Mersey Biochar

Carbon Negative Community Energy

PyroCore

Waste Transformed.

A Bristol Based Engineering and Technology company

MOD Contractor

We support 4 units on the Royal Navy’s Queen Elizabeth Class aircraft carriers (pictured right)

We own a demonstration facility in the UK with 3 pyrolysis machines

2 Commerical UK installations booked for 2024

MERSEY BIOCHAR PROJECT

The UK's first carbon negative energy system

Funded by BEIS

Carbon neutral feedstock

Creating neutral energy

Heat utilised in three ways:

1. **District heating**
2. **Data Centre cooling**
3. **Peak loading electricity**

Around 1,000 tonnes of Biochar created per year.

3,000 tons of carbon credits.

Not a *carbon removal concept* but a *community carbon negative flexible heat and power concept*

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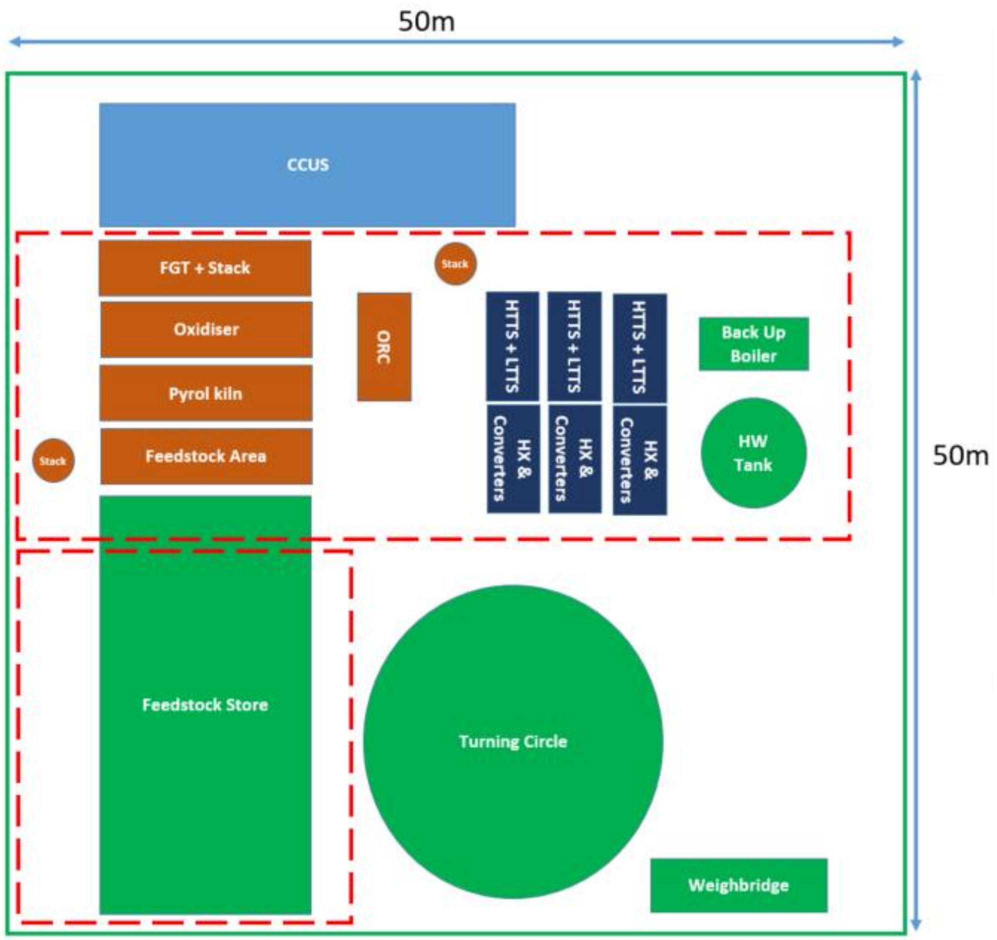
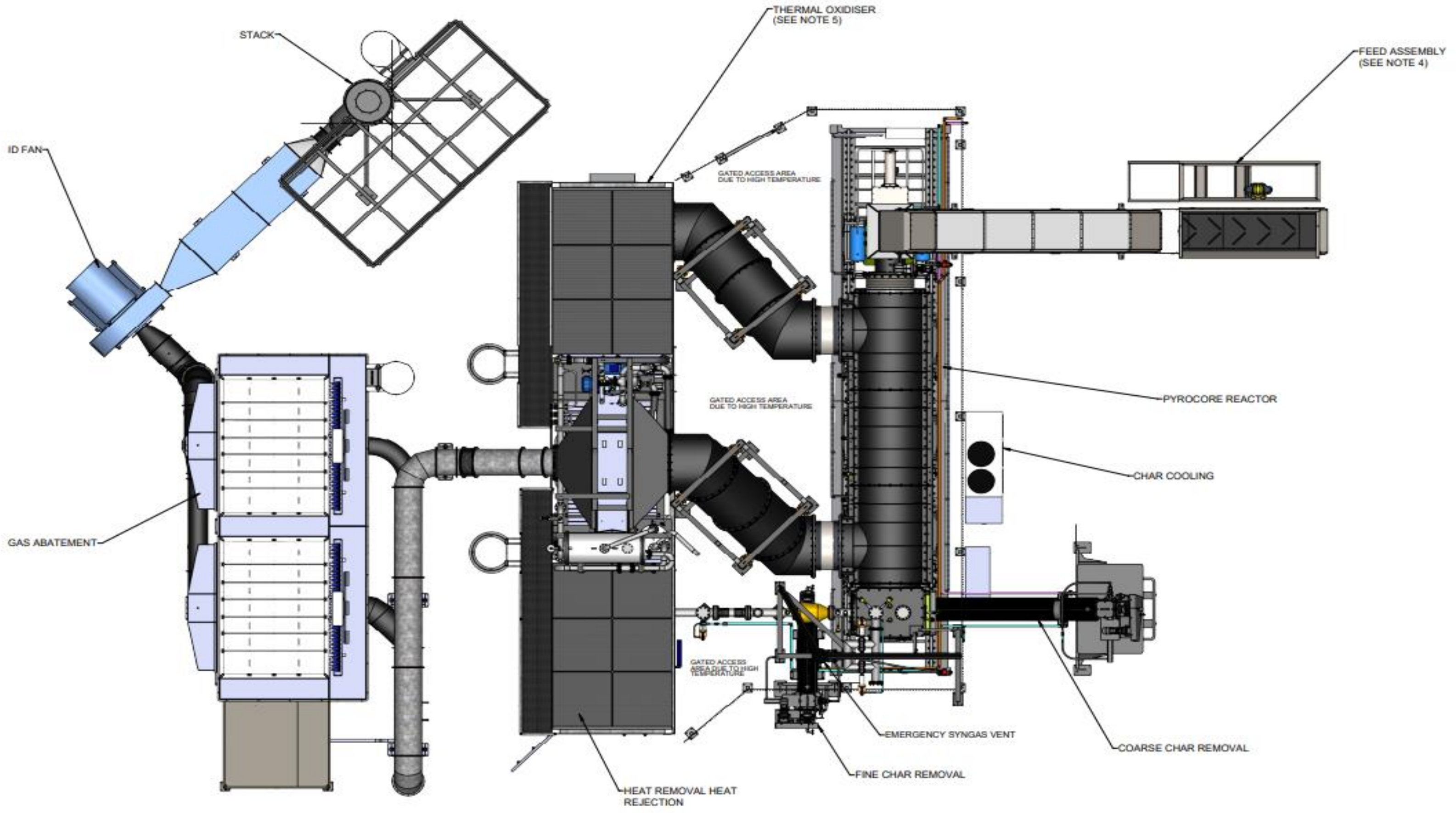
Host Site

Installation starting in Q2 2024



PyroCore

Standard layout



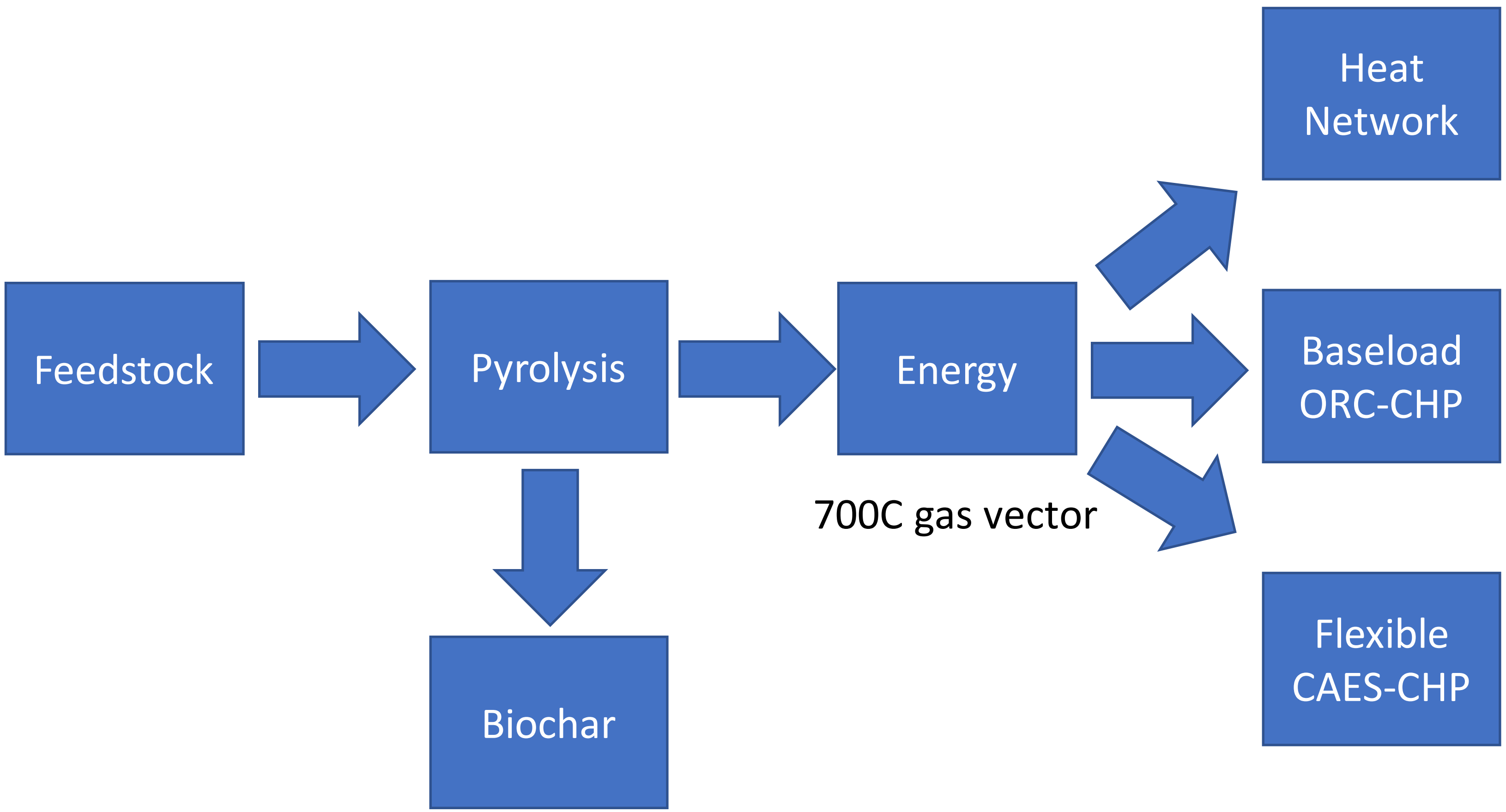
NOTES:

1 - THE PLANT SHOWN HERE IS THE STANDARD PRODUCT AND IS TO BE LOCATED OUTSIDE EXCEPT THE FEED HOPPER WHICH SHOULD BE LOCATED INSIDE A BUILDING.
2 - ELECTRICAL CONTROL PANEL / CONTAINER IS NOT SHOWN IN THIS DRAWING. THE CONTROL PANEL MUST BE LOCATED IN A SAFE AREA (NON-HAZARDOUS) WITHIN A BUILDING WITH SUITABLE CLIMATE CONTROL.
3 - COMPRESSED AIR AND NITROGEN GENERATION PACKAGE IS NOT PART OF THE STANDARD PRODUCT BUT IS REQUIRED FOR THIS PLANT, THESE PACKAGES CAN BE LOCATED INDOORS OR OUTDOORS.
4 - THE FEED ASSEMBLY SHOWN IS THE STANDARD PRODUCT VERSION AND IS NOT SUITABLE FOR MEDICAL WASTE.
5 - THE THERMAL OXIDISER SHOWN IS THE STANDARD PRODUCT VERSION AND IS NOT SUITABLE FOR MEDICAL WASTE.
6 - A SITE SPECIFIC LAYOUT CAN BE PRODUCED ONCE SITE LOCATION IS DEFINED AND PLANNING AND PERMITTING HAVE BEEN AGREED.

Pyrocore are modifying our core technology for Mersey Biochar project

- Optimising for biomass
- Up-scaled 500 kg/h feedstock / 140kg/h biochar
- Reduced size emissions abatement
- Reduced size oxidizer
- Removal of IED compliance
- Designing interfaces to novel heat offtakes

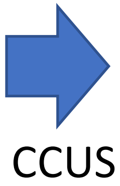
Technology: Energy



Heat Network
- Proven technology with pyrolysis
- Thermodynamically wasteful
- Operationally Challenging
- Not financially viable

Baseload ORC-CHP
- Novel technology with pyrolysis
- Thermodynamic improvement
- Operationally Challenging
- Marginally viable in 2020s

Flexible CAES-CHP
- Novel technology
- Thermodynamically ideal
- Operationally flexible
- Optimal economic solution towards 2030s



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Feedstock Strategy: Overview

We are developing a flexible, stable and long term feedstock strategy that will maximise local benefits and enable scaling UK wide.

Feedstock Flexibility – designed to be feedstock flexible across the range of identified sources. This ensures our procurement can fit into a range of contexts and encourage biodiversity where land use change occurs.

Local Secure & Stable Procurement – secure, stable and price certain feedstock supply through

- New contract model (lease or contract grow) diversification value propositions to landowners
- New land acquisition models for transferring land into trust

Maximising Local Benefit & Job Creation – local procurement means local value retention, providing new revenue streams to local natural capital

Feedstock Strategy: Sources

Our sources of feedstock will include both by-product from local woodland and from energy cropping. We have identified 4 categories that are being tested

Woodland Creation & Management Creation of new permanent woodland/bringing existing woodland into management	Energy Cropping Land use change of vacant and marginal land to energy crop cultivation

• Maximises - biodiversity gain, woodland & habitat creation
• Improves natural capital, flood alleviation
• Contributes to nature based sinks target
• Species - broadleaf species
• Yield – between 3-10 t/ha/yr
• Procurement – local woodland organisations, councils, utilities etc
	• Maximises - yield
	• Facilitates agricultural diversification
	• Species/Yield
	    • Miscanthus – up to 14 t/ha/yr
	    • Willow (SRC) – 6 – 14 14 t/ha/yr
	    • Eucalyptus (SRF) - 8-30 t/ha/yr

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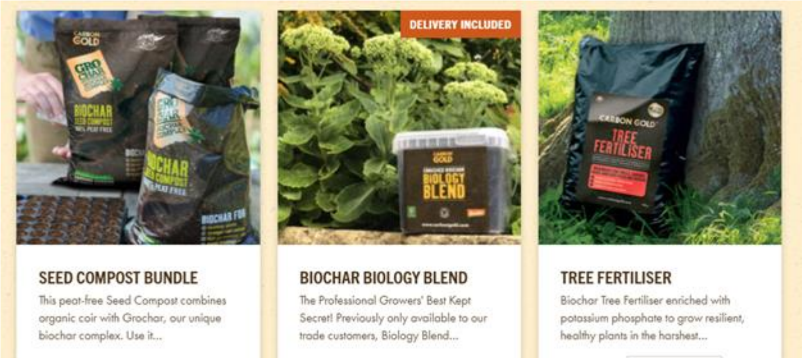
Char Characteristics & Uses

- Agriculture, Forestry & Horticulture
  - Slurry additive
  - Animal feed additive
  - Biofertiliser- EU Organic Fertiliser Regulations
  - Soil additive/amendment
  - Boosting biogas yields in AD
  - Growing substrate



Source: https://www.carbongold.com/

- Industry & Building
  - Odour control/filters
  - WWT
  - Tarmac/Cement additive
  - Metal production
  - Bio materials research

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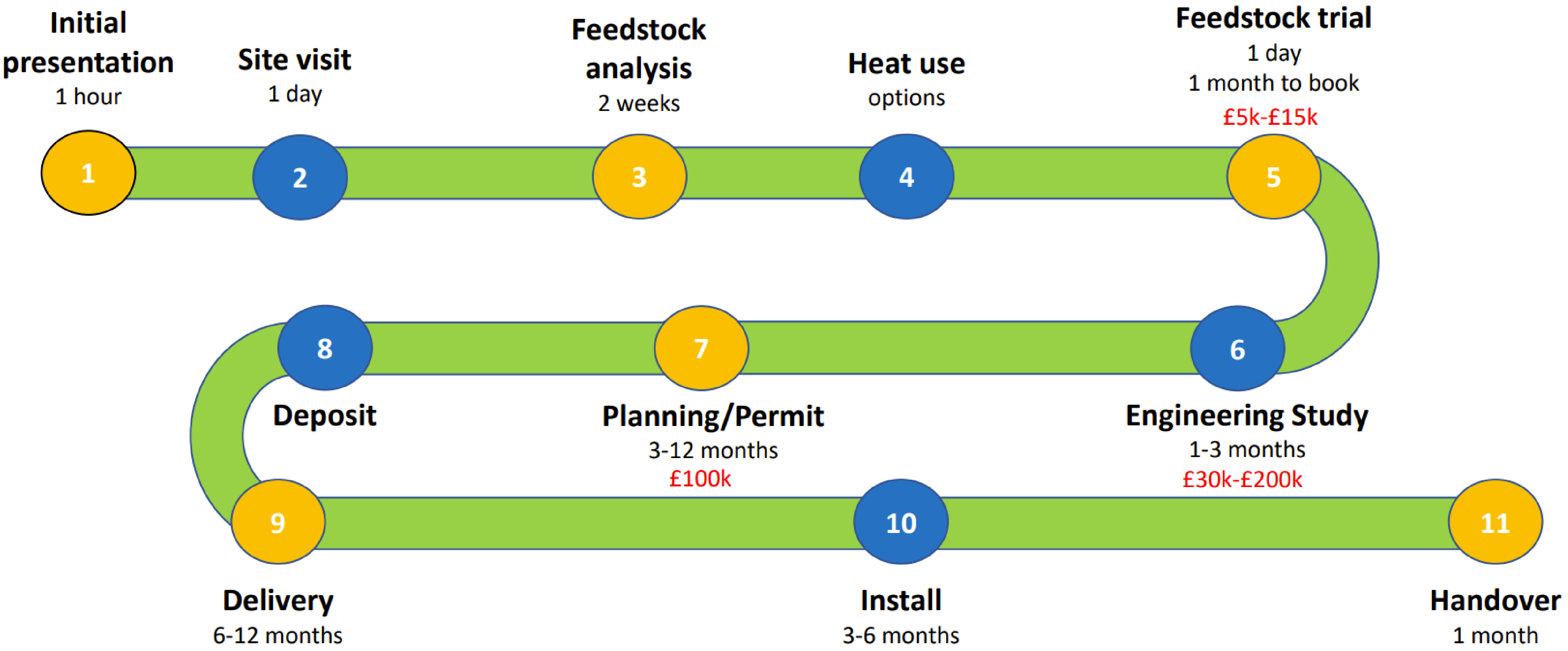
Initial presentation
1 hour
1
Site visit
1 day
2
Feedstock analysis
2 weeks
3
Heat use
options
4
Feedstock trial
1 day
1 month to book
£5k-£15k
5
6
Engineering Study
1-3 months
£30k-£200k
7
Planning/Permit
3-12 months
£100k
8
Deposit
9
Delivery
6-12 months
10
Install
3-6 months
11
Handover
1 month

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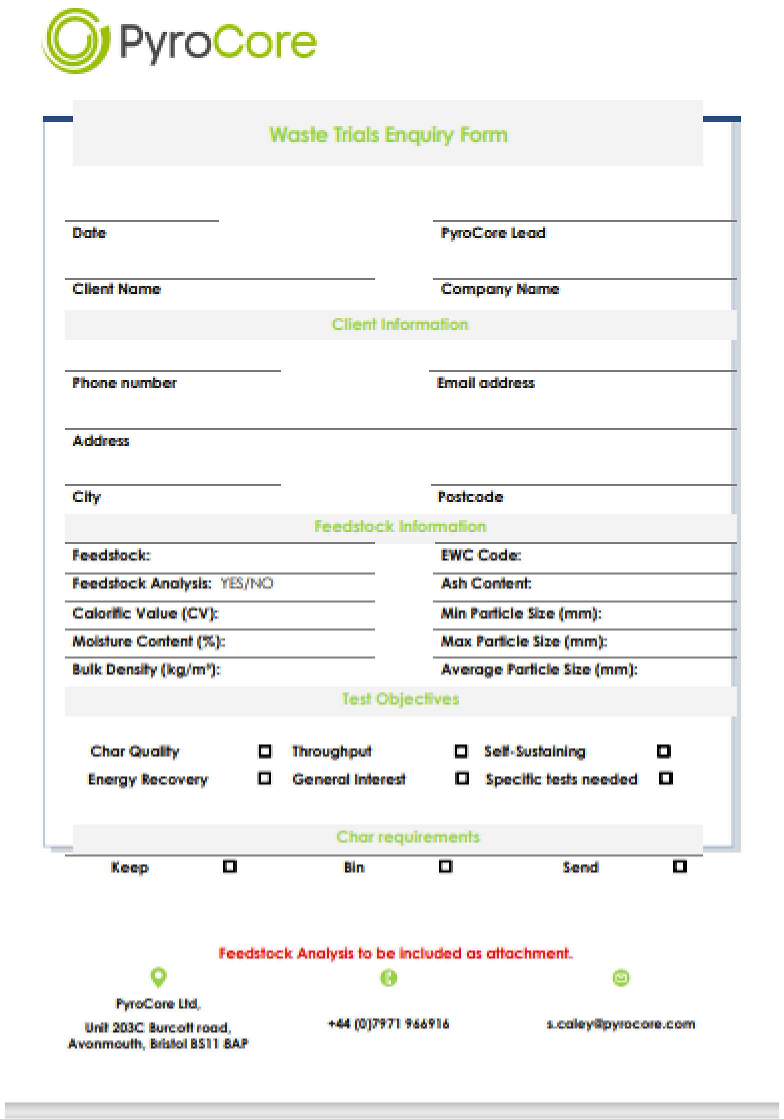
Feedstock Trail

- Chemical analysis of the feedstock
- 50 mil fraction size
- 20% moisture content
- 1-2 day trail
- Provides accurate information
- Heat mass balance
- Emissions data
- Syngas analysis
- Biochar analysed



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Waste Trials Enquiry Form

Date

PyroCore Lead

Client Name

Company Name

Client Information

Phone number

Email address

Address

City

Postcode

Feedstock Information

Feedstock:	EWC Code:
Feedstock Analysis: YES/NO	Ash Content:
Calorific Value (CV):	Min Particle Size (mm):
Moisture Content (%):	Max Particle Size (mm):
Bulk Density (kg/m³):	Average Particle Size (mm):

Test Objectives

- [ ] Char Quality
- [ ] Throughput
- [ ] Self-Sustaining
- [ ] Energy Recovery
- [ ] General Interest
- [ ] Specific tests needed

Char requirements

- [ ] Keep
- [ ] Bin
- [ ] Send

Feedstock Analysis to be included as attachment.

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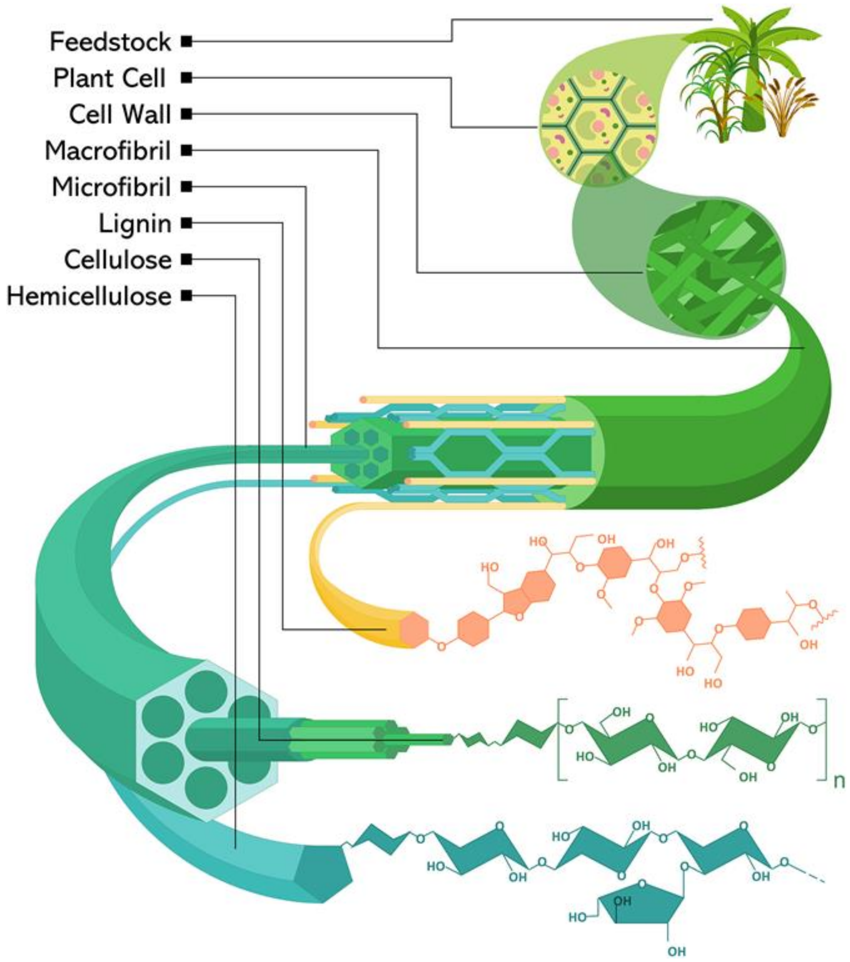
Avonmouth, Bristol BS11 8AP

+44 (0)7971 966916

s.caley@pyrocore.com

Performance & Char Testing



Source: Magalhães *et al*. 2019

Testing Classes

- EBC-Feed
- EBC-AgroBio
- EBC-Agro
- EBC-Material

Testing Parameters

- Elemental Analysis (C-total, Corg, H, N, O, S, ash)
- Physical Parameters (Water content, dry matter (DM), bulk density (TS), specific surface area (BET), pH, salt content
- Nutrients(N, P, K, Mg, Ca)
- Heavy Metals (Pb, Cd, Cu, Ni, Hg, Zn, Cr, As)
- Organic Contaminants (PAHs, PCB, PCDD/F, Benzo, Pyren)

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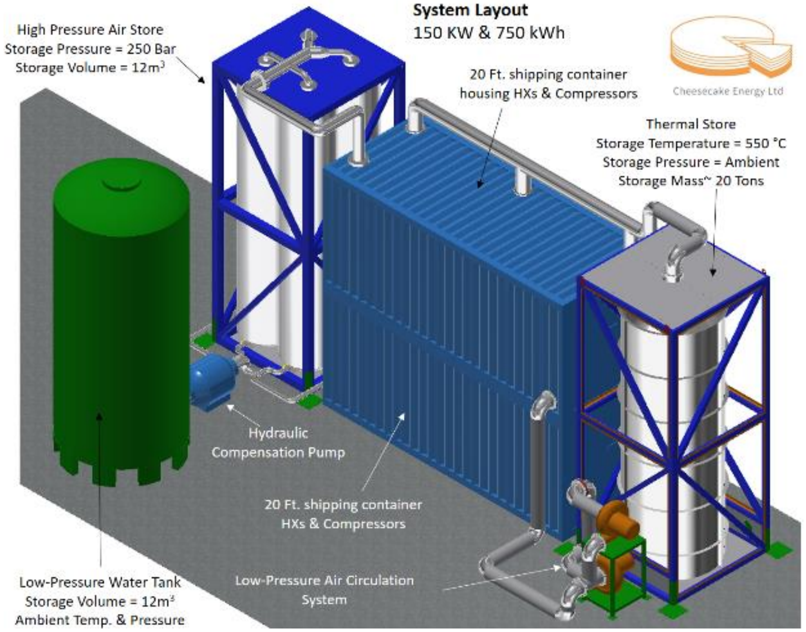
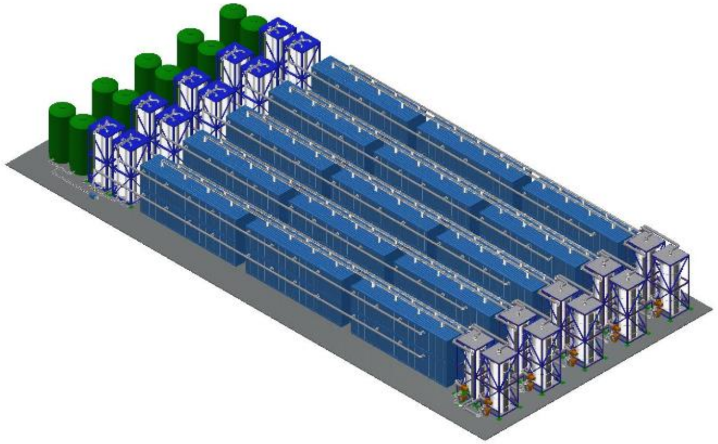
Mersey Biochar

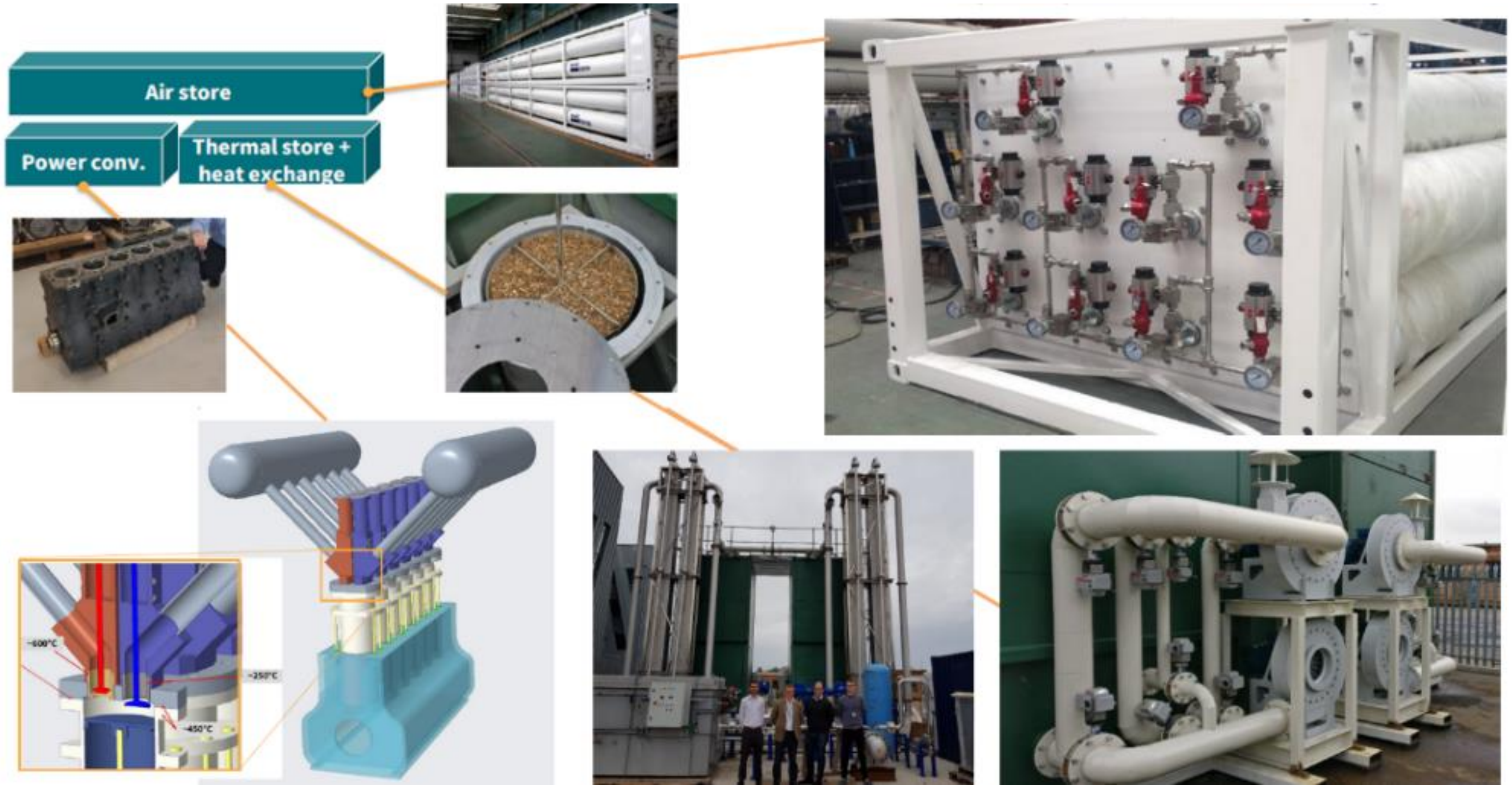
Carbon Negative Community Energy

Stand P50

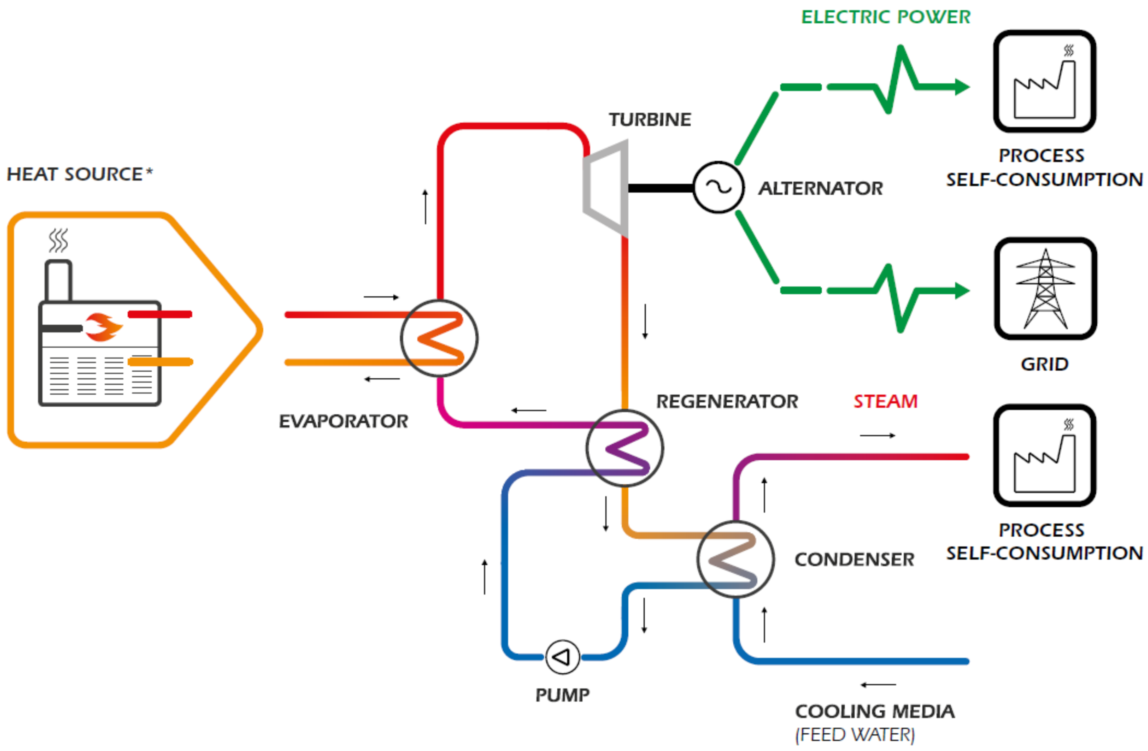
Technology: CAES-CHP



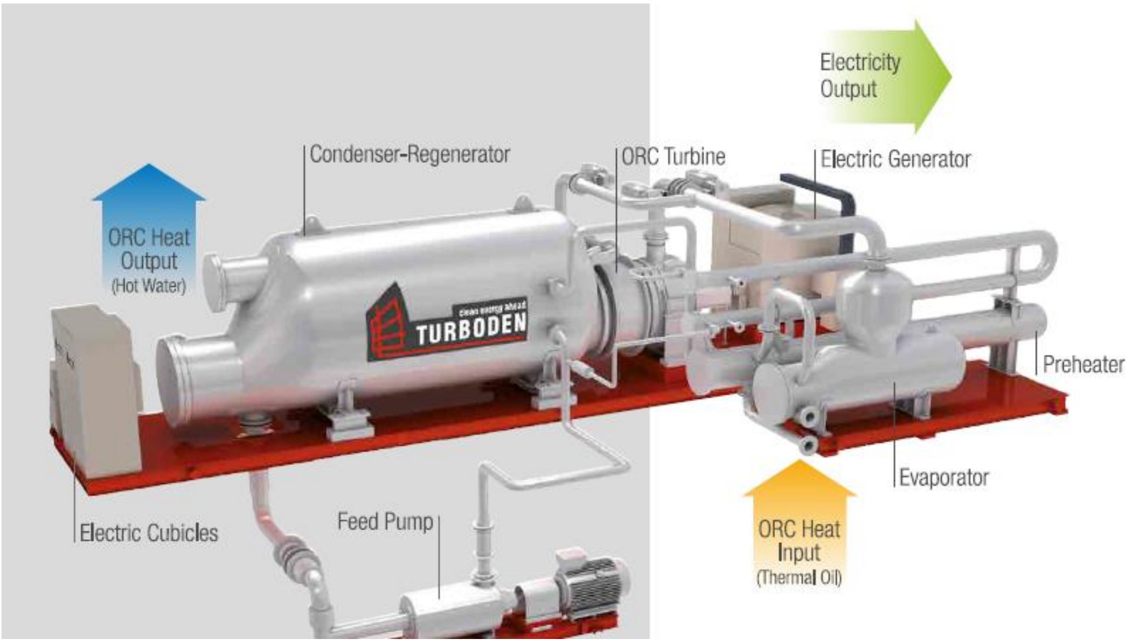




Technology: ORC-CHP



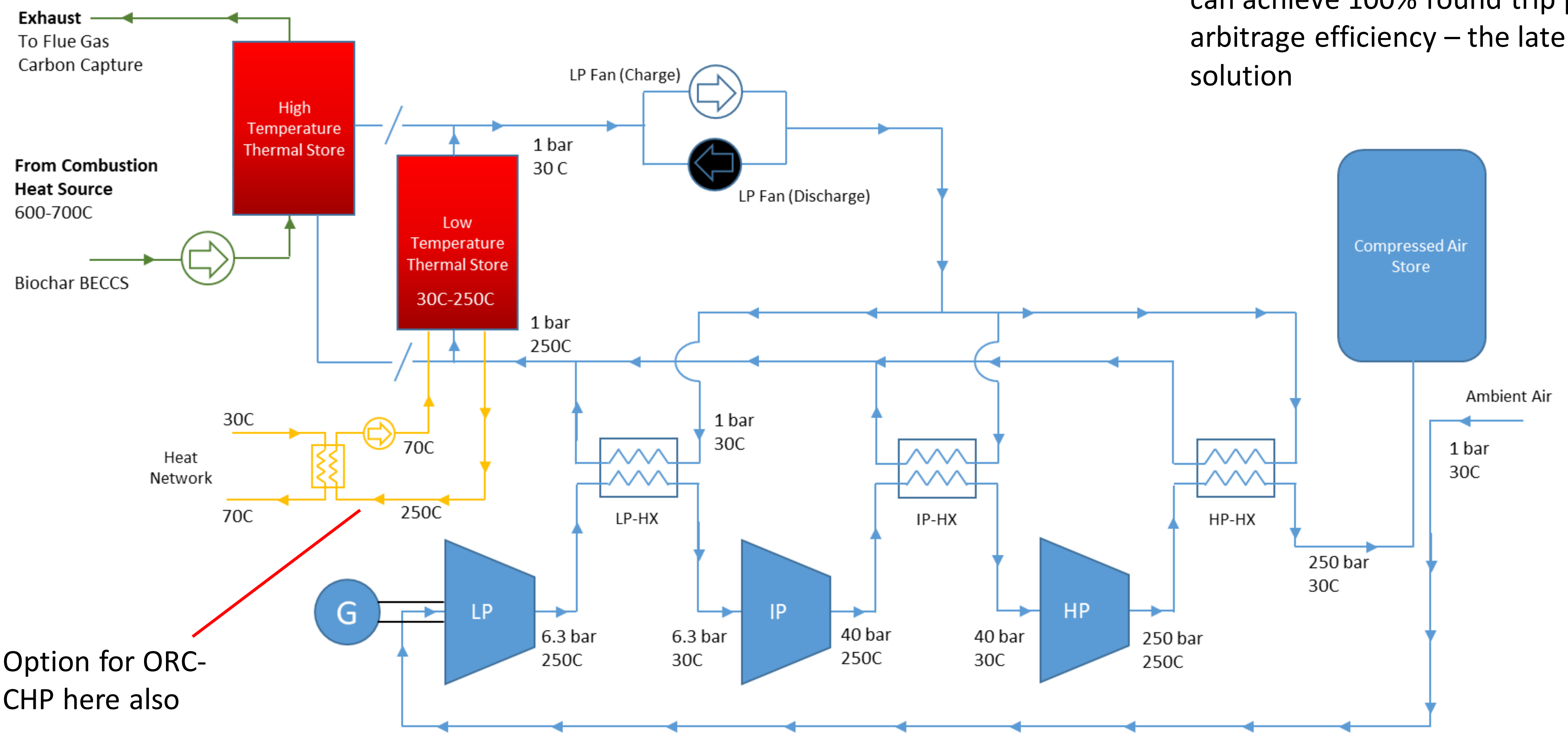
Technology is viable today and can be deployed reliably – but is very high CAPEX and performance is relatively poor



Around 15-20% electrical efficiency base load generator – the early **2020s solution**

Technology: CAES-CHP

Thermal Compressed Air Energy Storage can achieve 100% round trip power arbitrage efficiency – the late 2020s solution



Option for ORC-CHP here also

Technology: CCUS

Element Energy completing study into CCUS pathways for flue emission. We have filtered to 3 preferred pathways

1) Mineralisation to aggregates
2) CCU synthetic fuels
3) CCS geological sequestration

	pilot	2030 horizon			
CO_2 Disposal Pathways	Initial deployment (Merseyside)	Industrial cluster	Nearby industrial site	Urban	Rural off-gas
Release to Atmosphere (do nothing)	✓	✓	✓	✓	✓
Geological Sequestration	✓requires CO_2 transport (e.g. truck)	✓	✓may require road CO_2 transport	✖	✖
Aggregates & Waste Processing (via mineralisation)	✓ dependent on waste availability	✓ dependent on waste availability	✓dependent on waste availability	✖ only if local waste resource available	✓ only if local waste resource available
Polymers, Polyols & Foams (via catalytic reaction with higher chemicals)	✓ possible local user - Econic	✓	✓	✖ possible H&S and planning issues	✖ possible H&S issues, limited relevance
Algae / Algal Products (via algae growth)	✖ unclear developer interest, lower TRL	✓ if space available, residual heat could also benefit algae growth	✓ if space available, residual heat could also benefit algae growth	✖ land availability may be an issue	✓
Methanol (via catalytic reaction with H_2)	✖ dependent upon hydrogen availability	✓ if hydrogen available (likely)	✓ if hydrogen available (maybe)	✖ due to scale and potential toxicity of methanol	✖ due to reduced hydrogen availability
Synthetic Fuels (via F-T synthesis)	✖ lower TRL, scale	✓ if hydrogen available (likely)	✓ if hydrogen available (maybe)	✖ due to scale and H&S issues	✖ due to reduced hydrogen availability
Sale of CO_2 (e.g. greenhouses, concrete curing*)	✖ not aware of any nearby demand	✓ dependent on demand	✓ dependent on demand	✖ as local demand unlikely, transport needed	✓ possible e.g. if greenhouses exist in the area

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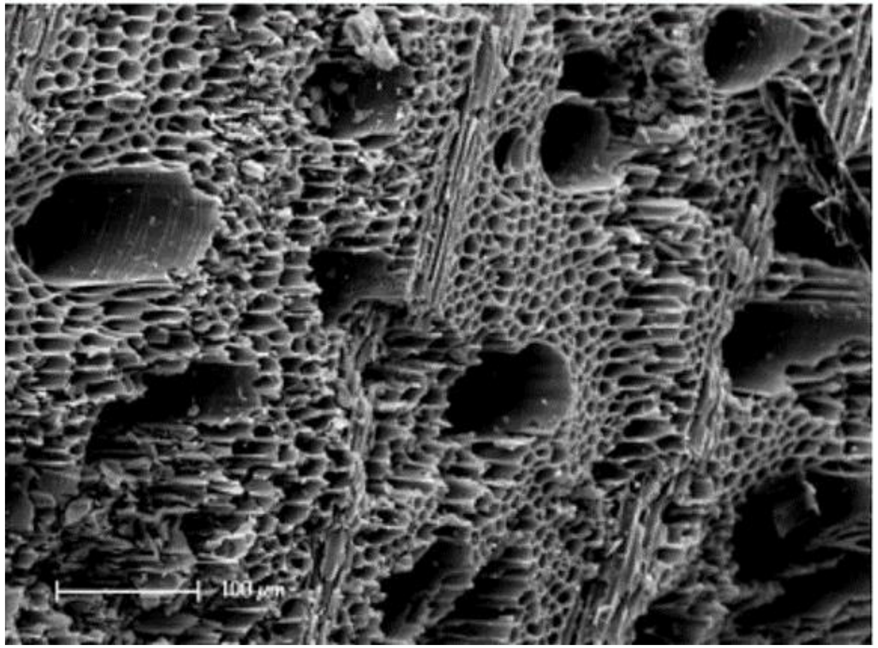
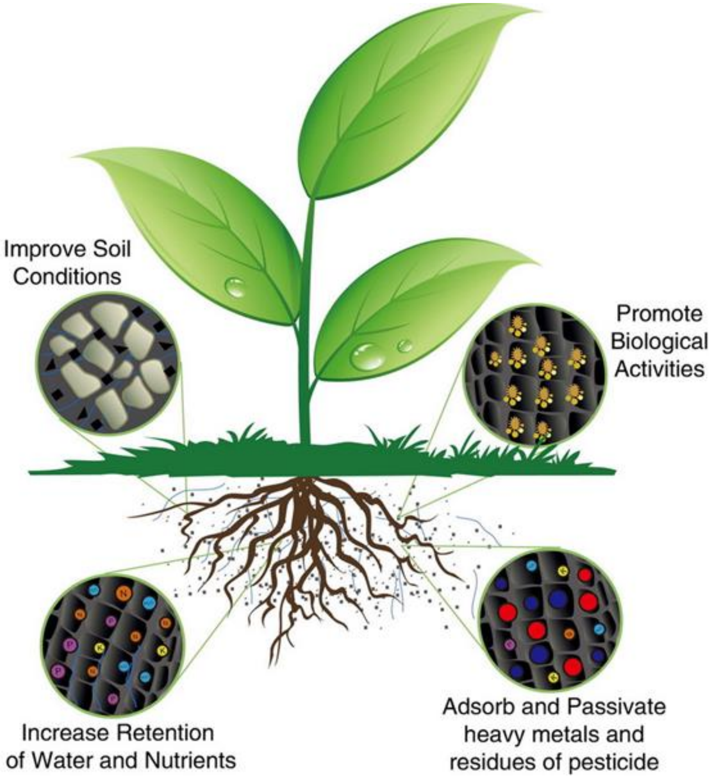
Char Characteristics & Uses





Source: http://www.seekfertilizer.com/

- Porous- Large surface area
- Cation exchange capacity (CEC)
- Can sequester carbon

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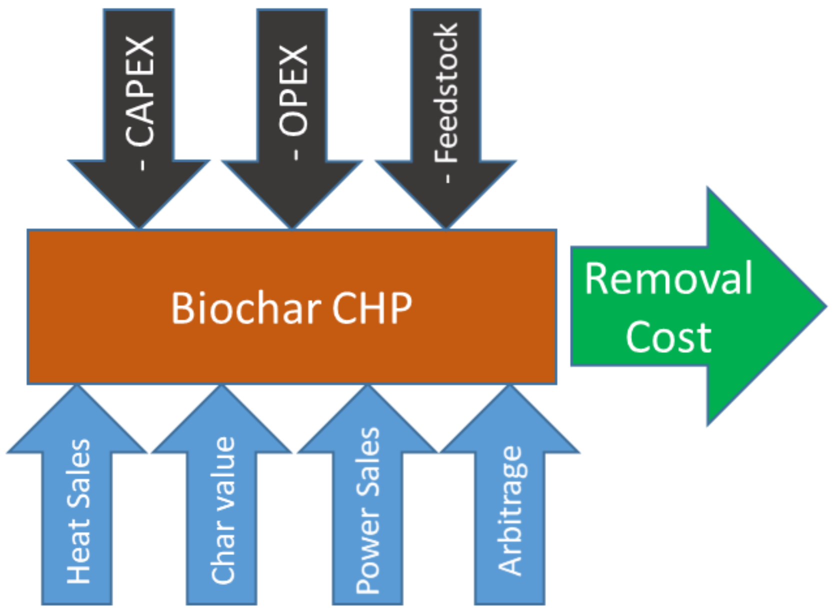
Commercialisation: Removal Cost

		2022	2030s
Carbon Removal Price:	£/tonne	£90	£50
Total Revenue	£	£23,319,326	£23,827,121
Carbon Removal Revenue:	£	£5,138,444	£2,854,691
Heat Revenue	£	£6,962,627	£7,689,226
Power Export Revenue:	£	£30,085	£25,865
Peaking Power Revenue:	£	£248,861	£274,897
Char Revenue:	£	£2,197,776	£884,493
Arbitrage Revenue:	£	£8,990,393	£12,372,846
Inertia Revenue:	£	£0	£0
Total Revenue Annual avg	£/yr	£932,773	£953,085
Pre-Tax IRR:	%	4.57%	12.07%
Post-Tax IRR:	%	2.98%	10.00%



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Commercialisation: Economic Modelling

Figure 14: Modelled capture prices for wind and solar power (2018 money)

Source: Cornwall Insight

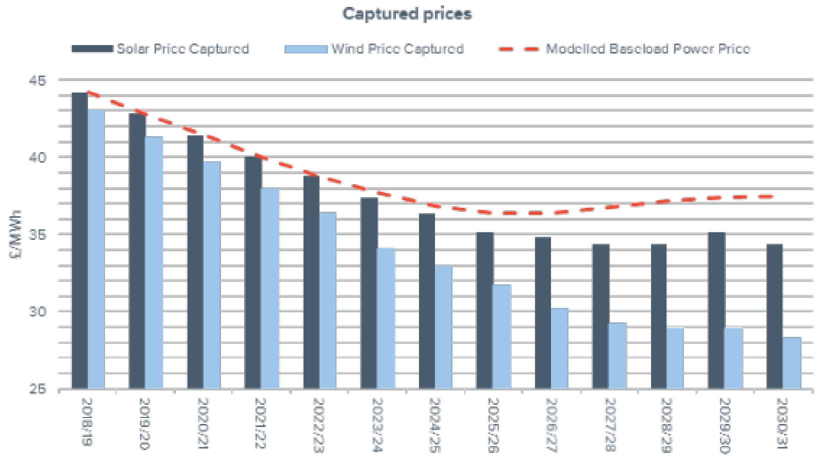
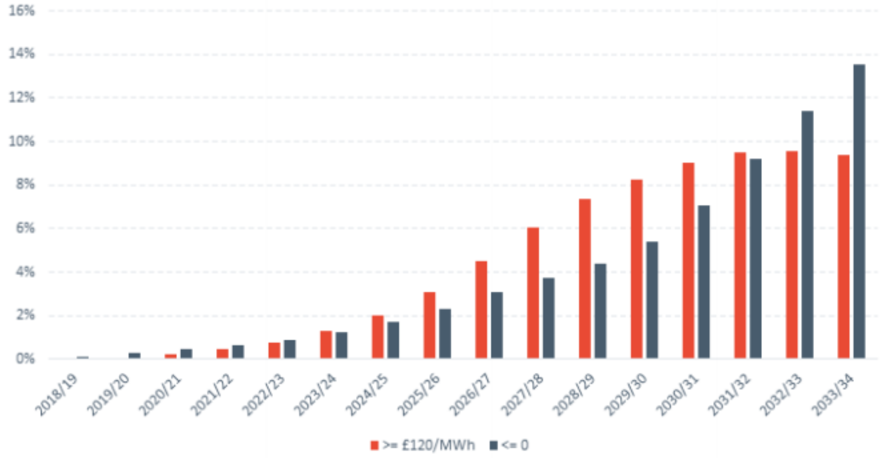
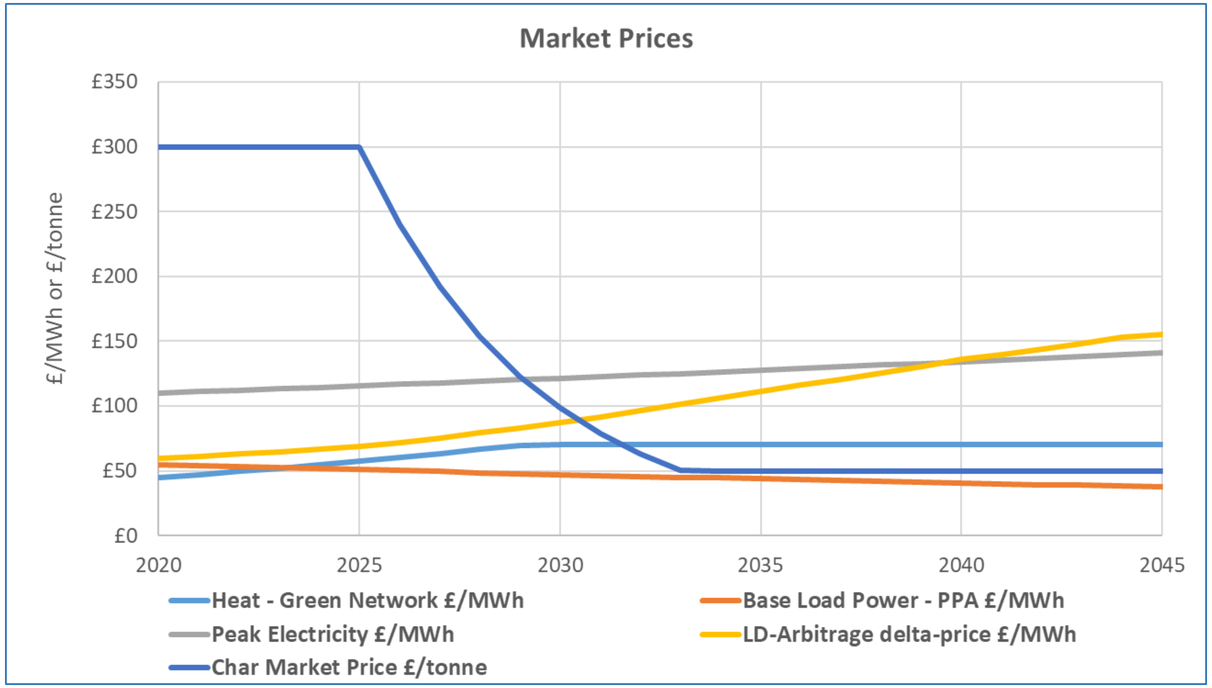
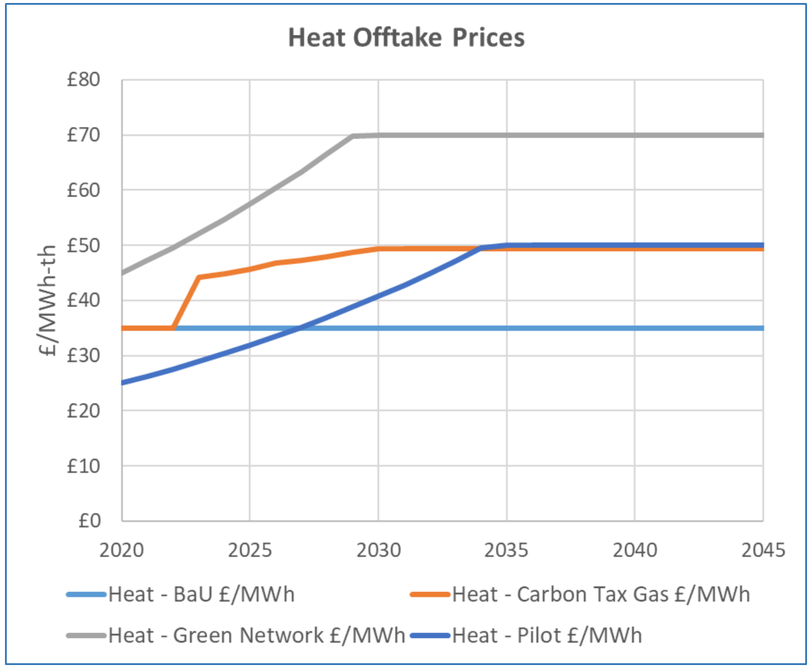


Figure 12: Annual frequency of <=£0/MWh & >=£120/MWh price periods 2018 through 2034

Source: Cornwall Insight





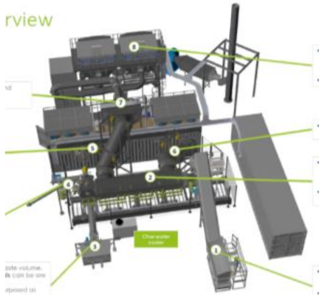


Commercialisation: Scaling to 50ktpa 2030

Small community sites – biochar removal only

Table updated from report

Pyrolysis Modules	Feedstock		Zero Carbon Energy	CO_2e Removal			Sites Required for 50 ktpa CO_2	
No	tpa	hecares*	GWh/yr	Char only - tpa	in CCS - tpa	Char + CCS - tpa	Char Only	Char + CCS
1	3,866	276	11.36	2,318	4,600	6,918	21.6	7.2
2	7,732	552	22.72	4,636	9,199	13,835	10.8	3.6
3	11,597	828	34.07	6,954	13,799	20,753	7.2	2.4
4	15,463	1,105	45.43	9,272	18,398	27,670	5.4	1.8
5	19,329	1,381	56.79	11,590	22,998	34,588	4.3	1.4
*@ 14t/ha/yr								



= 1 x module

Larger industrial sites – biochar + CCS removal (or CCU)
Challenge of heat sales, more likely industrial

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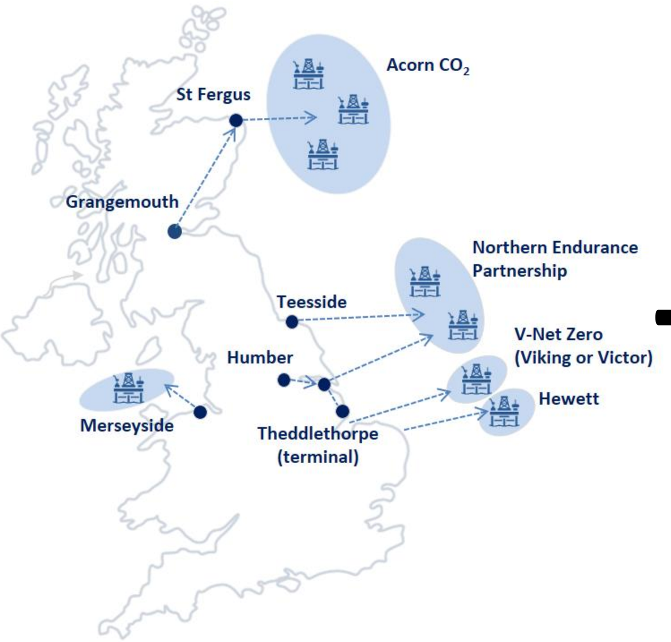
Commercialisation: Scaling to 50ktpa 2030 - Mapping

GIS Mapping exercise to identify market potential. Good locations for sites and for planting

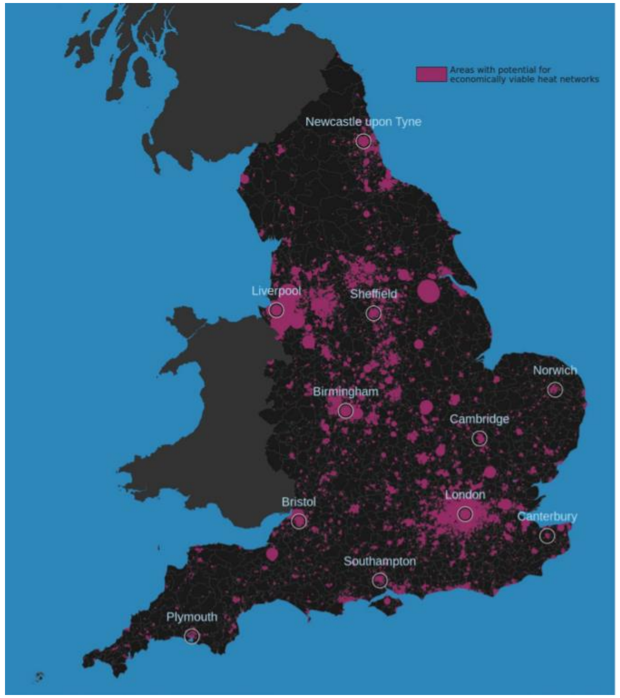


CCUS Infrastructure (large sites)

+

Energy Crop & Woodland Potential

+



Heat Network Opportunity Areas (small & large sites)

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Project Management: Budget & Time

	May				Jun				Jul				Aug					Sep				Oct				Nov					Dec				Jan		
Week Ending	09/05/2021	16/05/2021	23/05/2021	30/05/2021	06/06/2021	13/06/2021	20/06/2021	27/06/2021	04/07/2021	11/07/2021	18/07/2021	25/07/2021	01/08/2021	08/08/2021	15/08/2021	22/08/2021	29/08/2021	05/09/2021	12/09/2021	19/09/2021	26/09/2021	03/10/2021	10/10/2021	17/10/2021	24/10/2021	31/10/2021	07/11/2021	14/11/2021	21/11/2021	28/11/2021	05/12/2021	12/12/2021	19/12/2021	26/12/2021	02/01/2022	09/01/2022	16/01/2022
Pyrolysis process design and modelling.																																					
Power generation feasibility.																																					
Heat network feasibility and design.																																					
Pyrolysis trials & biochar tests																																					
Carbon Capture Technology assessment.																																					
Site location study.																																					
Planning and permitting overview.																																					
Site visits.																																					
Biochar market study.																																					
Negative emissions market study.																																					
Feedstock and co-benefits study																																					
Life cycle analysis.																																					
Financial Modelling																																					
Draft report																																					
Financial reporting and claims.																																					
Reporting to BEIS Monitoring Officer.																																					
Dissemination.																																					
Final report.																																					
Partner management																																					

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Project Management: Principal Risks

Phase 1 Risks

- **Time** - Completion of certain delayed work packages (CCUS Study & Heat Network) for incorporation to final report
- **Site Identification** - Firming up the viability of our preferred demonstrator site

Phase 2 Risks

- **Planning** – gaining planning permission at preferred site. Public perception risks, projects with stacks that are related to incineration always get attention
- **Interface Risk** – between pyrolysis and novel heat storage technology
- **Biochar Uses & Value** – uncertain future uses and value and regulation of application.

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Summary

Despite delayed start all work packages under way and well progressed

The preferred project concept is identified

The financial modelling is well advanced and supports a £50-£100/tonne outcome

We have expanded the scope with new GIS mapping and widening the CCUS study

Project budget is as per the application

Phase 2 budget is still TBC

Feedstock and biochar testing under way

Feedstock strategy is taking shape

Host site is identified and site visit due soon

Thank you for listening

Q&A

Heat Network Data

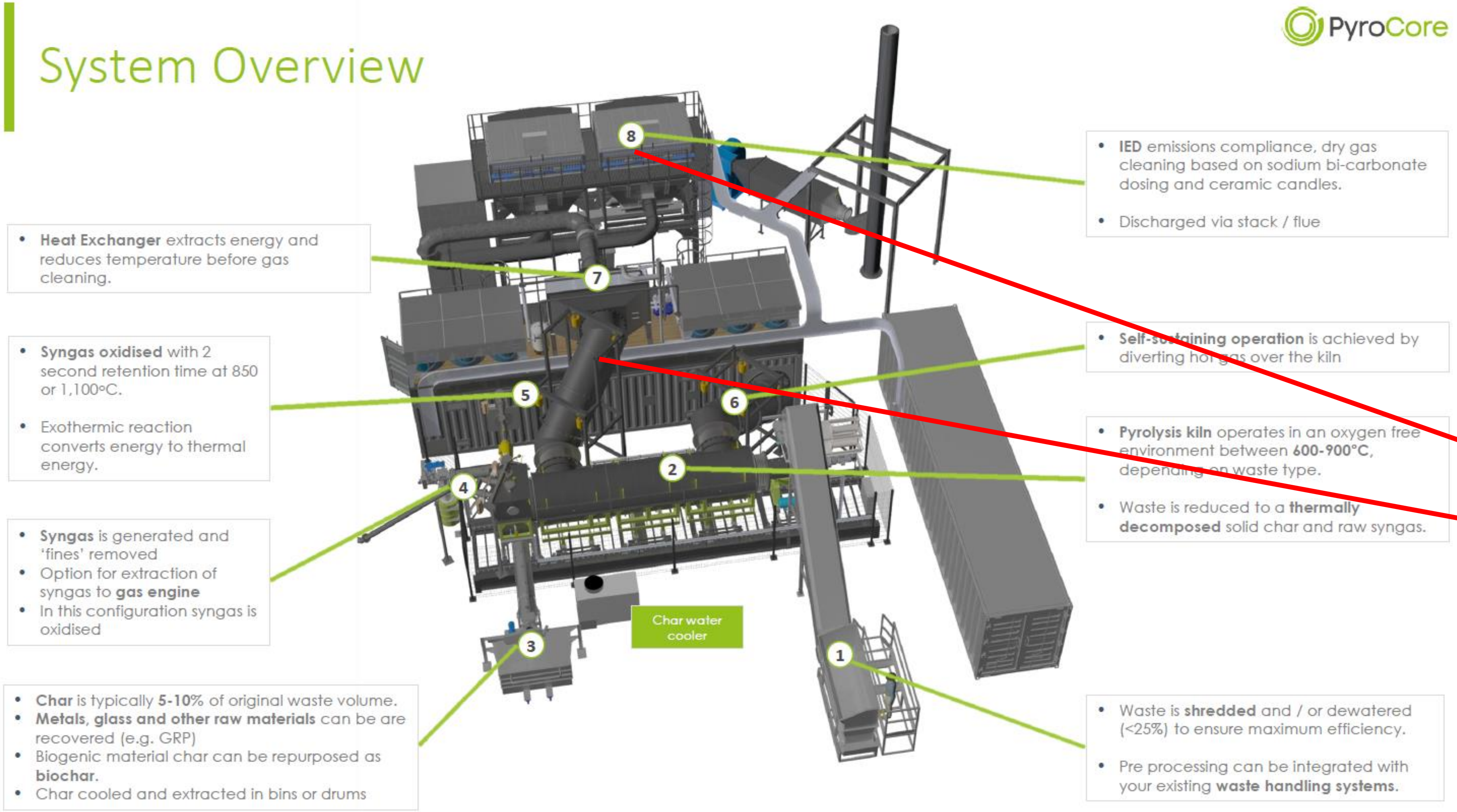
Project Consortium

- **Severn Wye Energy Agency** – community energy charity
- **Pure Leapfrog** - not for profit climate energy & innovation
- **PyroCore** – Pyrolysis technology supplier
- **Mersey Forest (s/c)** – community woodland organisation
- **Stobart Forestry (s/c)** – forestry and logistics
- **Vital Energy (s/c) –** heat network, energy centre & general contractor
- **Element Energy (s/c)** – CCUS consultancy
- **The Environment Partnership (TEP) (s/c)** – GIS mapping

Project Stakeholders

- **Cheesecake Energy (Nottingham University)** – CAES technology developer
- **Terravista** – miscanthus innovation and supply (feedstock innovation programme)
- **Rickerby Estates** – willow SRC innovation & supply (feedstock innovation programme)
- **Wildwood Fuels** – eucalyptus and SRF pioneers
- **United Utilities** – water utility / potential site host

Technology: Pyrolysis



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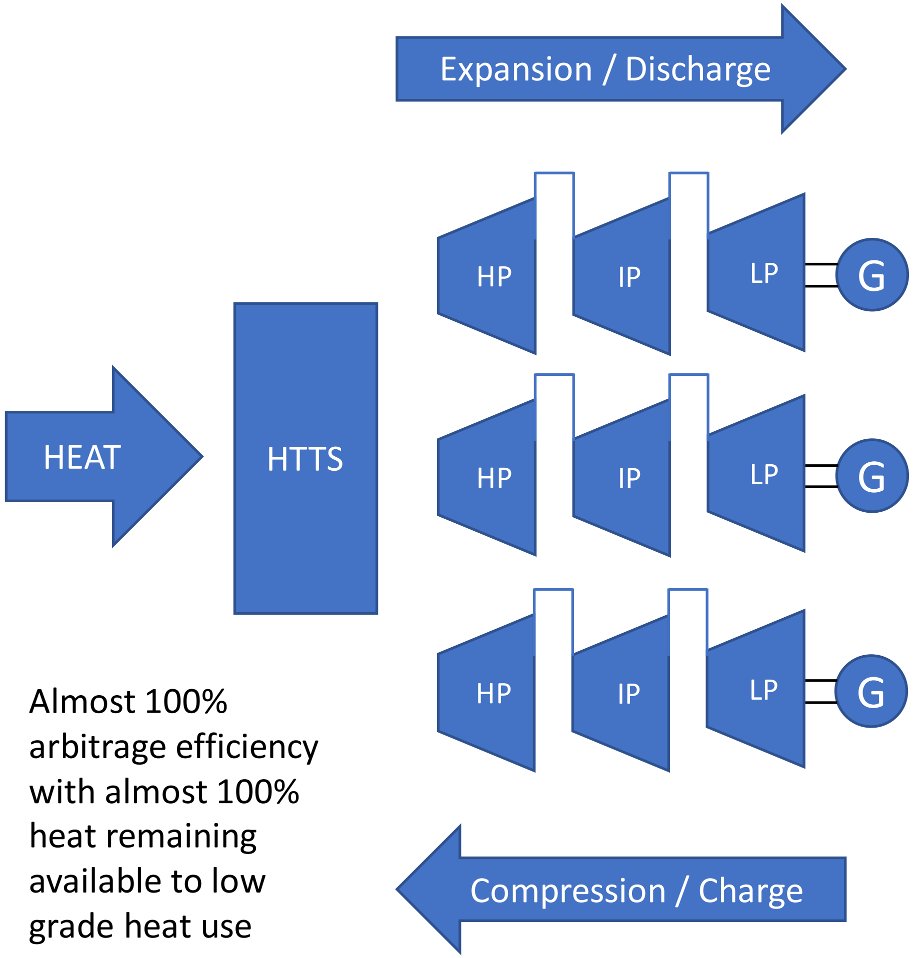
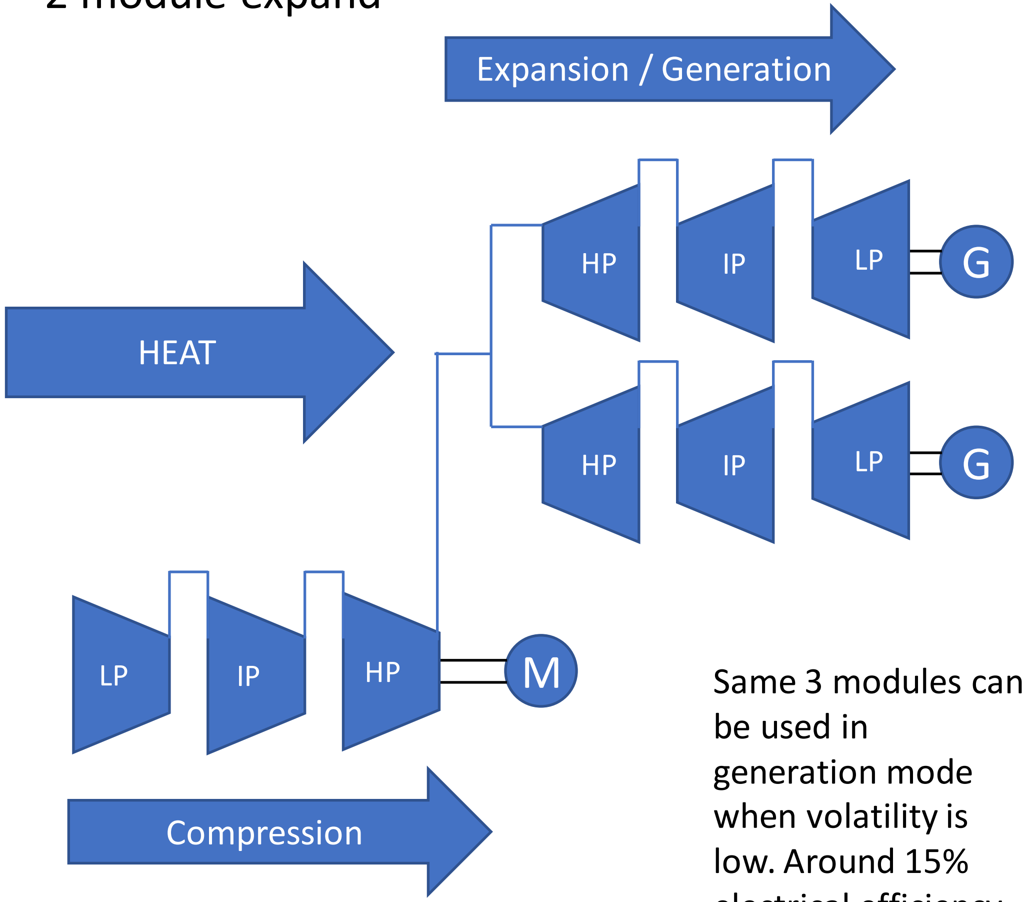
Technology: CAES-CHP

Power Arbitrage Mode – 3 module charge/discharge



Almost 100% arbitrage efficiency with almost 100% heat remaining available to low grade heat use

Power Generation Mode – 1 module compress/ 2 module expand



Same 3 modules can be used in generation mode when volatility is low. Around 15% electrical efficiency

Pilot: Cost and Build

We will aim to demonstrate the technical and commercial viability of pyrolysis ORC-CHP today (the 2020s solution) and the technical viability of pyrolysis CAES-CHP for tomorrow (the 2030s solution)

- **Pyrolysis Plant** – 1 x 500kg/h module modified and optimised for pure biomass/biochar operation
- **Organic Rankine Cycle CHP** – high efficiency oil circuit ORC sized at 150 – 300 kWe
- **Compressed Air Energy Storage** – a novel thermal CAES system to enable high temperature thermal storage and use optimisation sized to 450kWe / 2.25 MWhe
- **Onsite Drying & Storage** - automated storage and loading system
- **Heat Network Offtake** – offtake infrastructure to connect to local heat demand
- **CCUS** – there is uncertainty around what CCUS technology we will test for the pilot
- **COST** – We project CAPEX costs at around £4.5million. OPEX TBC