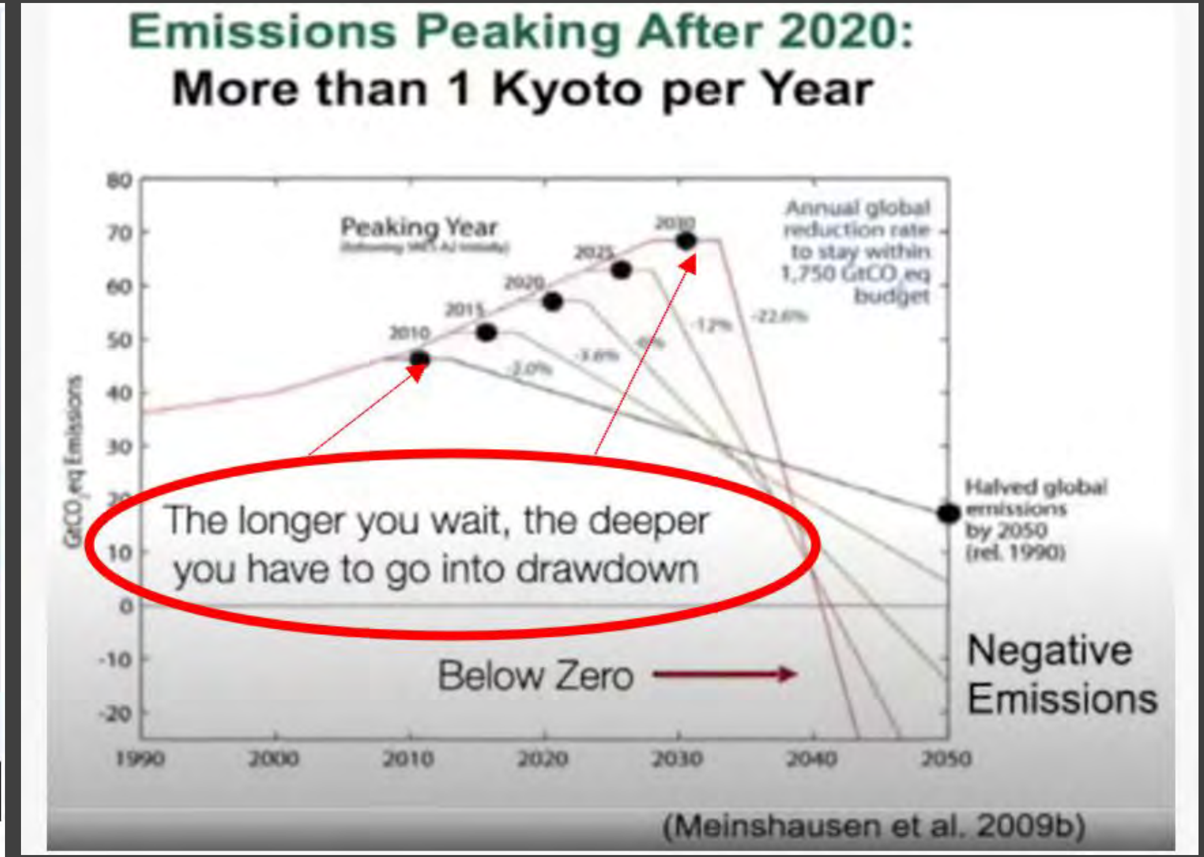
….in reality we need well <u>BEYOND</u> Net Zero. 1 to 1 CDR <u>is not enough</u> when tracking toward 3.2°C (not just 1.5°C)…

➔ Urgent need for Gt scale CDR of all forms to "take the blanket off the planet"

"In 2050 the carbon net-negative economy needs to be as big as the oil industry is today." *Mariannne Tikkanen, Puro Earth*

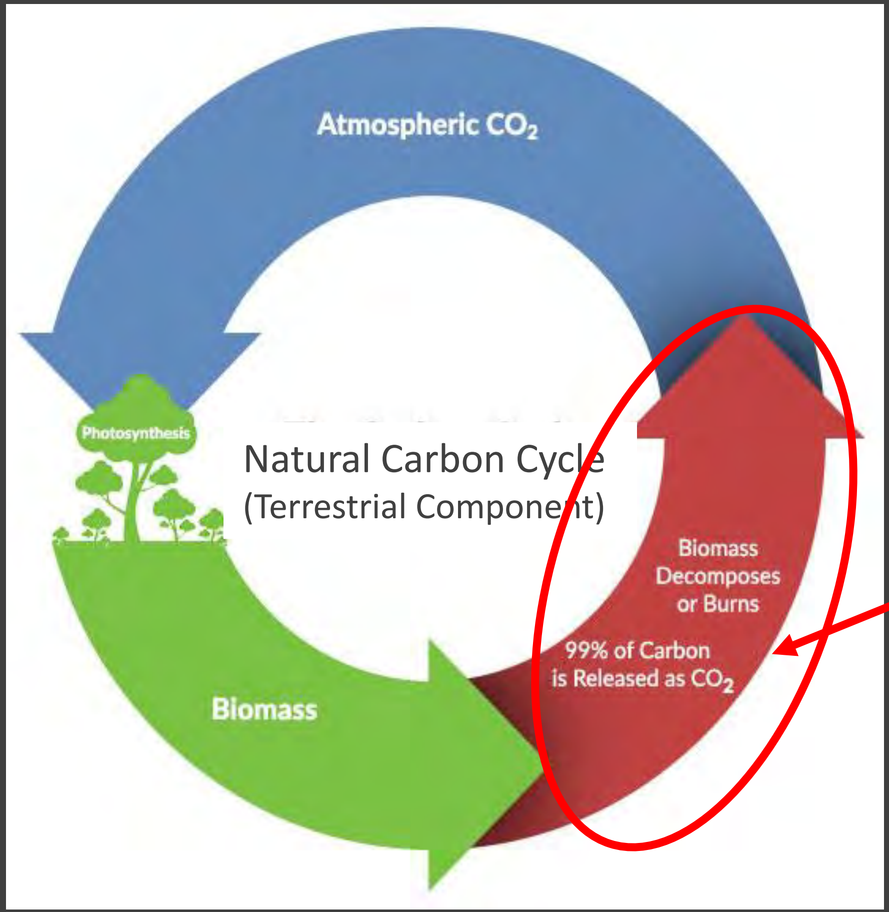
Drawdown with Negative Emissions Technologies (NETs)





- Biochar is one of six key NETs identified by the IPCC (2018) urgently required for CDR to combat climate change
- In 2019 the IPCC established recognized methods demonstrating sequestration *permanence* for biochar

How does Biochar achieve Drawdown?



99% of C re-released in natural cycle = opportunity to intercept / prevent

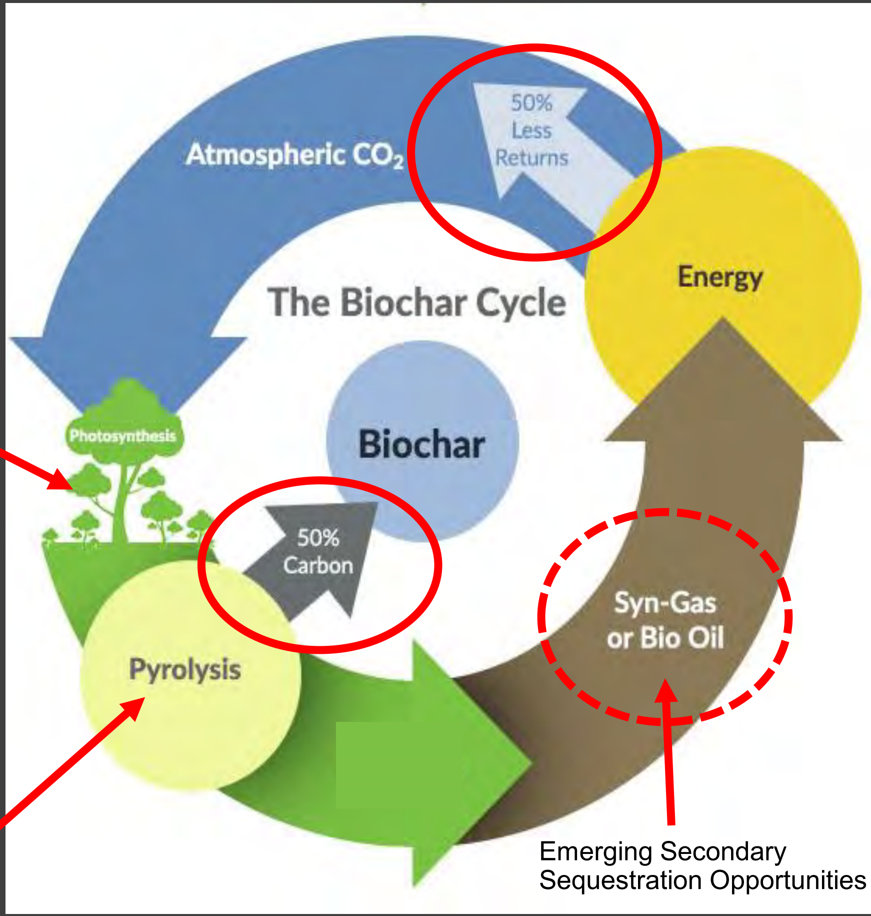
CDR Drawdown by plant photosynthesis

*>80 Mtpa of surplus plant residues n Australia alone**

** CSIRO 2017*

Capture & Utilisation (CCU) by technology

Half the C in pyrolyzed biomass is captured in long term stable solid form (biochar)



Pyrolysis char ~30-50% of infeed C (much lower for gasification)

Net drawdown: Life Cycle Analysis (LCA) is required for '*cradle to grave*' assessment (upstream emissions, production and use)

SEATA Technology – Introducing *Circular* Thermal Treatment

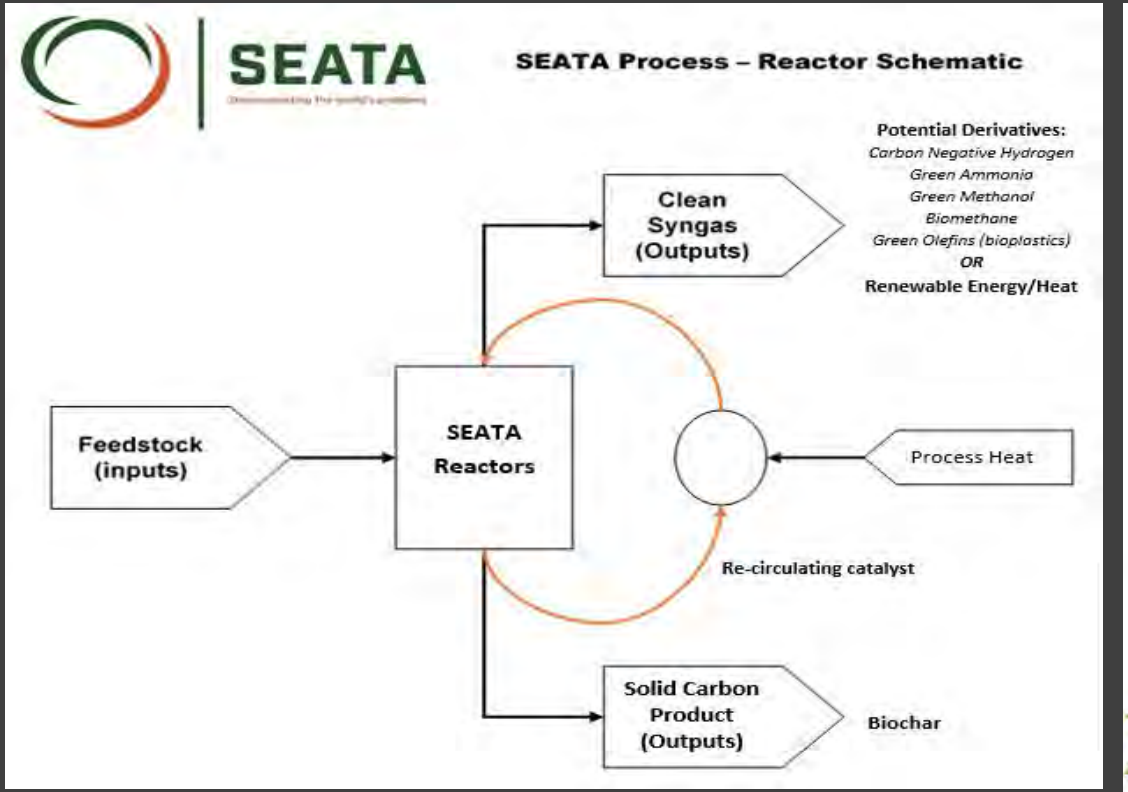
Conventional Thermal Treatment (Waste to Energy)

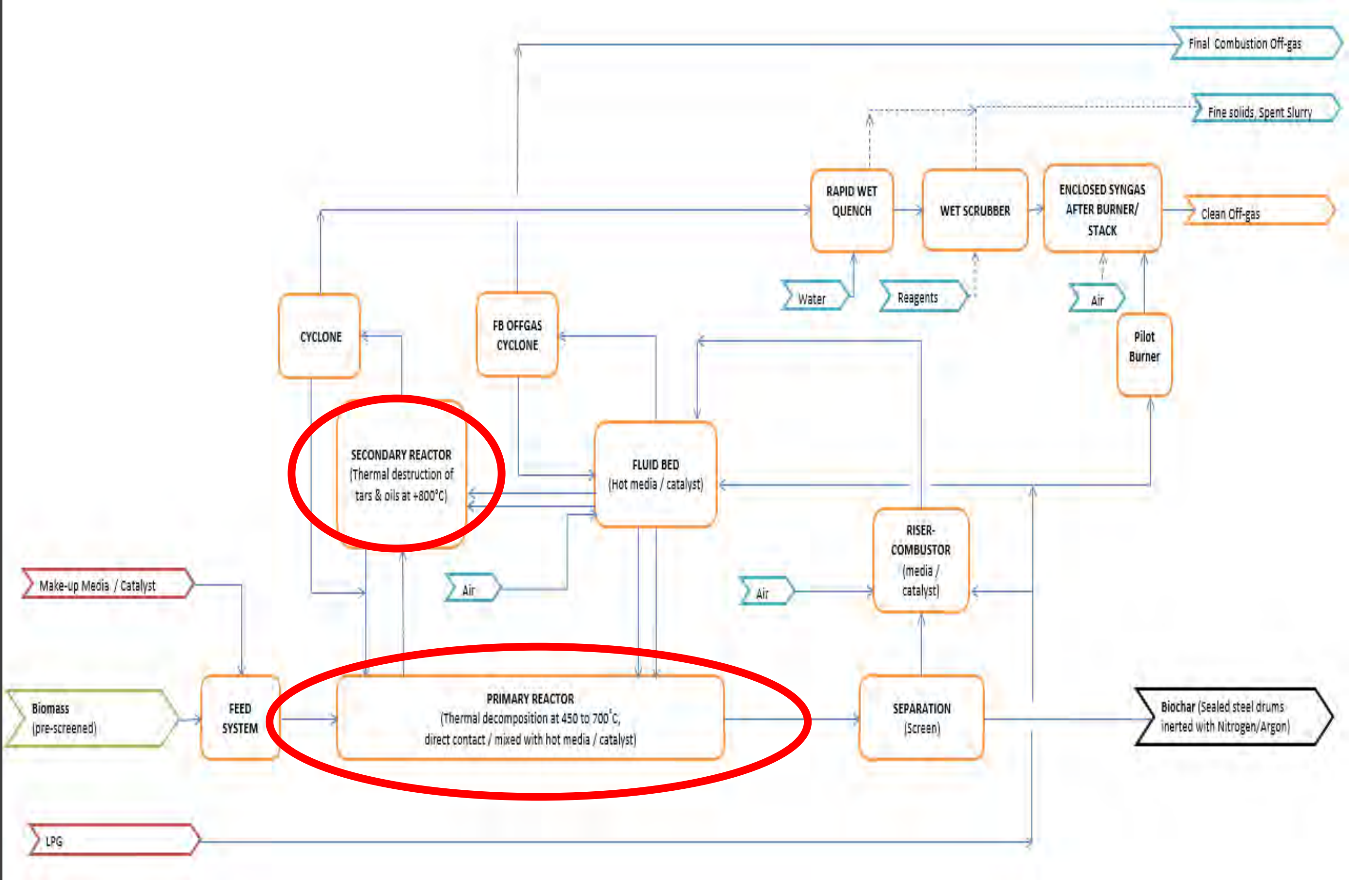
- Incineration (Full Combustion)
- Conventional Gasification & Pyrolysis
- Gases only usable for electricity / heat (and typically not easily storable)
- Biochar up to ~35% yield by pyrolysis (by mass of infeed), biochar by gasification much lower.

SEATA Thermal Treatment (Waste to **Resources / Commodities**)

1. **Undiluted** Syngas (no atm N_2) = economically recoverable chemical commodities ("building blocks")
2. **Storable** syngas (don't have to immediately combust/use)
3. **Significant carbon sequestration** as solid char (1st reactor) and potential secondary sequestration (high purity CO_2)
4. Conventional electricity/heat still available if needed
5. **Genuine "bridging" technology** – best of both worlds

SEATA - Deconstruction to Chemical **Building Blocks**





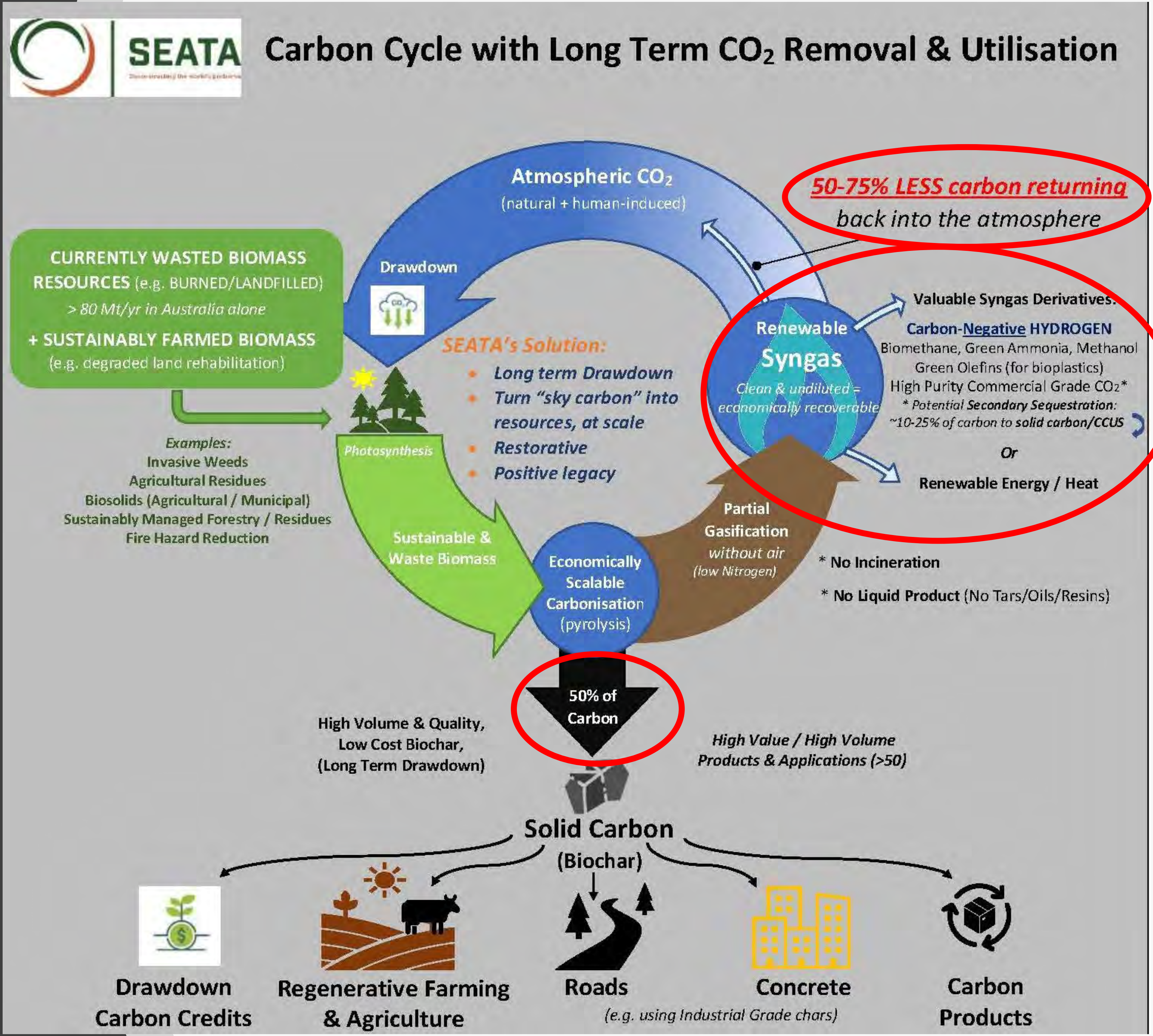
SEATA Technology

…Hydrogen *with* significant carbon sequestration and co-benefits

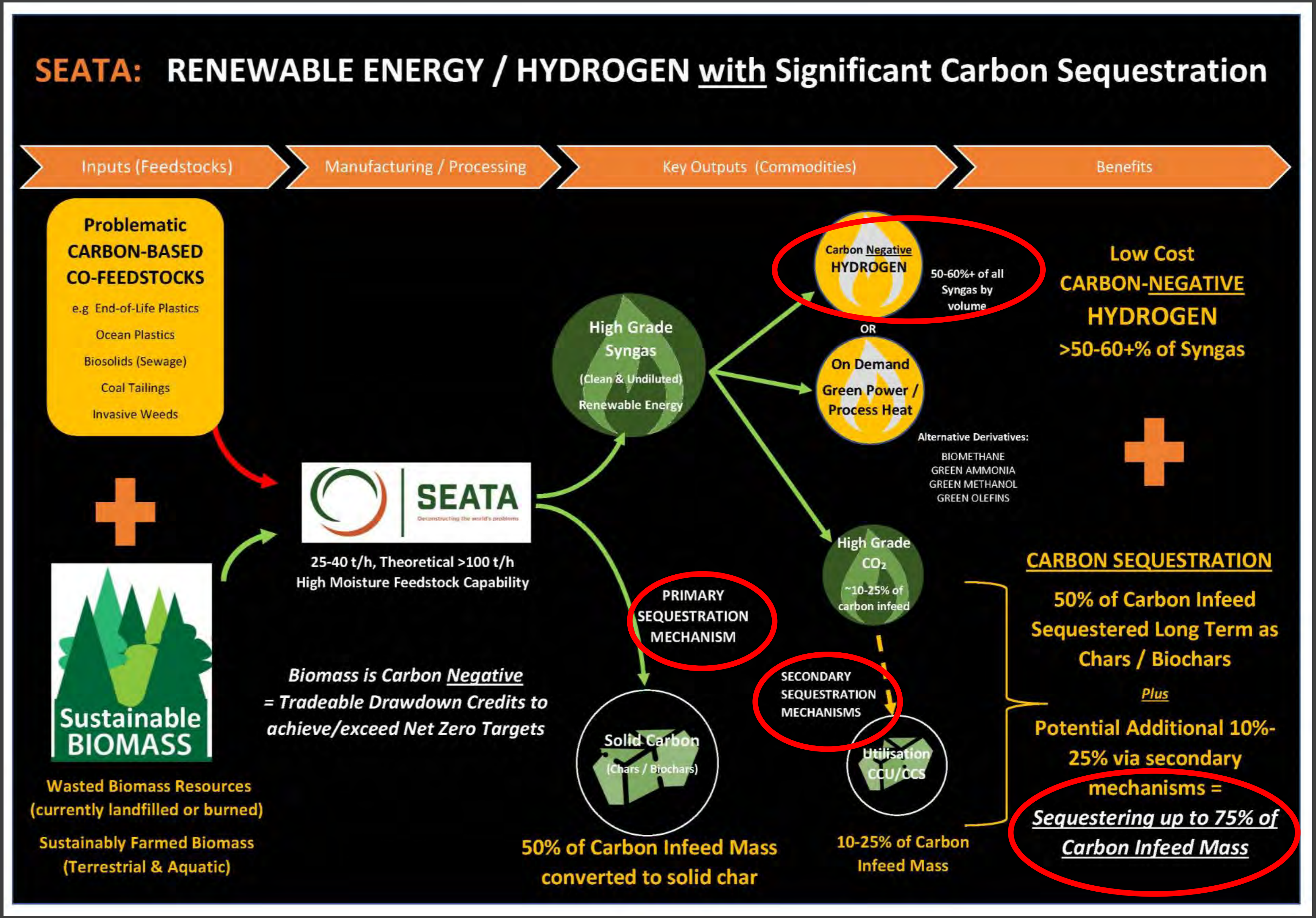
Key Points Of Difference:

SEATA aims to harness all of the potential feedstock value into solid and gas products

- **Rich undiluted Syngas** (no atm Nitrogen as not air-blown) = economically recoverable gases (hydrogen and high purity food & medical grade CO_2)
- **Direct Heat Transfer** – high thermal efficiency, consistent gas and char product quality.
- **One process, multiple higher value outputs**
- **Genuine industrial scalability**
- **Co-feeds/processing** (wide range)
- **High moisture capability** (up to 70%)
- **Bridging technology** – adaptable to existing fossil fuel installations AND transition to renewables.
- **Safe management of Halogens & Emerging Contaminants** (e.g. PFAS)
- Improved **Circularity** and **Sustainability**
- Avoided Emissions *plus* CDR Sequestration
- Emerging **secondary sequestration options**
- **Lower Cost, High Volume, High Quality Biochar**



SEATA - Carbon *Negative* Hydrogen with co-benefits



Complementary Aspects to Assist Conventional Green & Blue Hydrogen

- **Night-time generation to optimize CAPEX investment in integrated systems = 24/7 continuous hydrogen generation**
- **CO_2 Removal for overall system Net Zero and beyond (to Carbon-Negative systems)**
- **Carbon for battery storage technologies (solar/wind renewables)**
- **Sodium-Carbon Batteries – potential to help turn desal brine wastes into *resources* to avoid ocean disposal - *Zero Liquid Discharge***
- **Biochar to increase biomethane & efficiencies from Anaerobic Digestion** (another potential green hydrogen source)
- Potential to **also assist blue and grey hydrogen** (through high purity CO_2 economically into CCUS applications)
- **Additional Revenue streams** from co-benefit markets (carbon commodities & removal credits) to optimize CAPEX and OPEX
- **Potential to add further emissions reduction and *displacement/avoidance* credits via CCUS applications** (in addition to providing carbon *removal* credits).
- **Provide additional "green" jobs, notably in rural and regional areas**

SEATA vs Conventional Industrial Scale Gasification Plants including Methanation For Hydrogen

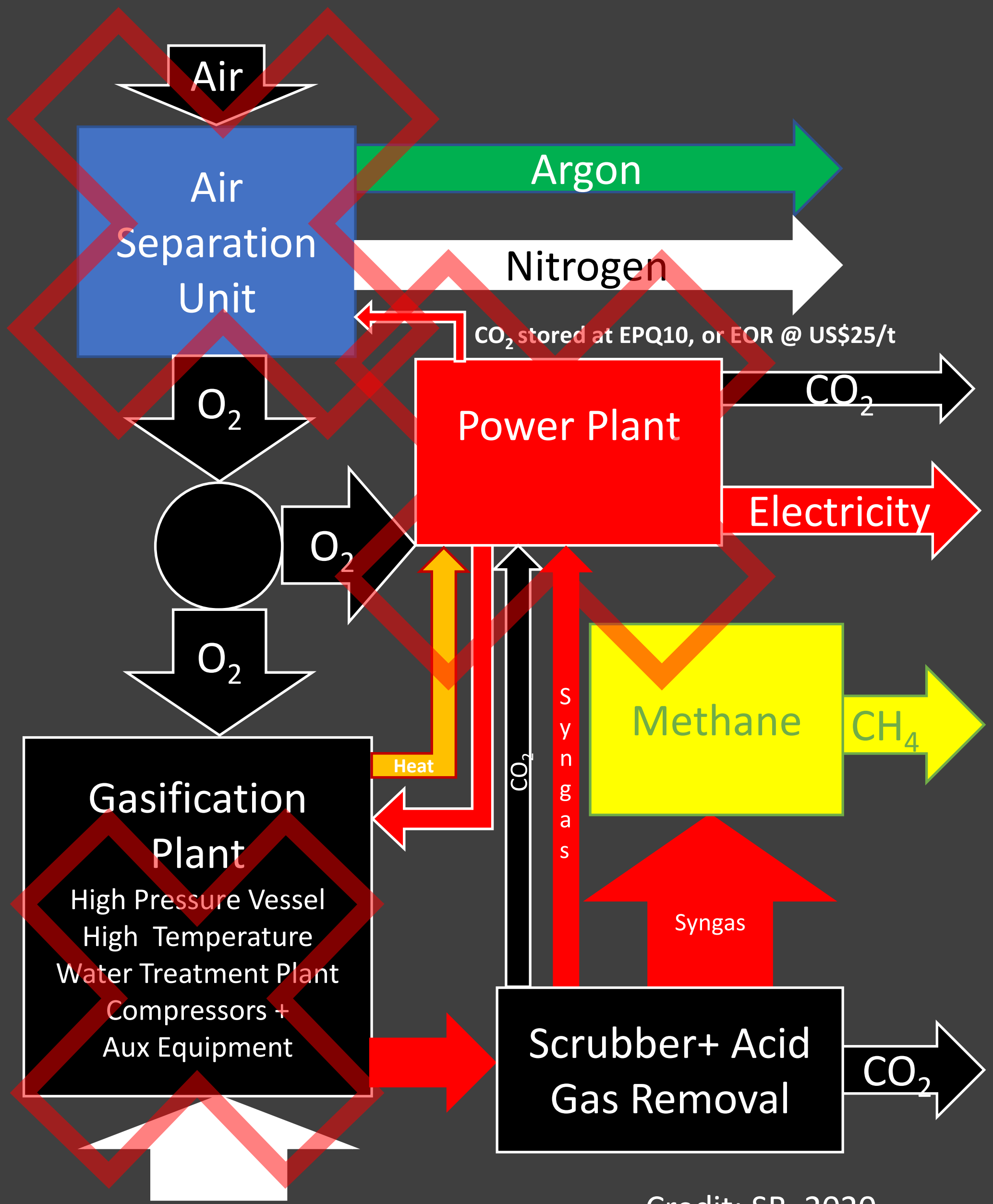
No ASU + No Power Plant + No High Pressure

Carbon Reports to Char in SEATA Plant

- Up to half infeed carbon reports to Char
- Gasification Matches Methane CO_2
- Process Efficiencies compensate for Carbon losses in Char

Chemical looping simplifies gasification

- Reduced Thermal Process Energy Losses
- No Air Separation Unit (ASU) - $$$ very high CAPEX
- No High Pressure Compressors
  - SEATA at atmospheric pressure
- No slag water quenching
  - No black water treatment plant
- No Power Units
  - Low power consumption
  - Co-generation plant unnecessary



Credit: SB, 2020

SEATA Development Pathway – Pilot to Commercial

	Pilot 1 <300 kg/h (**Clean Feeds**)	Pilot 2 <500 kg/h (**'Dirty' Feeds TBC**)	Up to 5 tph Infeed **Commercial Plant**	Up to 40 tph Infeed **Industrial Scale Plant**
Timing Targets	**Commence Q2 2022** *(SEATA R&D Centre, Glen Innes NSW)*	**Q4 2022** *(industrial site)*	Q4 **2023**	~ **2025**
Indicative Infeed *(@7,500 hrs/yr, ~85% use)*	2,250 tpa	3,750 tpa	37,500 tpa	300,000 tpa
Design Carbon Yield *(conservative @~25% yield per tonne of infeed)*	~560 tpa		Up to ~9,400 tpa	75,000 tpa *(current total Aust production <20,000 tpa)*
Indicative Drawdown Via Biochar *(using plant biomass feeds only)* *(**+ up to ~25% more if all CO_2 gas is also sunk into CCUS**)*	**~1,400t** CO_2e/yr *(assuming net ~2.5 tCO_2e per tonne of biochar after LCA)*	**~2,300t** CO_2e/yr *(biomass feeds only)*	**23,500t** CO_2e/yr *(assuming net ~2.5 tCO_2e per tonne of biochar)*	**187,500t** CO_2e/yr *(assuming net ~2.5 tCO_2e per tonne of biochar)*
Design H_2 Yield (as % of infeed)	Flared Initially*, Then 7% by mass	**7% by mass** (recovery eg via PSA)	7-10% by mass (recovery via PSA or WSR)	**10% by mass** (Recovery eg via WSR)
Design Annual H_2 Yield *(tpa, uncompressed)*	Nil initially* *(**157.5 tpa** thereafter)*	**262.5 tpa**	**2625 – 3750 tpa**	**30,000 tpa**

Context: World's largest Commercial Scale Direct Air Capture (Climeworks Project Orca, 2021) = **4,000 tpa (8x 500 tpa units)**

- Batch scale system construction and testing 2010-current (various feeds). Continuous Pilot scale system constructed/mods 2018-2022
- Estimated net production cost of hydrogen **$2-$4/kg** for commercial scale plant
- **10-15 FTE Green Jobs per plant** (pilots through to commercial, providing falling unit costs of production)
- ** "Walk before Run"* approach…Pilot 1 trial per NSW EPA *Energy from Waste Policy* – initially no energy recovery proposed. ➔ Establish data as genuine reference site for subsequent DA Mod to allow energy recovery (e.g. for hydrogen trial).
- All scenarios pending funding secured. Bankable Feasibility Studies to be completed following pilot trials, ahead of commercial plant.

Sustainable & Waste Feedstocks

- **Photosynthetic** feedstocks (plant biomass) provides drawdown via atmospheric carbon *removal*) All other carbon-based feeds are carbon–***recycling***.
- Estimated ~up to **80M tonnes /yr** of plant biomass residues that are wasted, burned insitu or landfilled in Australia (CSIRO 2017)
- **NSW Biomass Residues ~22.5 Mtpa,** of which cropping residues 12.2Mtpa dominated by cereal straws 8.41Mtpa (more info NSW DPI).
- **+ Non-competing energy crops** on **non-productive** marginal land (not viable for food crops). Potential for carbon back into poor soils to rehabilitate lost farming land
- **+ Aquatic biomass** – Fastest growing biomass on earth. Conventional thermal treatment technologies require <20% moisture (thermally pre-dried). SEATA can handle wet wastes to 70% moisture (mechanically dried) when co-fed with high calorific feeds, with the moisture increasing hydrogen recovery.

Example Sustainable / Waste Biomass Feeds	Other Problematic Waste Potential Co-Feeds	Comments
Terrestrial Biomass:	**End of Life Plastics (EOL)**	'Dirty' feeds (including EOL plastics) = industrial chars
Agricultural and Horticultural waste residues (e.g. wheat straw, Sugar Cane bagasse, cotton trash, winery wastes, nut shells etc)	**Recovered Ocean Plastics**	
Invasive Species (including INS)	**Biosolids & AD Digestates** – Municipal, Agricultural	Biosolids require high calorific co-feeds to balance moisture content. If 'dirty' feed = industrial chars
Uncontaminated Wood Waste (e.g. untreated pallets), Plantation Forestry Residues (currently trash is burned) & Source-separated Commercial and Urban Green Waste	**Organic Tailings / Coal**	
Aquatic Biomass (fresh and marine):	**Mixed Waste Organics (MWO),** **C&D Wood wastes / Treated & Engineered Timbers**	
Algae	**PFAS and Hydrocarbon Contaminated Soils, GAC & PAC**	As above for biosolids high calorific co-feed required.
Kelp (Seaweed)	**Medical Wastes** (incl **Covid 19 waste** materials)	As above. Includes residues from kelp processing.

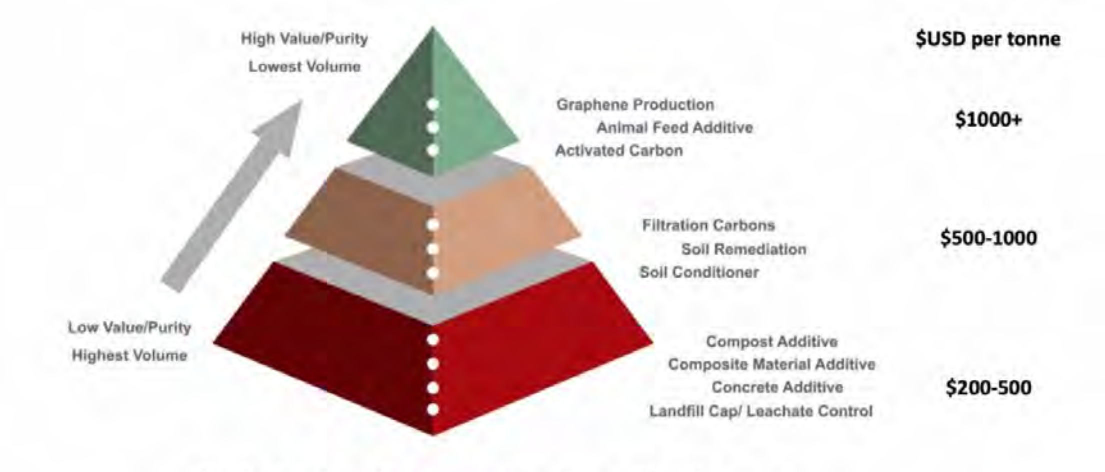
Carbon Commodity Applications - *'Horses For Courses'*

Feedstocks without significant contaminants

ANZBIG Standard (or Feed) Grade Biochar

Higher Order Use of 'clean' resource

Agricultural
Markets / Applications



Biochar's value-added streams by volume and market price.

Feedstocks not suitable for soil application (e.g. due to inorganic contaminants)

Higher Order Use of 'unclean' resource

ANZBIG Industrial Grade Biochar

Industrial
Markets / Applications

Example High Volume Applications:

- Broadacre Agriculture, Silviculture, Land / Mine Rehabilitation
- Substitute Steel Reductant (for coke)
- Amendment for Bulk Compost & Organic Fertilisers
- Feed Chars, Low Odour Animal Bedding / Litter

Example High Value Applications:

- High value Orchards/Horticulture
- Non-bulk/boutique distribution (e.g. bagged biofertilisers)
- Water filtration (cheaper substitute for activated carbon)

ANZBIG COP Grades:

1. Feed Grade
2. Standard Grade (Soils)
3. Industrial Grade

Audi AG unveils sustainable dealership model featuring carbon storing facade modules

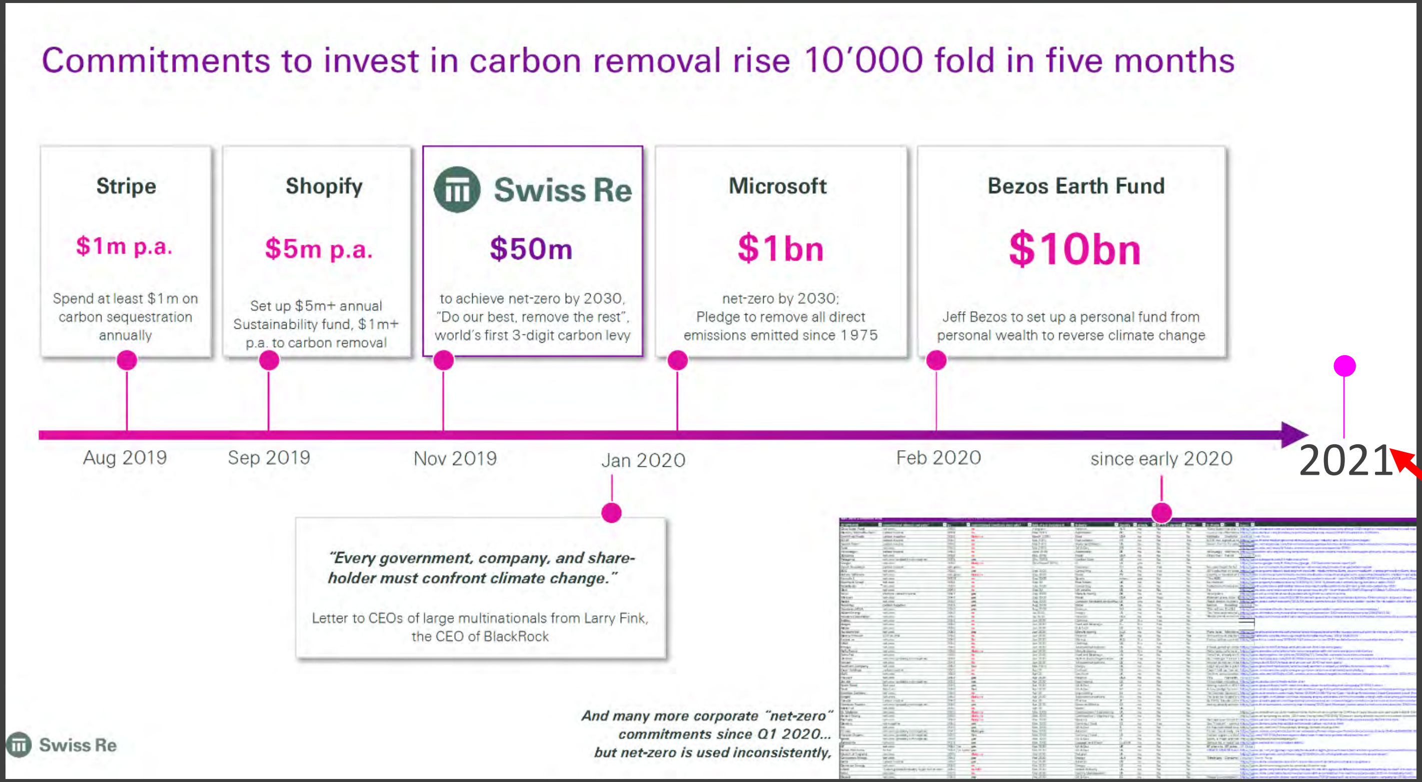
Example High Volume Applications:

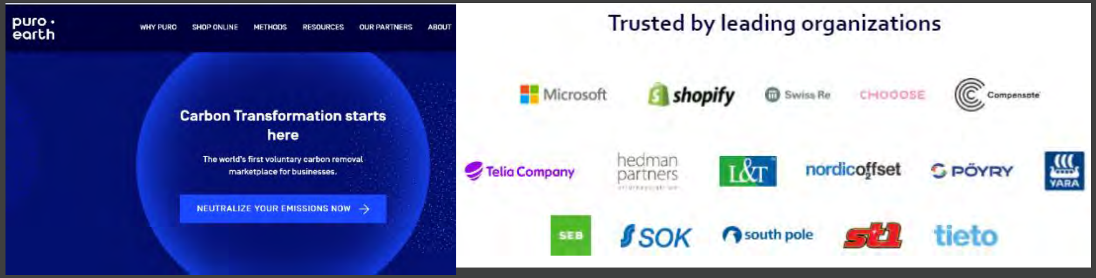
- Roads & Construction - Green Roads & Concrete/Cement
- Carbon batteries (emerging)
- Fillers in plastics

Example High Value Applications:

- Carbontech (broad range)
- Composites / Bio-plastics
- Contaminant Filtration (pseudo activated carbon)

Multi-national companies seeking to meet Net Zero are now specifically targeting biochar





More info:

- *ANZBIG 2021 Webinar Recording:* ***International Carbon Drawdown in Australia & New Zealand*** *(public access)*
- *NASDAQ press release June 2021*

Lessons Learned To Date Toward Piloting & Commercialisation

- **Collaboration is pivotal** – **Industry organisations** such as **New H2** (hydrogen) and **ANZBIG** (carbon) play important roles
- Early engagement with Regulators
- Challenges in funding new innovation
- Risk mitigation – building trust with regulators, investors, suppliers, off-takers
- Commercial scale demonstrations needed at industry level (cant easily be done by individual companies)
- **Patience**

Thankyou. Questions?

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*"During WWII no-one asked, 'Can we afford to fight the war?' We could not afford **not** to fight it. The same goes for the climate crisis."*

Joseph Stiglitz, 2019