Recent advances in gasification for waste-to-fuel applications

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Today's Waste – Tomorrow's Resource
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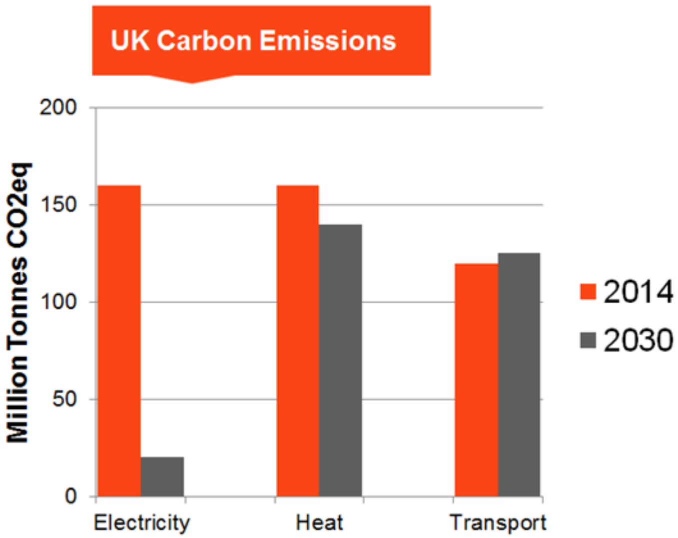
The UK Fuel Networks role in a 2050 whole energy system



'2050 Energy Scenarios The UK Gas Networks role in a 2050 whole energy system' KPMG (2016)
'Future of Gas' National Grid (2016)

- ✓ We need low carbon, secure and affordable solutions for heat and transport (HGV, Aviation, Shipping)
- ✓ In its recent report, the CCC acknowledged that the UK has made good progress decarbonising the power sector, but '*almost no progress in the rest of the economy*'
- ✓ Sustainable drop-in fuels provide the lowest cost pathways to decarbonised heat and transport using existing infrastructure
- ✓ Feedstock should be cheap, abundant and not compete with land for food production

Renewable Gas – Practical Decarbonisation

World Class Gas Grid

Delivering heat now and transport fuel for the future

Low Cost Non-disruptive Low Carbon Heat

5th C. budget requires 17.5MtCO_{2e} savings by ≈80TWh of fossil gas replacement by 2030

Heat pumps are expensive and disruptive for consumers & require substantial electricity network reinforcement

Low Carbon HGV Transport

5th C. budget requires 10MtCO_{2e} savings from HGV sector

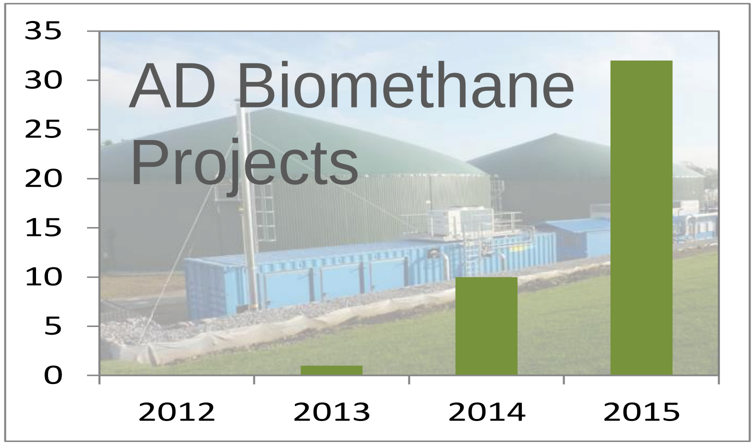
HGVs Emit over 20% of transport emissions with very limited other low carbon solutions

Pathway to deeper savings

High quality CO_2 captured in process

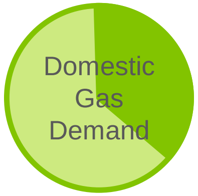
Low cost capture of biogenic CO_2 delivers negative emissions. Route to hydrogen.

Renewable Gas – Practical Decarbonisation



- Anaerobic Digestion: important role, but limited by feedstock type & availability

- BioSNG offers the potential to exploit a much wider range of feedstocks



The BioSNG process

Feedstock → **Syngas Production & Conditioning** → **Methanation** → **Refining**

The evolution towards BioSNG

Dakota

The largest SNG facility in the world, with 3GWth input capacity (producing ~200,000 Nm3/hr CH_4), fuelled by lignite. Gasifiers: Lurgi Dry Ash with Rectisol gas cleaning. Has Carbon capture fitted.

GobiGas

Fuel: Wood pellets. Indirect gasifier. Phase 1: 32MWth input, Technology: Repotec

Edmonton

Fuel: MSW. Steam-Oxy gasifier. Scale: 100k tonns/year input, Technology: Enerkem

- Waste-to-Alcohols
- Biomass-to-Gas
- Power to Gas
- Coke oven gas (CO_2 meth.)
- Coal-to-Gas
- Methanation for gas cleaning (Ammonia synthesis, Hydrogen production, PEM fuel cells, etc.)

1902 Sabatier

1910 Haber-Bosch patent

1925 Fischer-Tropsche

1950

1973 Oil crises

2000

2014

2018 Waste pilot

The evolution towards BioSNG

FEEDSTOCK

- The UK's dominant biomass resource is waste derived.
- Globally no BioSNG projects using waste feedstock

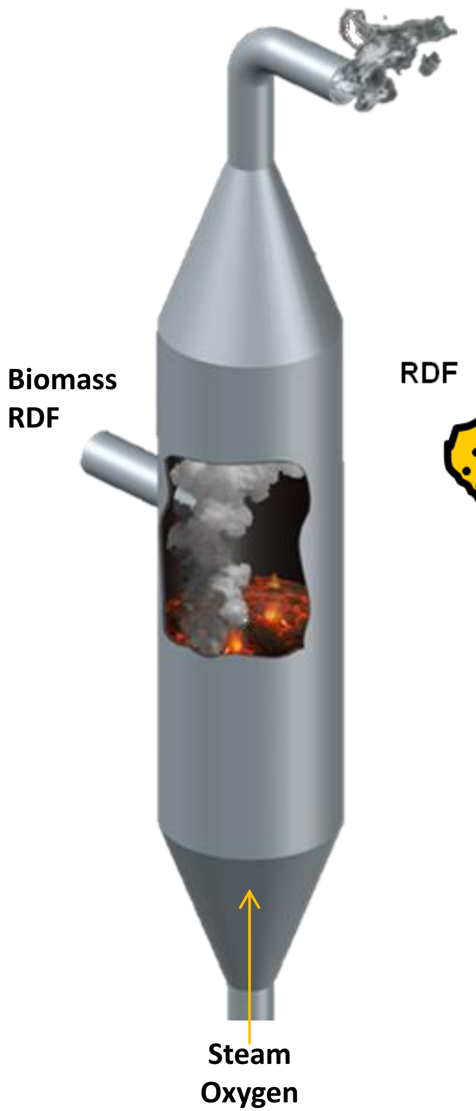
TECHNICAL CHALLENGES

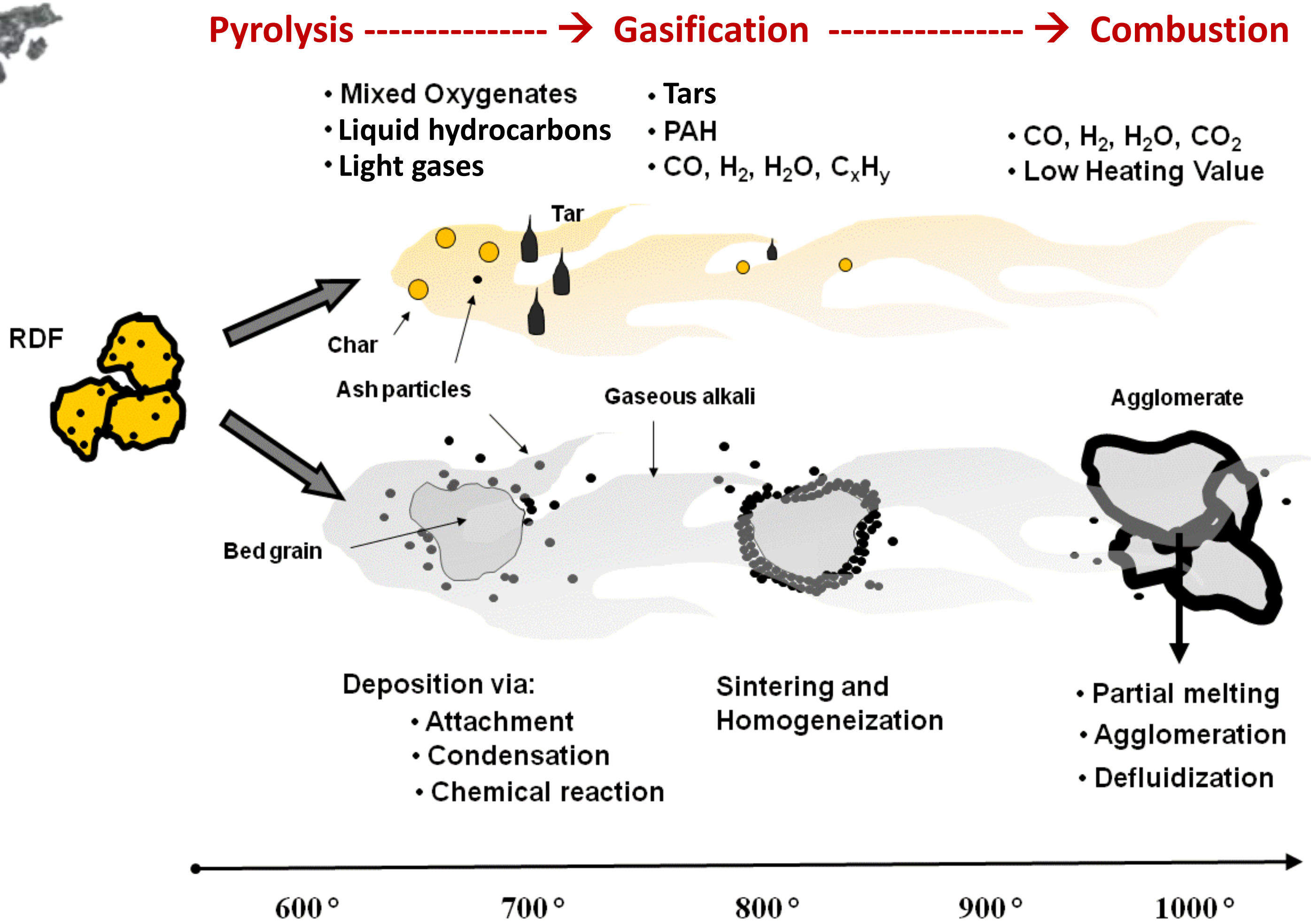
– **Heterogeneous feedstock** (size and composition)
– **Sensitivity to ash content** (quantity and composition)
– **Tar yield**
– Provision of **clean, high quality synthesis gas**
– Gas cleaning and Catalytic transformation at **moderate scale**, implicit in renewable resources

DEVELOPMENT PATHWAY

– The technical approach needs piloting and sustained operation
– R&D efforts on new technologies

The gasification step





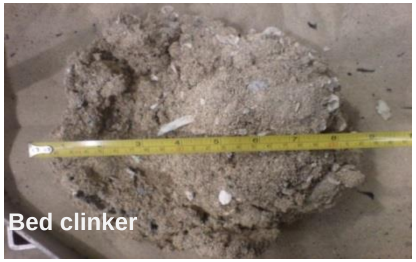
The gasification step

- Gasification by oxygen and steam
- Suited to non-homogeneous feedstocks
- Readily scalable
- No need for fuel pellettization/torrefaction
- Typically operate at 700-850ºC

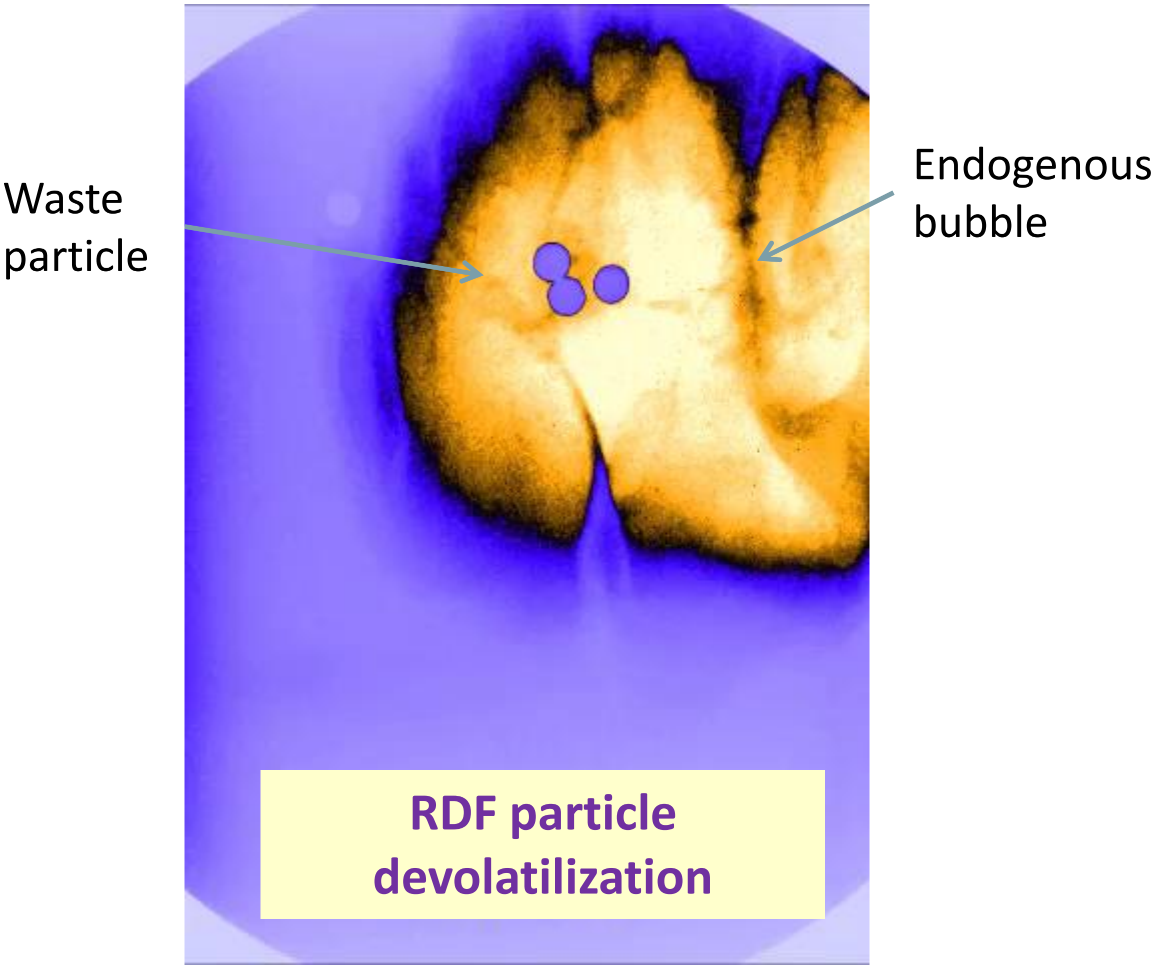
Ravenna (Italy) 200t/day RDF Fluidised Bed Plant

Challenges with operation on waste

- Agglomeration risk (defluidization)
- > 100-10,000 mg/Nm^3 tar content
- > 5-10 g/m^3 VOC, $C_{<6}H_x$
- > 5-10 ppmv organic sulphur
- Increase rates of ash deposition in the ducts and on heat transfer surfaces

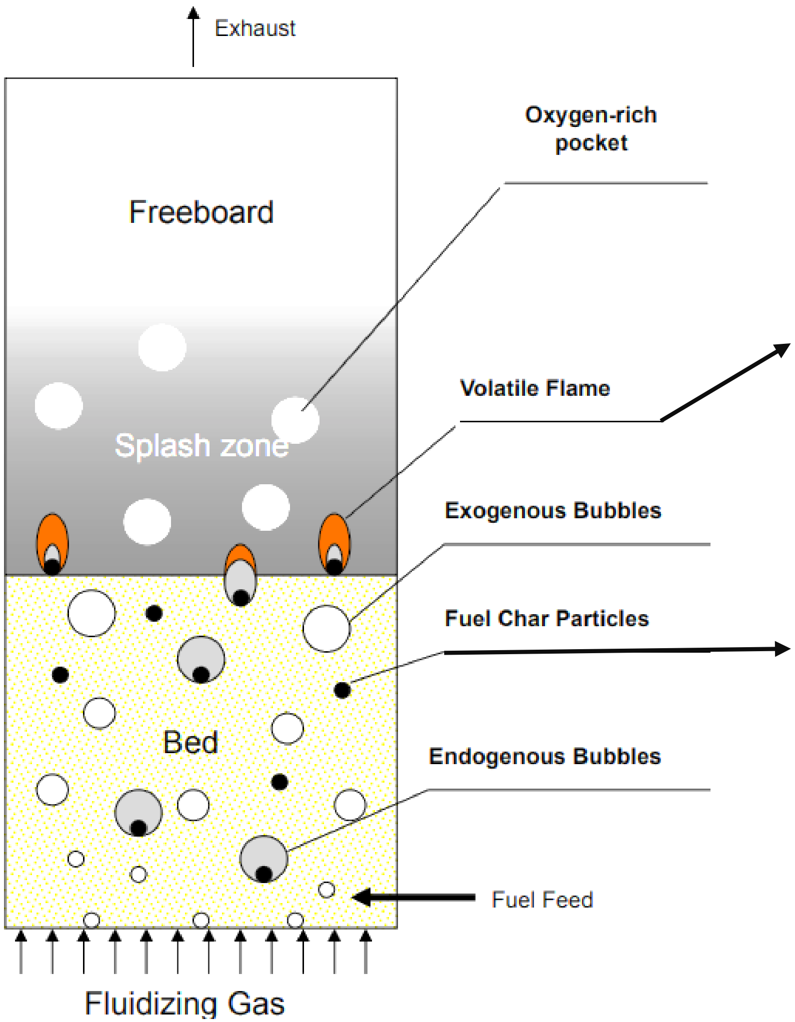


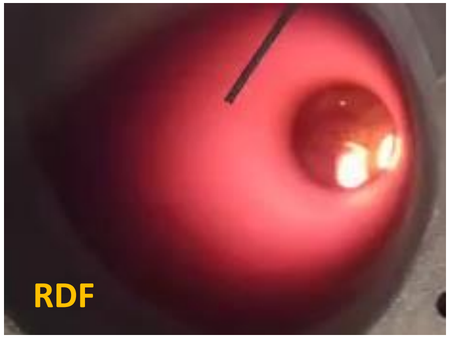
X-Ray analysis of FBG at UCL

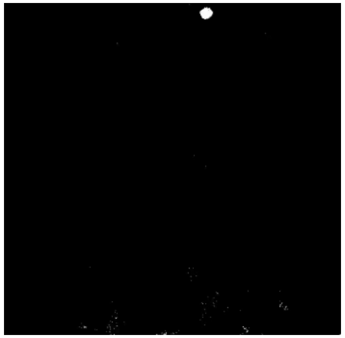


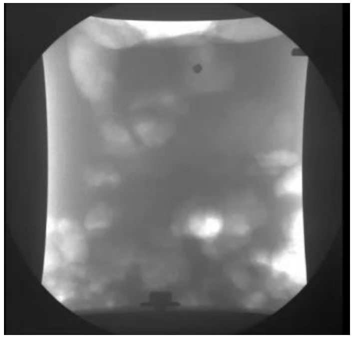
Materazzi, M. (2016). Conversion of biomass and waste fuels in fluidised bed reactors

Enhanced segregation from RDF…









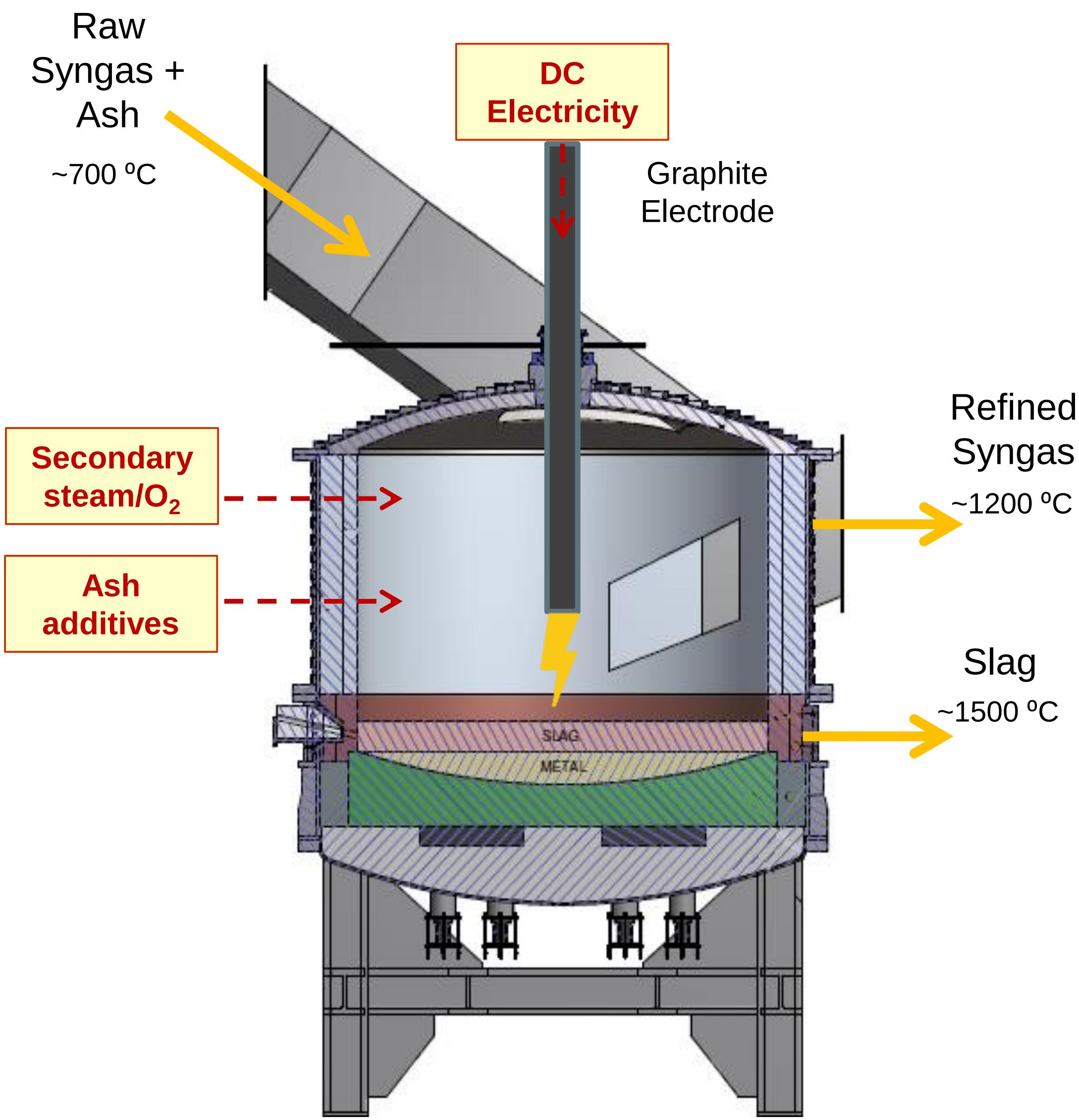
Materazzi, M. (2016). Conversion of biomass and waste fuels in fluidised bed reactors

… and solid drops

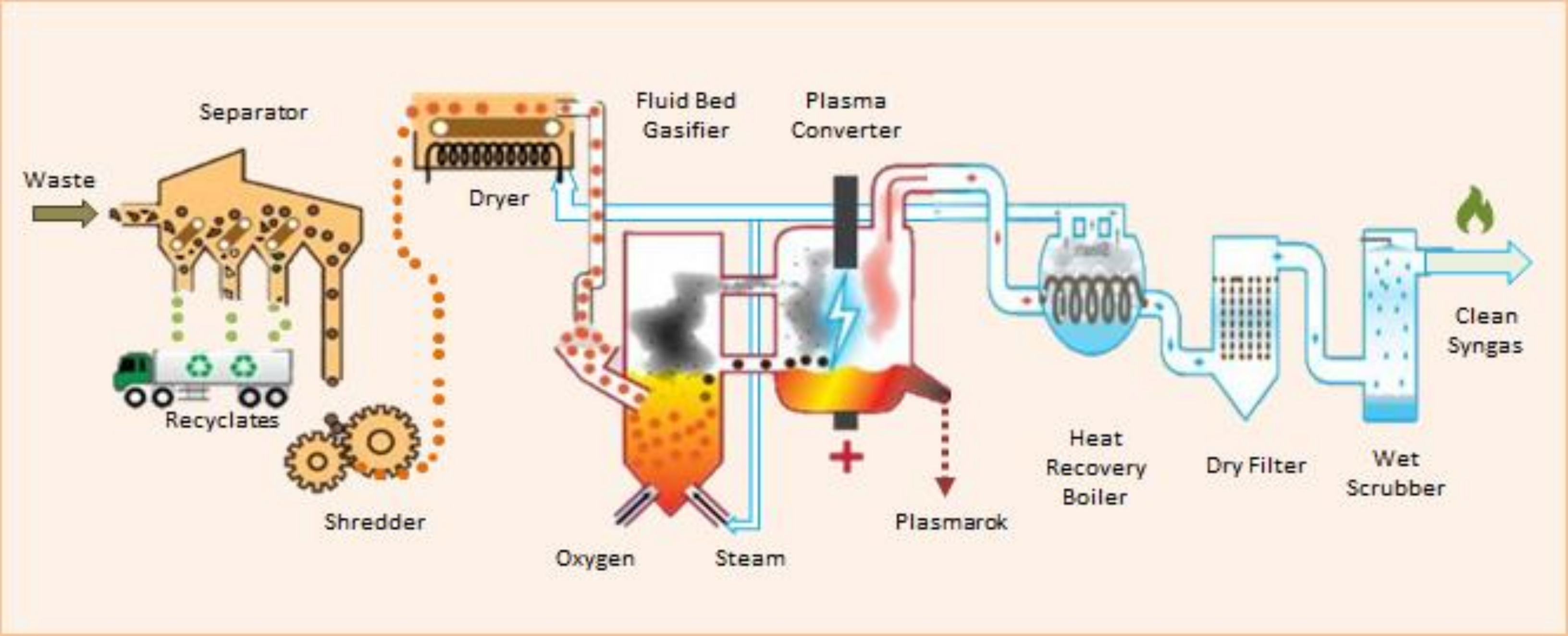
Plasma assisted gasification: a multi-disciplinary and multiphysics problem

- Formed by DC or AC electric arcs, radio-frequency or microwave electromagnetic fields
- Highly ionised (typically 100%, at least 5%)
- Strong radiative emission
- Local T_{gas} = 2,000-20,000K (close to equilibrium)
- Highly electron density (~10^{23} m^{-3})
- Very widely used in manufacturing and other industries (ash smelting, metal recovery, etc.)
- Quick start-up, possibility to couple with renewable electricity

Thermal plasma reforming in DT furnaces



The plasma-assisted gasification process



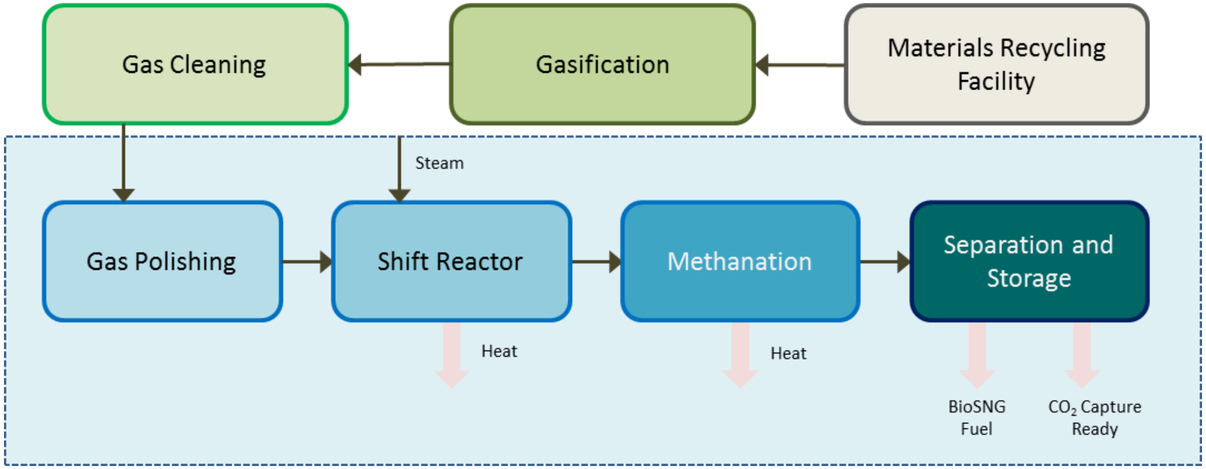
- Tars are converted overwhelmingly to CO and H_2
- Organic-S is less than 500 ppbv, i.e. ~ 93% less than that of a conventional FBG gasifier
- **Ash is collected mostly as inert material**
- **Carbon to carbon conversion efficiency >96%**

The Pilot Plant

BioSNG PILOT PLANT (50 kWth)

Project

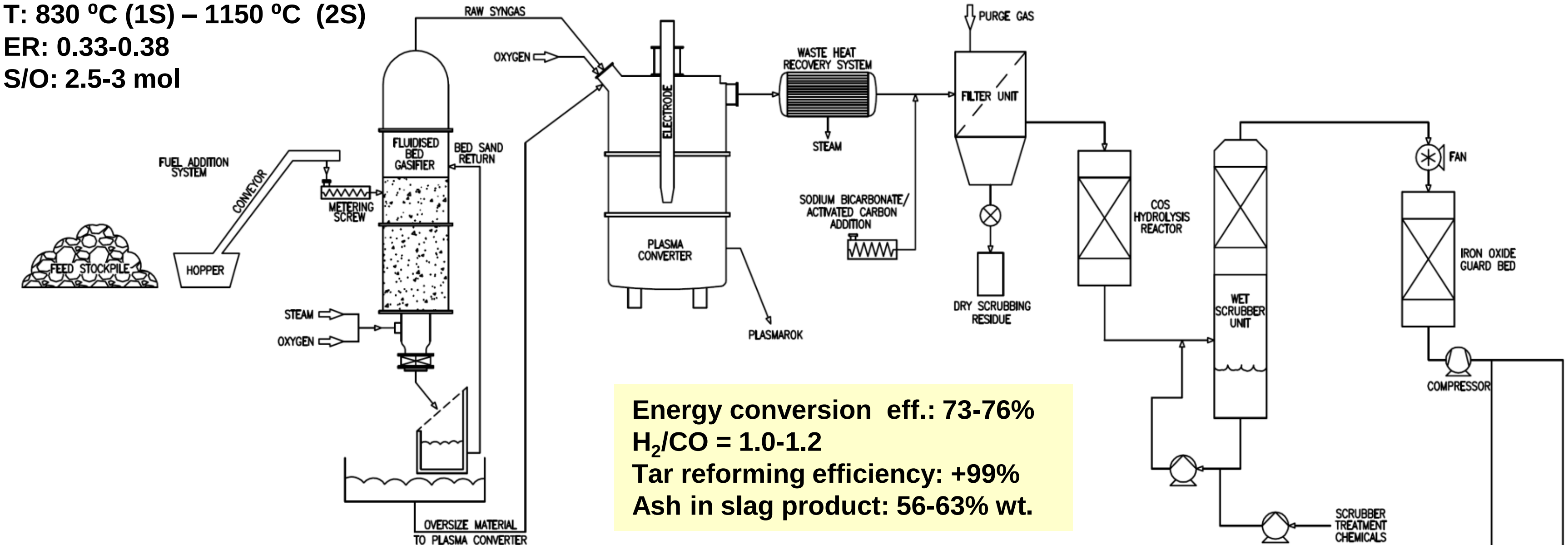
- Three year programme to establish technical, environmental and commercial viability of BioSNG production from waste and residues.
- Successfully completed March 2017.
- Overall cost £5m (£4m EU and UK grants).



Pilot plant configuration

Gasification plant

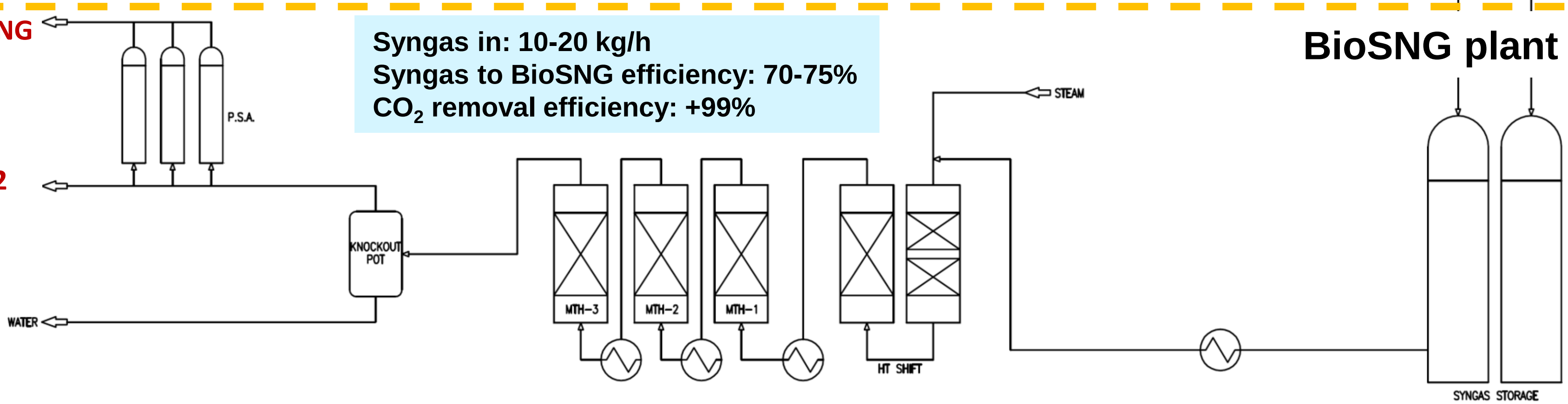
- ~100 kg/h RDF (GCV:22.1 MJ/kg)
- T: 830 °C (1S) – 1150 °C (2S)
- ER: 0.33-0.38
- S/O: 2.5-3 mol



- Energy conversion eff.: 73-76%
- H_2/CO = 1.0-1.2
- Tar reforming efficiency: +99%
- Ash in slag product: 56-63% wt.

BioSNG plant

- Syngas in: 10-20 kg/h
- Syngas to BioSNG efficiency: 70-75%
- CO_2 removal efficiency: +99%



Feedstock

RDF (Refuse Derived Fuel)

Description:	RDF (as received)
Proximate analysis, % (w/w)	
Fixed carbon	6.4
Volatile matter	59.6
Ash	19.1
Moisture	14.9
Ultimate analysis, % (w/w)	
C	41.0
H	5.7
O	17.5
N	1.2
S	0.2
Cl	0.4
GCV, MJ/kg (dry basis)	22.1

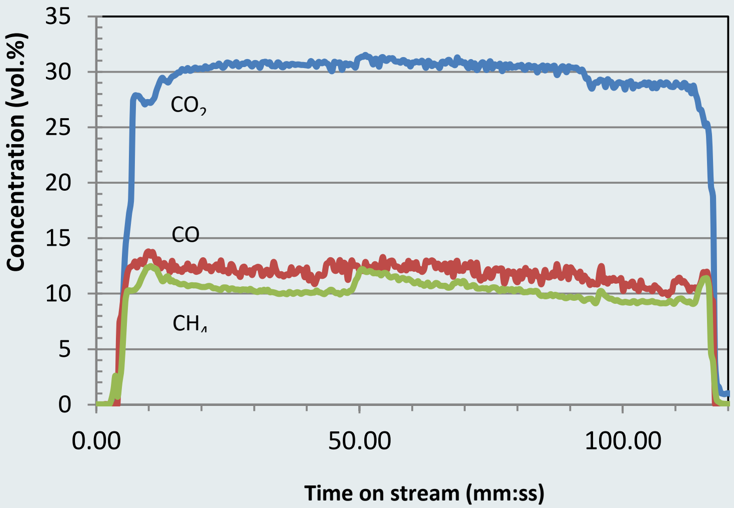
ROC: > **60% wt. biomass content** in the feedstock

Category	Design Point	Lower limit	Upper limit
Paper (wt%)	30.36	19.47	64.00
Plastic Film (wt%)	5.72	3.55	17.80
Dense Plastics (wt%)	8.38	5.50	16.20
Textiles (wt%)	3.64	0.20	8.17
Disposable Nappies (wt%)	4.91	0.00	8.00
Misc Combustible (wt%)	6.40	2.29	10.92
Misc Non-Combustible (wt%)	6.08	0.00	8.93
Glass (wt%)	7.01	0.60	11.00
Putrescible (wt%)	16.82	3.00	27.00
Ferrous (wt%)	6.61	1.10	11.69
Non-ferrous (wt%)	1.96	0.60	2.90
Fines (wt%)	2.13	1.00	5.50
Total	100.00		
CV (MJ/kg)	10.05	9.08	13.62
RDF biomass content (wt%)	67.7	49.1	80.1
RDF biomass content (energy%)	64.1	39.9	79.8

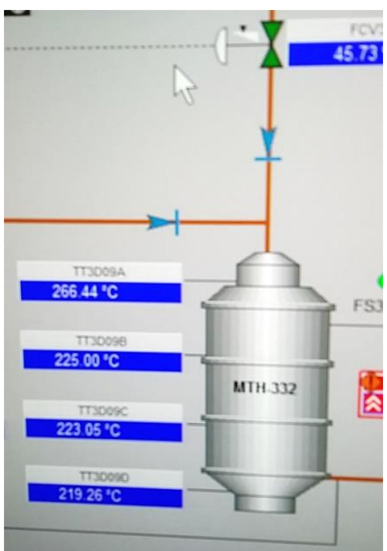
Syngas quality

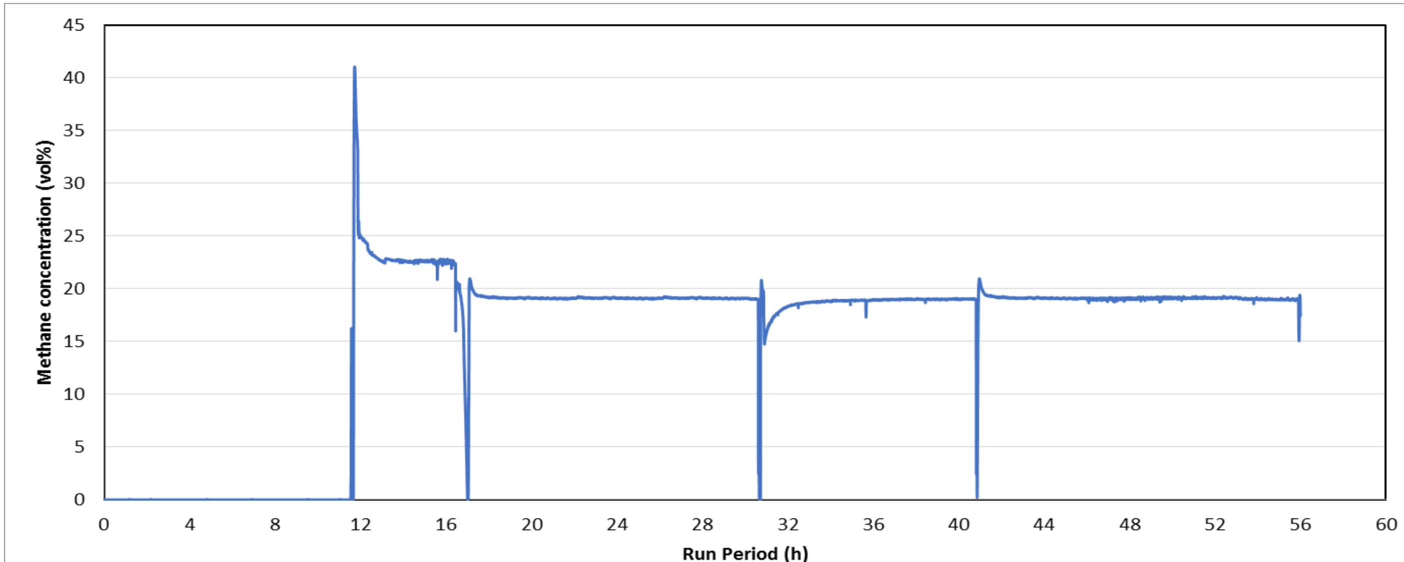
Quality Parameter:		Stored syngas
Composition:		
H_2	vol.%	35.77
CO	vol.%	33.20
CO_2	vol.%	23.54
CH_4	vol.%	1.67
H_2O	vol.%	0.89
Other	vol.%	4.90
Energy Analysis		
NCV	MJ/kg	8.75

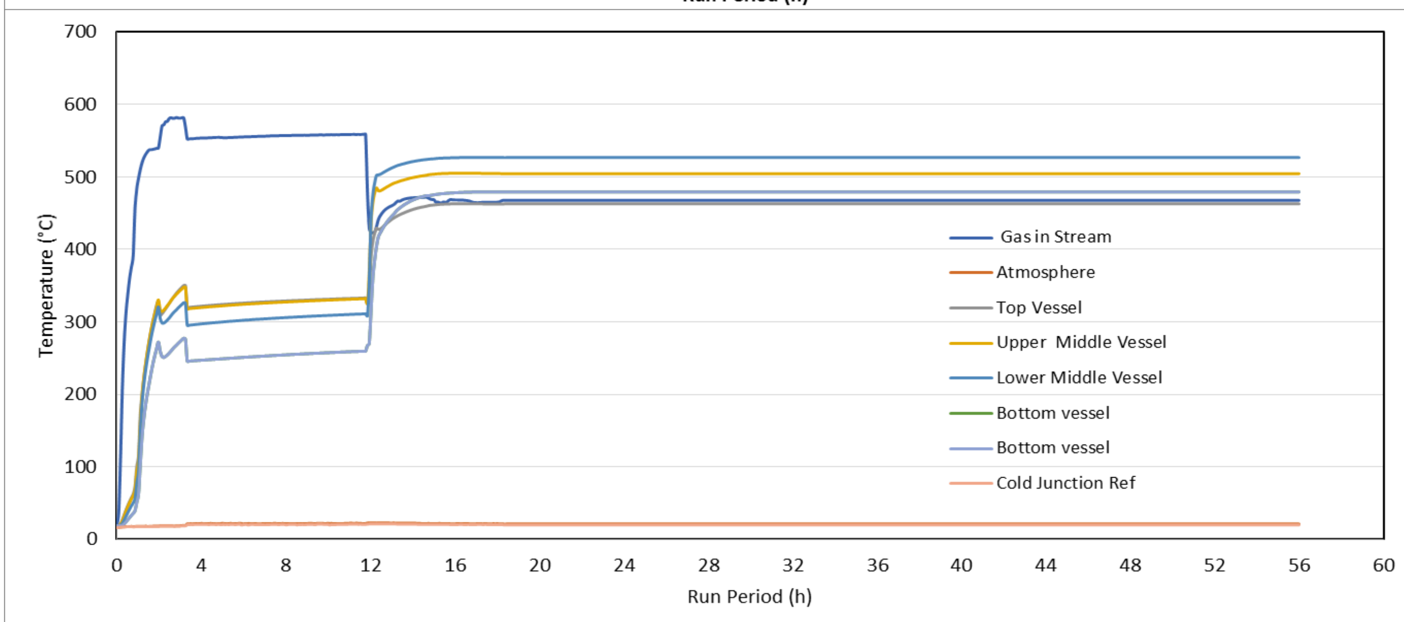
Methanation trials



4-day methanation with waste-derived syngas …

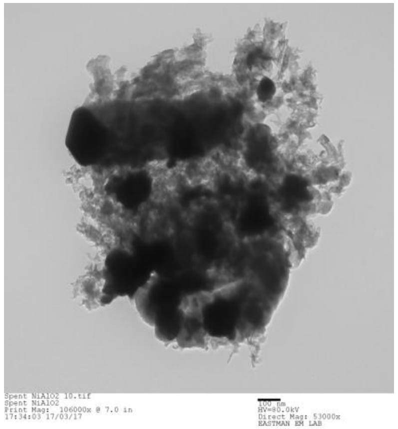




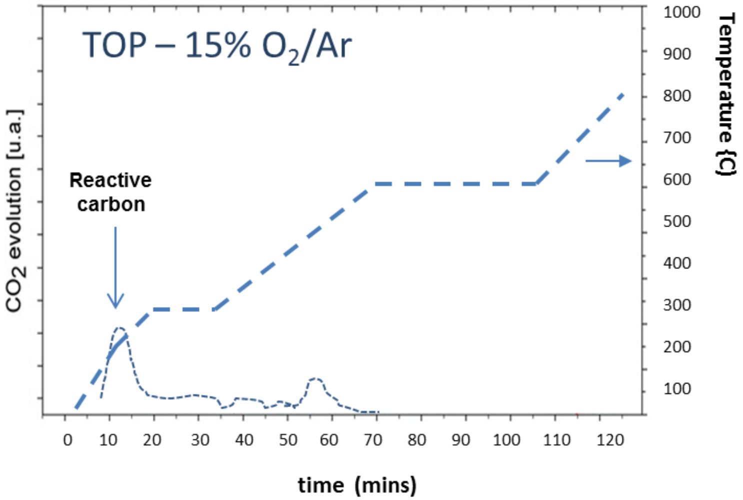


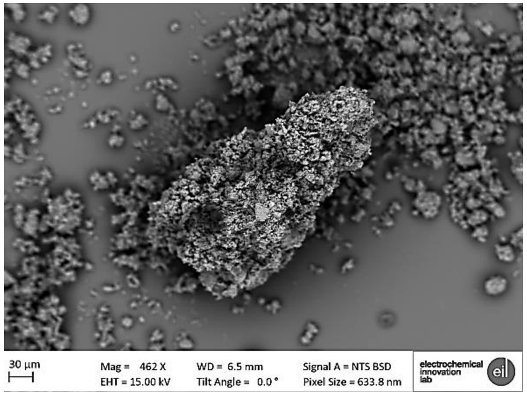
Spent catalysts analysis

Temperature Programmed Oxidation (TPO) analysis of the catalyst samples from the first methanation reactor clearly showed that during trials almost no polymeric carbon was formed nor detectable sulphur was deposited.



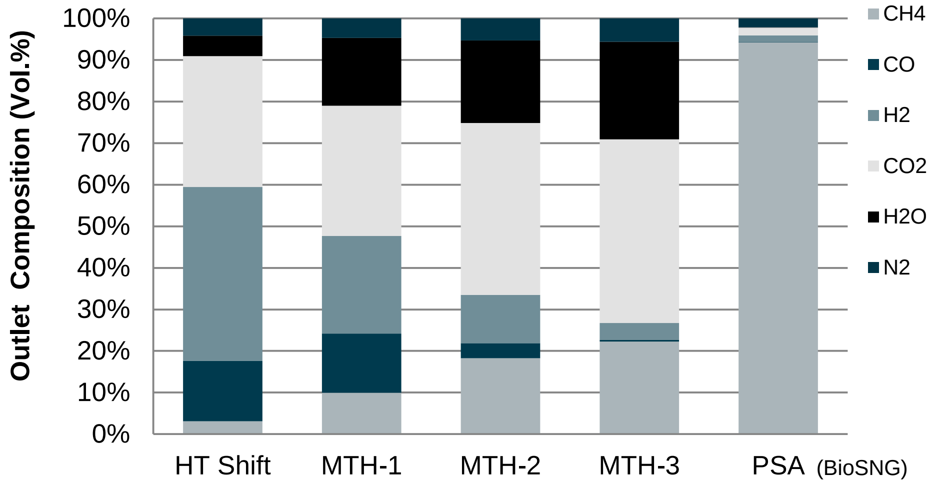
Transmission electron microscopy (TEM) showing Ni particles (black) and surface carbon



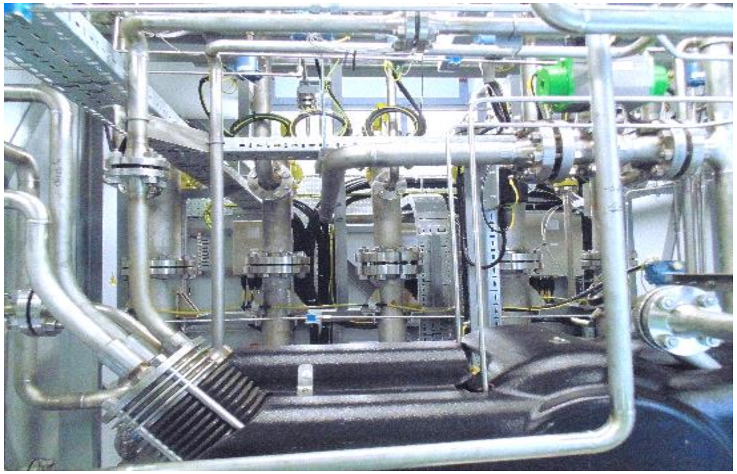


SEM image (X470) with Back-scattered electrons (BSE)

Final BioSNG product



	GS(M)R	Pilot
Sulphur	< 50 mg/m³	None
H_2	< 0.1 % (molar)	0.1 – 1.5%
O_2	< 0.2 % (molar)	None
Wobbe	> 47,2 MJ/m³ < 51,4 MJ/m³	35.0-41.6 MJ/m³ (pre-enrichment)
Other impurities	No liquid below HC dewpoint	None



FULL CHAIN 4.5 MW_{TH} SMALL COMMERCIAL FACILITY

Swindon Borough Council

absl

wood.

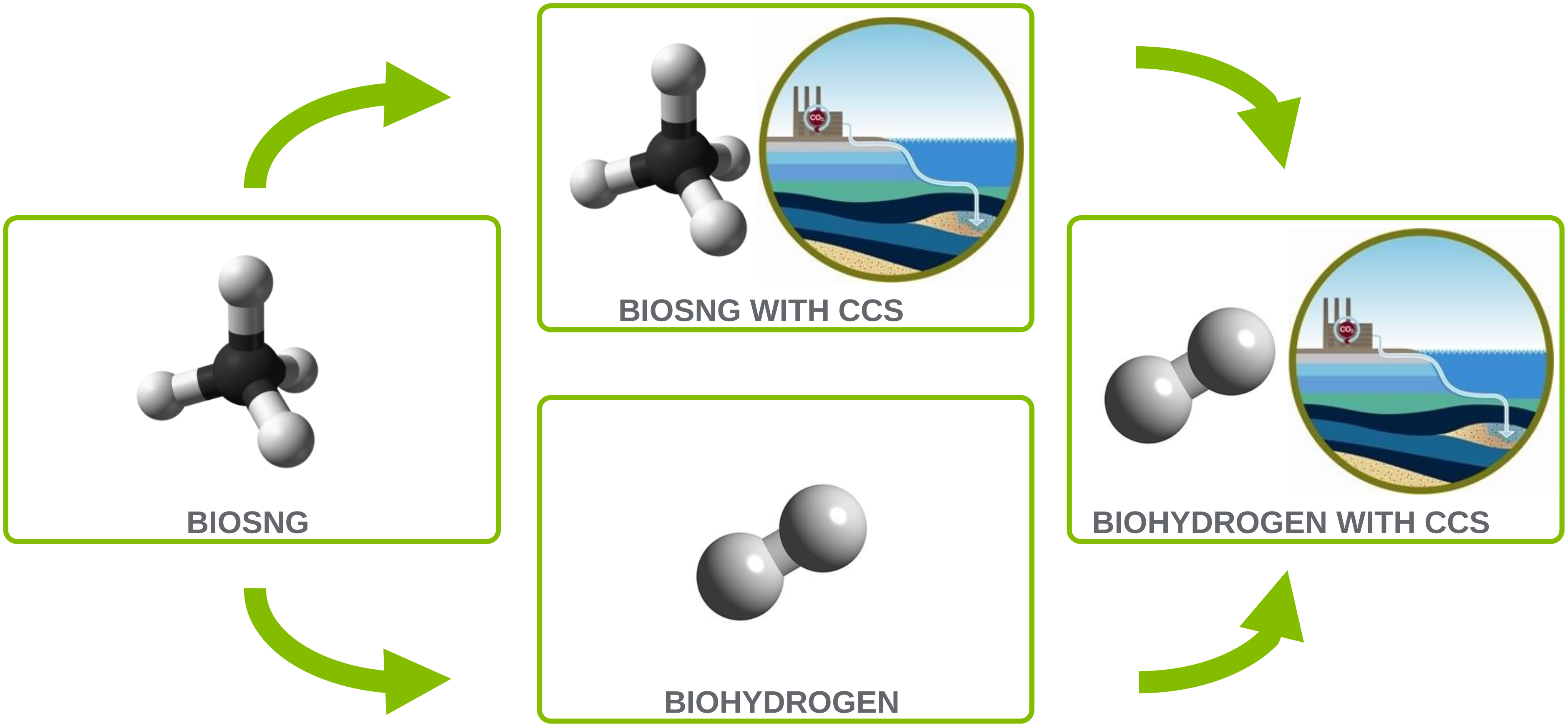
Howard Tenens

Wales&West Utilities

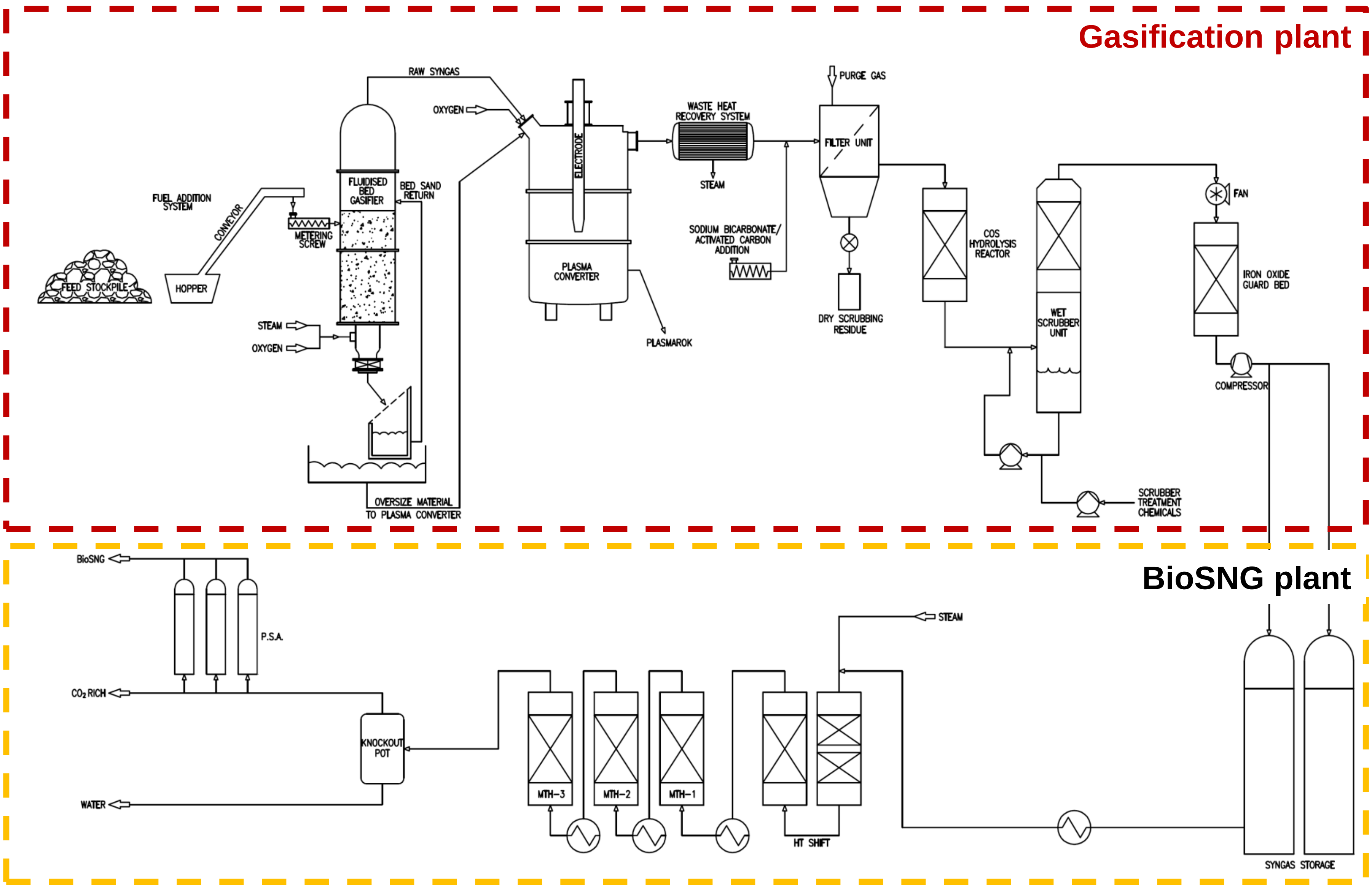
THE WORLD'S FIRST GRID CONNECTED, FULL CHAIN, WASTE TO SNG FACILITY OPERATING UNDER COMMERCIAL CONDITIONS

Pathways to deeper decarbonization

DEEPER Decarbonisation Route Maps



Pilot plant configuration



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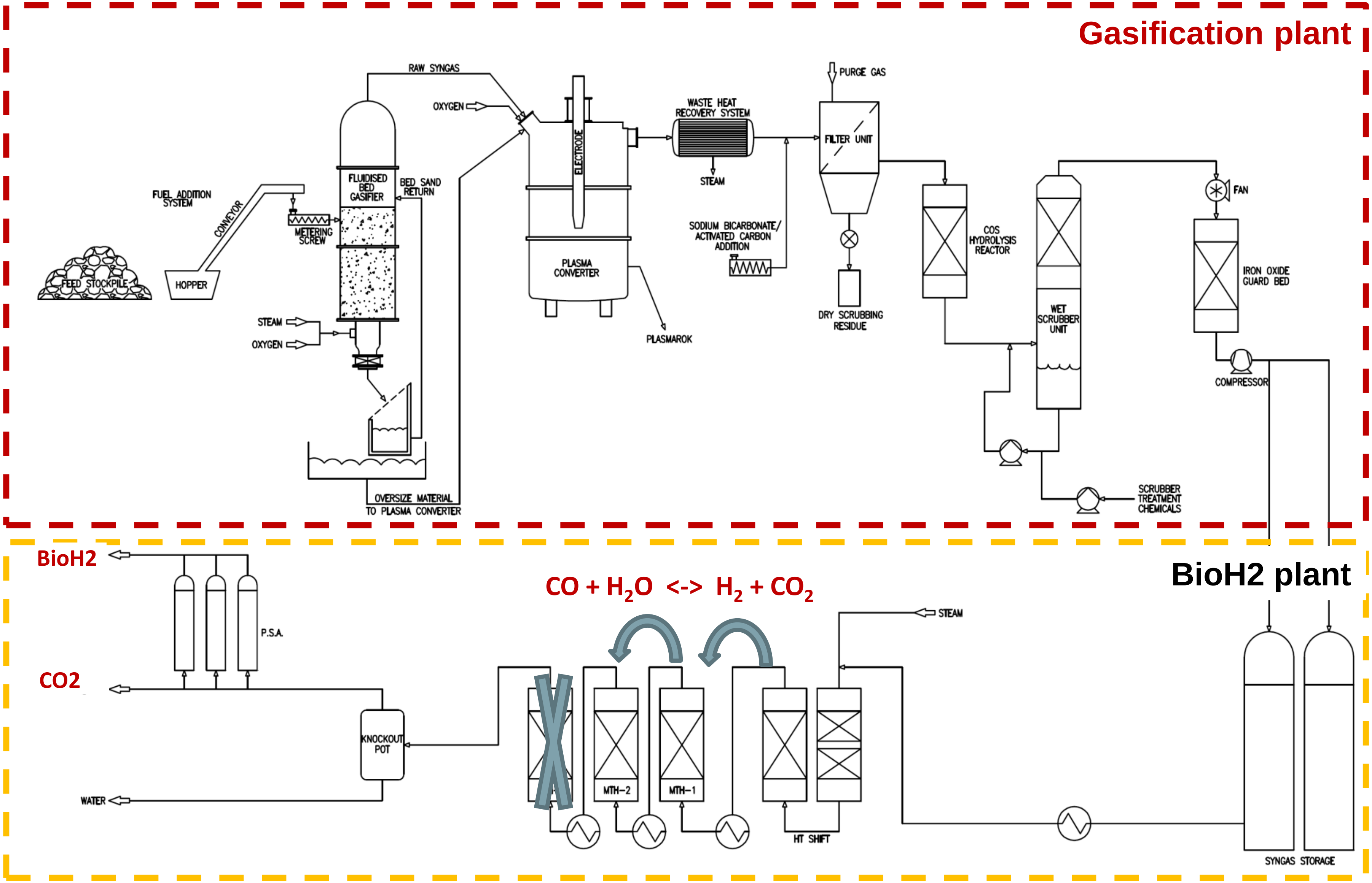
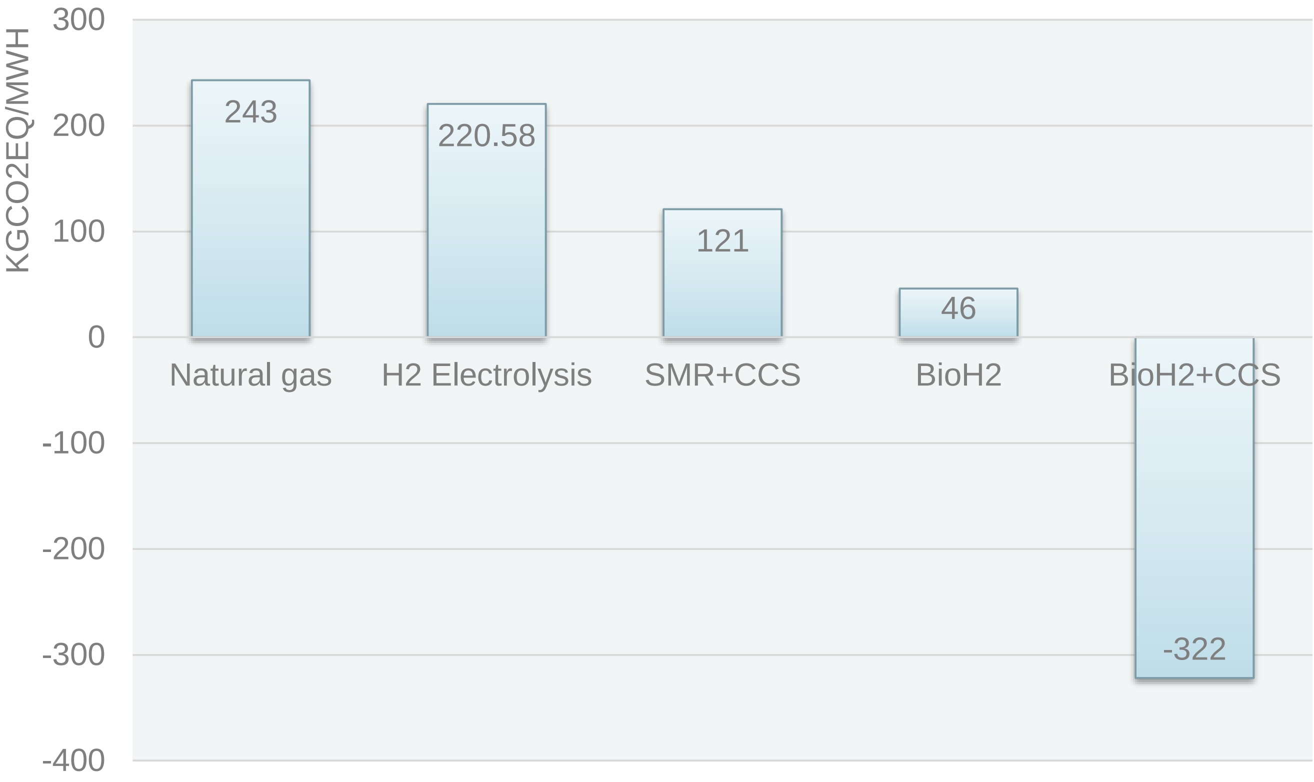


A Pathway to deep carbon savings



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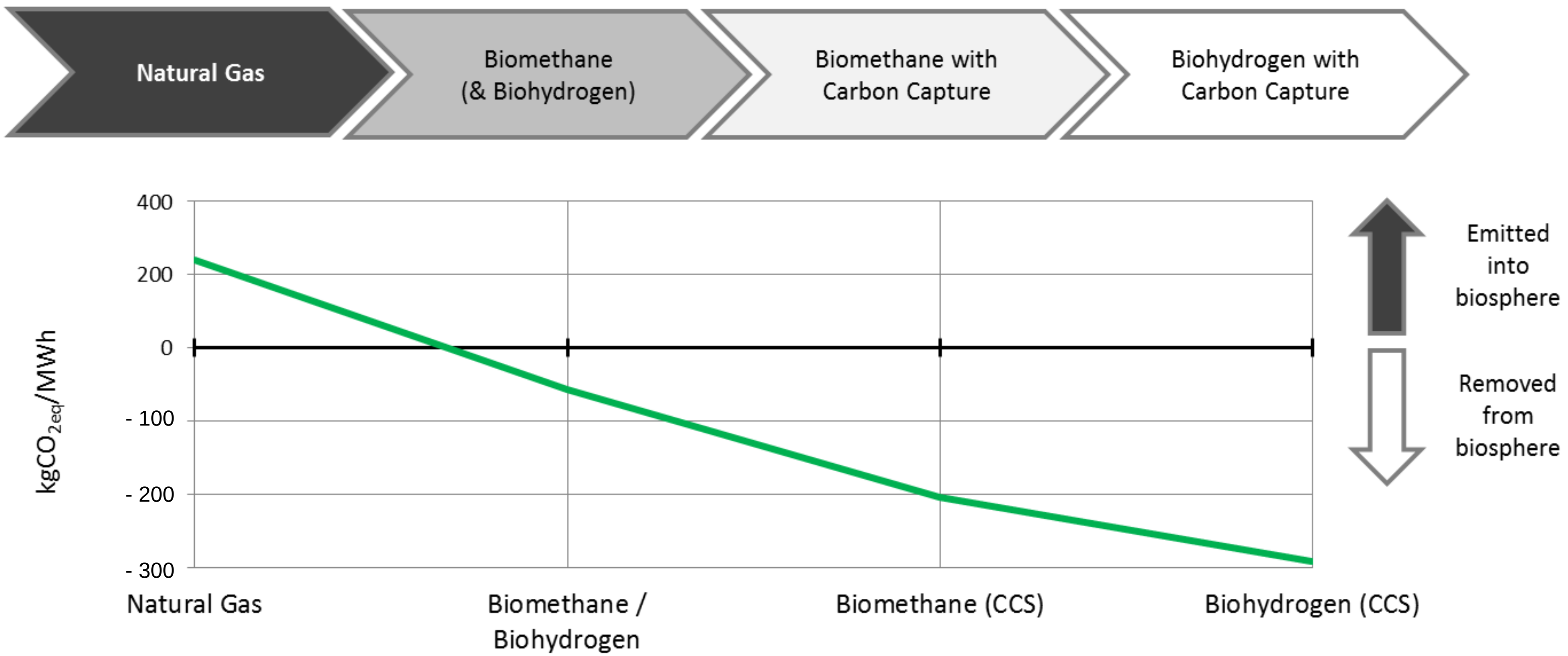

Summary

GASIFICATION WILL ENABLE THE CONVERSION OF THE UK'S LARGEST SOURCE OF RENEWABLE CARBON TO ALTERNATIVE FUELS TO MEET HEAT & TRANSPORT DEMAND.

Challenges:

- The technical approach needs piloting and sustained operation on real waste
- R&D efforts for new technologies to increase availability

UCL

Thank you

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