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Targeting new and cleaner uses for wastes and biomass using gasification

Dr Geraint Evans - Programme Manager Bioenergy

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ETI10 TEN YEARS OF INNOVATION 2007—2017

Agenda

- Energy Technologies Institute
- Value of bioenergy
  - Wastes
- We can already use combustion to get energy from waste - why do we need something different and why gasification?
- What is gasification and why is ultra-clean syngas important?
- What is the current UK gasification project landscape?
- The ETI’s project work

energy technologies institute

The Energy Technologies Institute (ETI)

- The ETI is a public-private partnership between global energy and engineering companies and the UK Government.
- Targeted development, demonstration and de-risking of new technologies for affordable and secure energy
- Shared risk

ETI members

bp

CATERPILLAR®

EDF ENERGY

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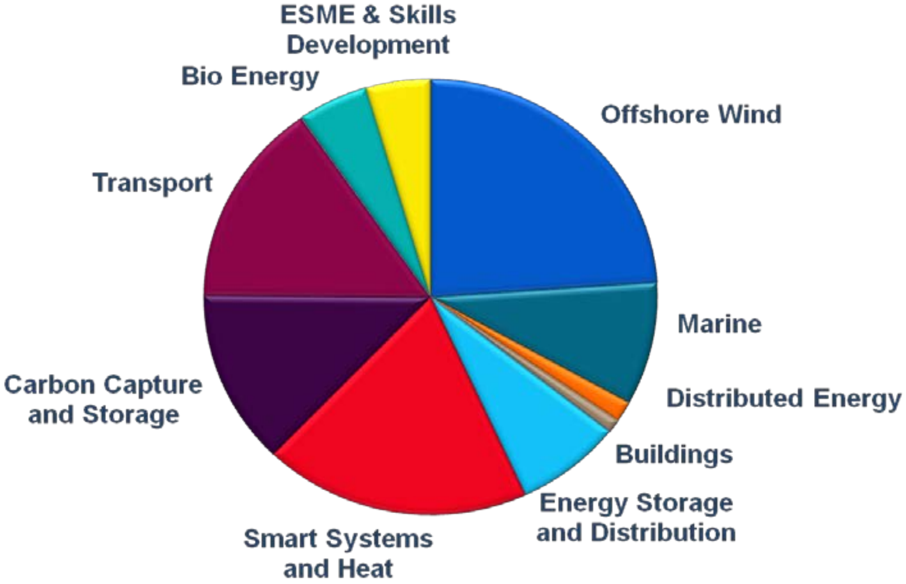
Department for Business, Energy & Industrial Strategy

EPSRC Pioneering research and skills

ETI programme associate

HITACHI Inspire the Next

ESME analysis has driven ETI's nine key technology programme areas



Innovation thinking and innovation delivery

- New knowledge
  - o Up to £5M / 2 years
- Technology development
  - o £5-15M / 2-4 years / TRL 3-5
- Technology demonstration
  - £15-30M+ / 3-5 years / TRL 5-6+
- Reduced risk

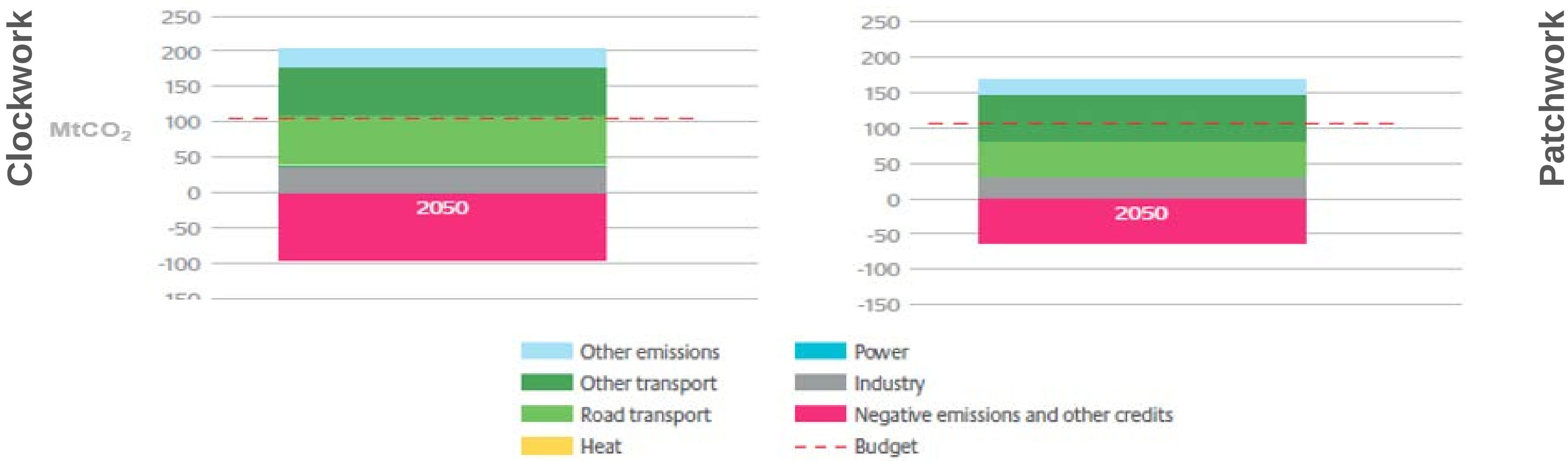
Bioenergy

A key lever – particularly with CCS
Requires sustainable supplies – imports and indigenous

- Major potential for creating 'negative emissions' via CCS
- Could support a range of conversion and utilisation routes - flexibility
  - Hydrogen
  - SNG
  - Heat
  - bioeconomy
- ETI investing in soil science, logistics and value chain models
- Informing decisions
  - "what do we grow ?"
  - "where do we grow it ?"
  - "how do we use it ?"

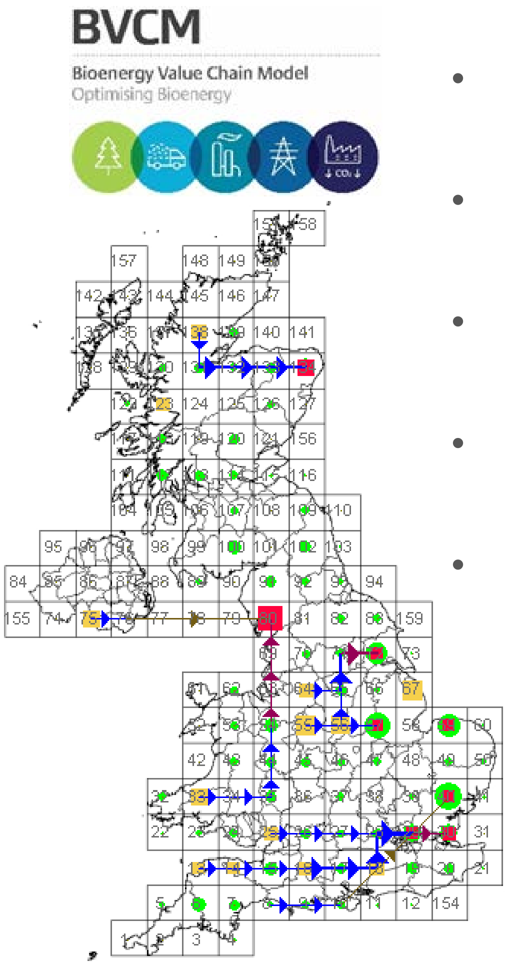
Value of bioenergy in the energy system: transition and credits

Negative emissions provide flexibility, headroom



- Target is 105 million tonnes of CO_2 in 2050
- Bioenergy could deliver net negative GHG emissions of around -55 million tonnes of CO_2 per year in the 2050s (approximately half our emissions target in 2050), and meet around 10% of UK future energy demand (~130 TWh/yr in 2050).
- This extra headroom helps avoid expensive abatement actions such as in transport
- Provides more flexibility on transition

Key insights from BVCM modelling



- Gasification technology is a key bioenergy enabler and resilient to a number of different scenarios
- **The sector will need a combination of feedstocks – wastes, UK-grown and imported biomass**
- Planting around 1.4 Mha of second generation bioenergy crops would make a significant contribution to the sector
- Location preferences for resource production are apparent (Miscanthus – South/East, SRC – North/West, SRF - Midlands)
- Deployment of BECCS makes a significant difference to the bioenergy sector:
  - With CCS, BECCS technologies dominate, clustered around key coastal hubs
  - Without CCS, more heat and bio-methane are produced and the sector is more spatially distributed

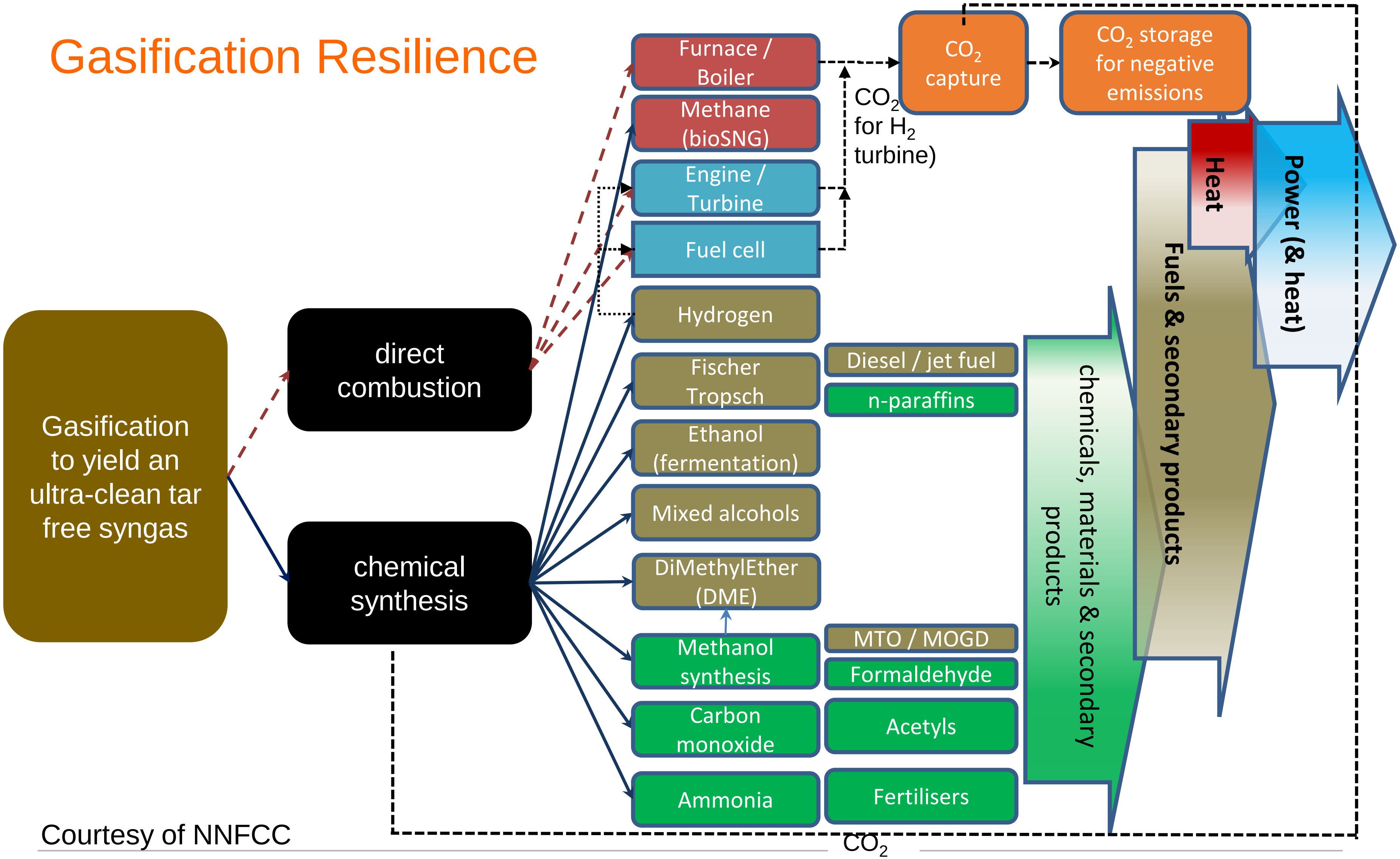
Biomass – many sources, each with different strengths & weaknesses

- Sugars, oils starches
  - Wheat grain, corn, rape oil, soy
- Forest derived – long rotation forestry (LRF)
  - Forest sourced (residues)
- Energy crops
  - Miscanthus, Short Rotation Willow, Short Rotation Forestry
- Agricultural residues
  - Straw, rice hulls, bagasse
- Wastes
  - Waste wood (pallets), MSW, C&I

We can already use combustion to get energy from waste - why do we need an alternative and why gasification?

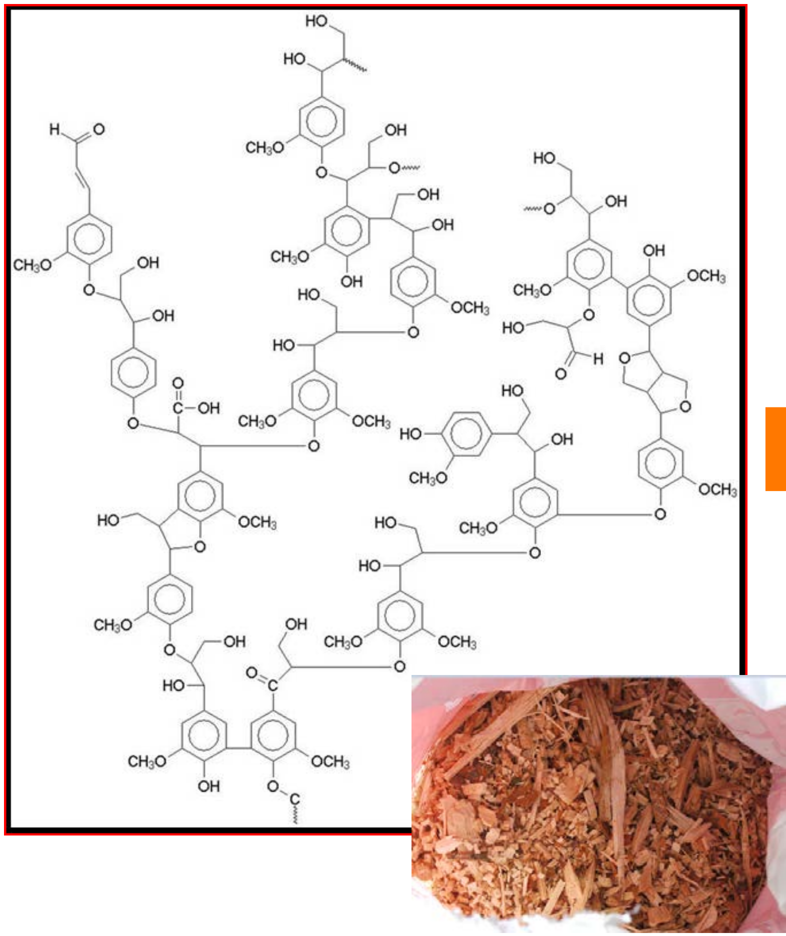
- Need to be able to effectively use the variety of feedstocks available to the UK at the smaller scale in the nearer term
  - Feedstock flexibility
  - Wastes, especially in the nearer term
  - Steam cycle efficiencies drop sharply at smaller scales – engines maintain efficiencies at smaller scales
- Resource efficiency
  - Existing EFW business models focussed around waste disposal
    - Drives low efficiency regional scale plants – not easy to use waste heat
  - Stronger focus on recycling
- Integration within towns
  - Lower plant impact e.g. visual
  - Integration with heat networks
- Future uncertainties – resilience
  - Wide variety of outputs, not just electricity
  - Product compatibility
- It is the most efficient way to generate future “negative emissions” from biomass with CCS.

Gasification Resilience

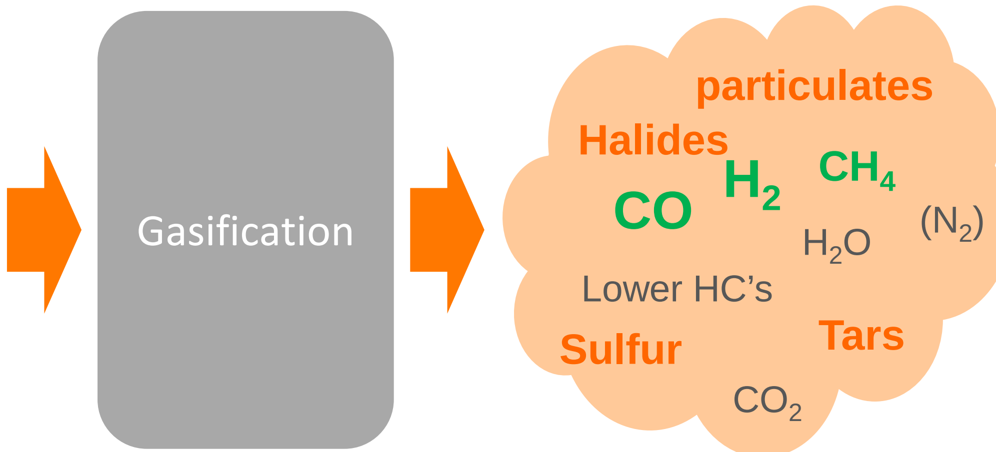


Courtesy of NNFCC

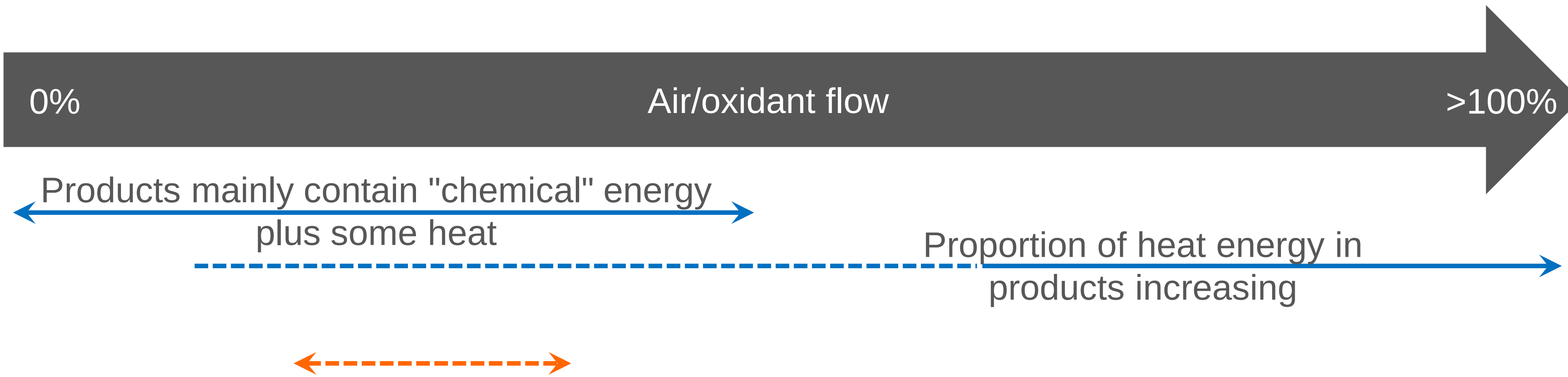
What is gasification and why is ultra-clean syngas important?



How to get from $C_xY_{1.77x}O_{0.49x}N_{0.24x}$ to CO, H_2 and some CH_4 (synthesis gas) without any undesirables



Partial combustion at high temperatures (700-1200°C)

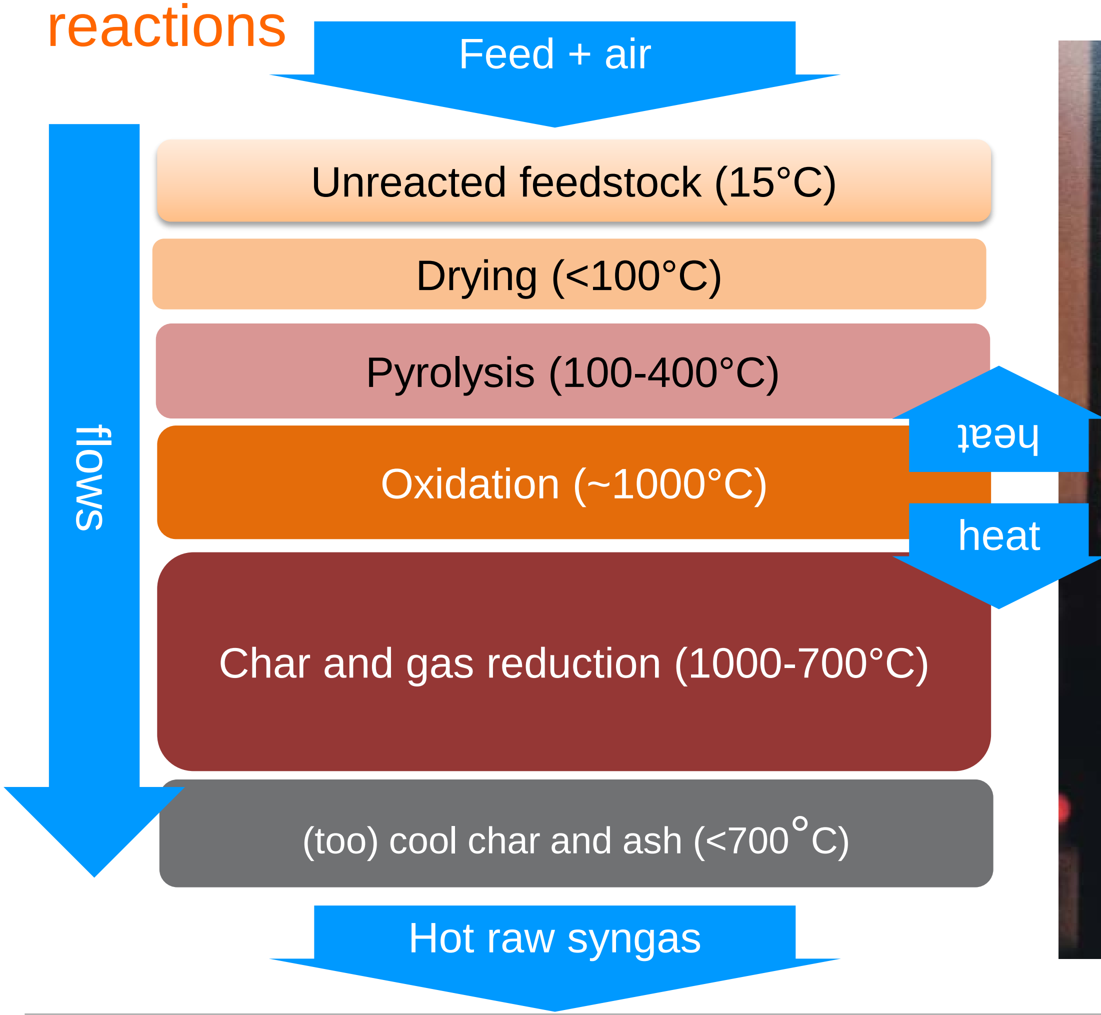


Pyrolysis
Produces mix of gases, condensable vapours, char & ash

Gasification
Produces smaller mix of gases compared to pyrolysis (H_2, CO, CH_4, CO_2, N_2 if air used), minor lower hydrocarbons, some char, & ash

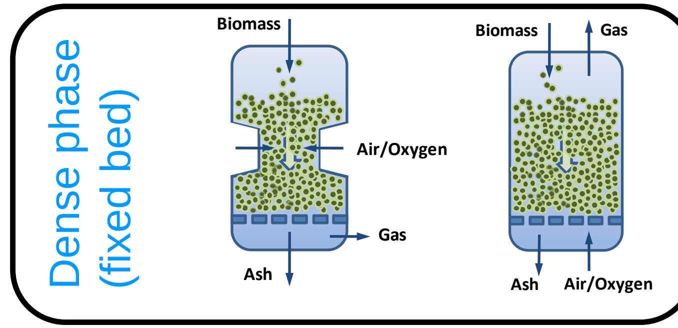
Combustion
Produces hot gaseous combustion products comprising mainly of CO_2, N_2, minor CO, minor others, ash

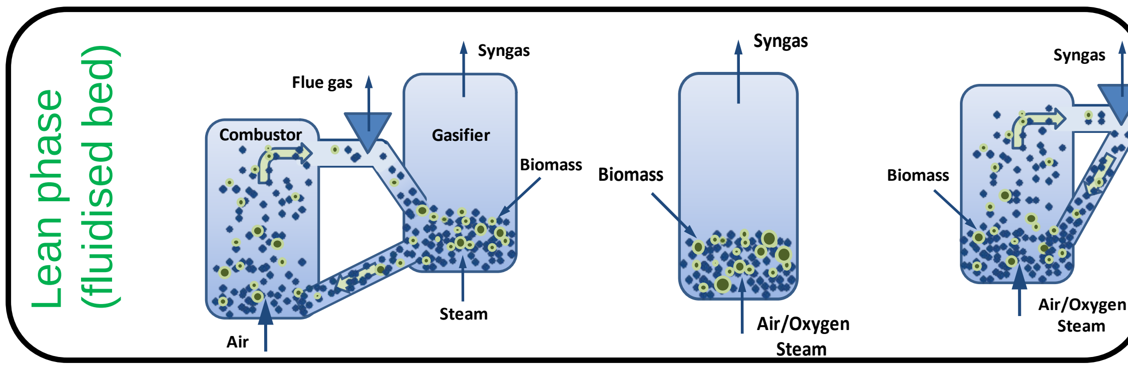
Balance “heat making” reactions against “heat using” gasification reactions

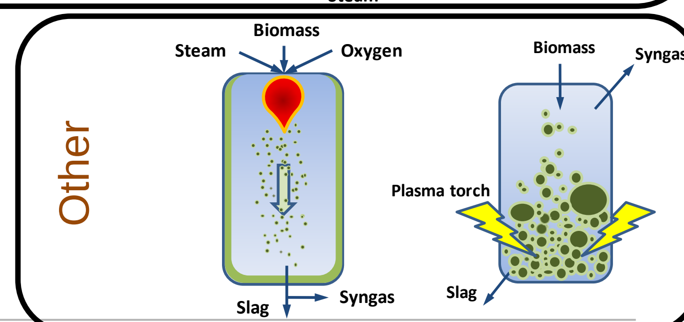


There's a wide variety of gasifier types – but, to get the value from gasification to deliver its potential, the syngas must be delivered ultra clean and tar free

- Downdraft
- Updraft
- **ABFB – atmospheric bubbling fluidised bed – BC & RD**
- PBFB – pressurised BFB
- ACFB – atmospheric circulating fluidised bed
- PCFB – pressurised CFB
- **Indirect CFB (Dahlman)**
- Entrained flow
- Plasma gasifier

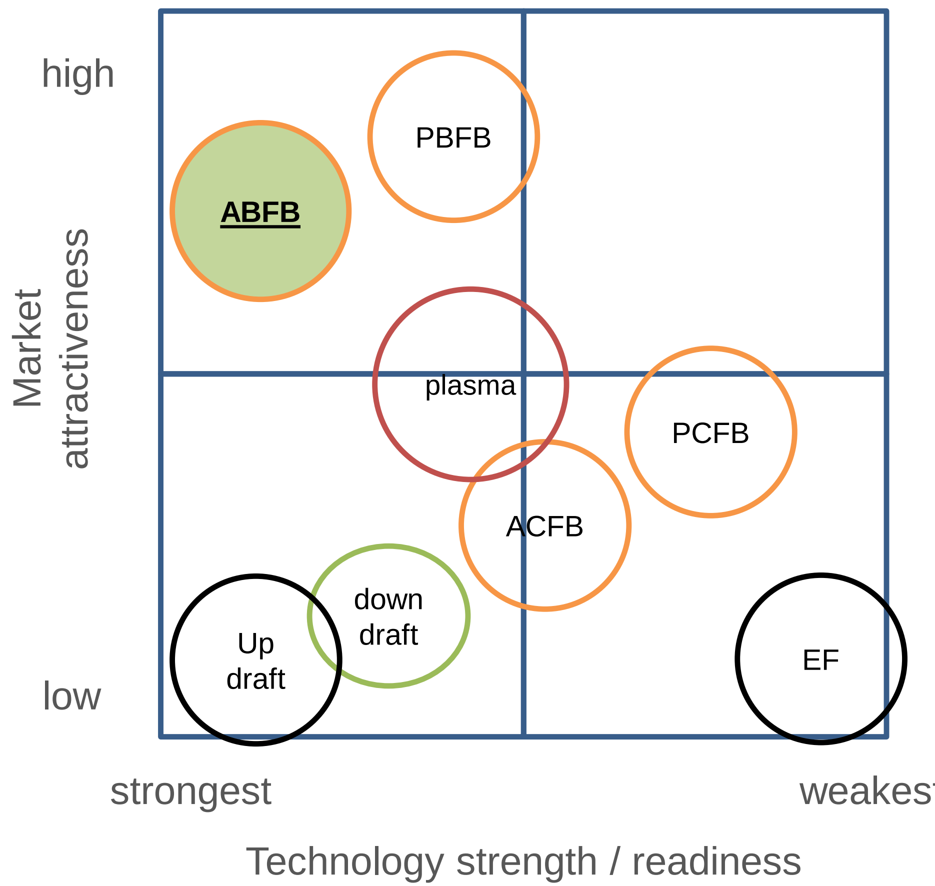






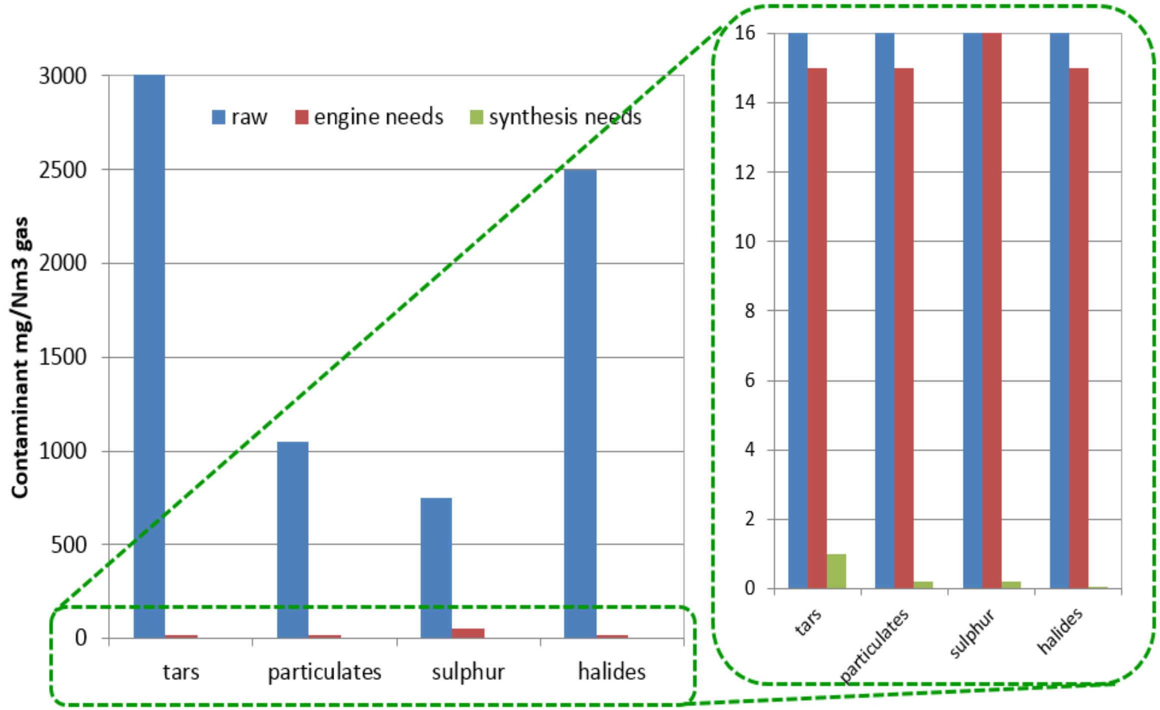
Market attractiveness (town scale, waste)

- Each has its own strengths and weaknesses
  - Each may be more or less suited to a particular feedstock and/or application
- Market attractiveness very much depends on application and resource to be gasified
  - For high hazard wastes, plasma becomes more desirable
  - For fuels production from torrefied woodchips, entrained flow becomes more desirable
- Lack of gasification technologies for clean syngas in <10MWe scale
  - Atmos BFB starting to emerge
  - Pressurised BFB not far behind
  - Downdraft not successfully delivered
  - CFB's may be too large for town scale



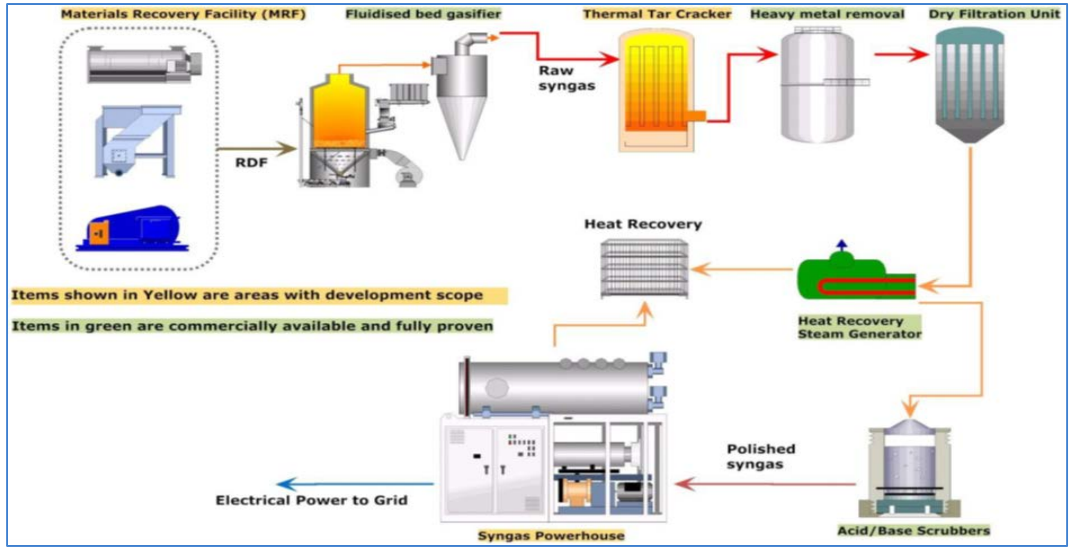
Syngas applications from "easiest to hardest"

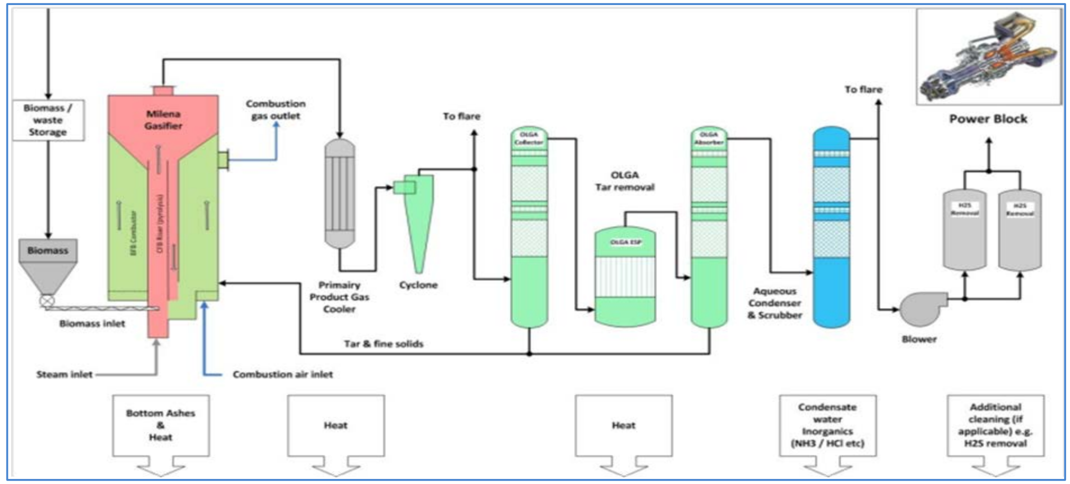
- **Clean desirable – tars not removed**
  - Boiler/furnace
    - Power/heat
- **Ultra clean AND tar free**
  - Engine
    - Power + heat
  - Gas turbine
    - Power + heat
  - Biological synthesis
    - Ethanol
  - Chemical synthesis
    - Hydrogen
    - Methane
    - Methanol
    - Jet fuel
    - Etc.



Two pathways to remove tars

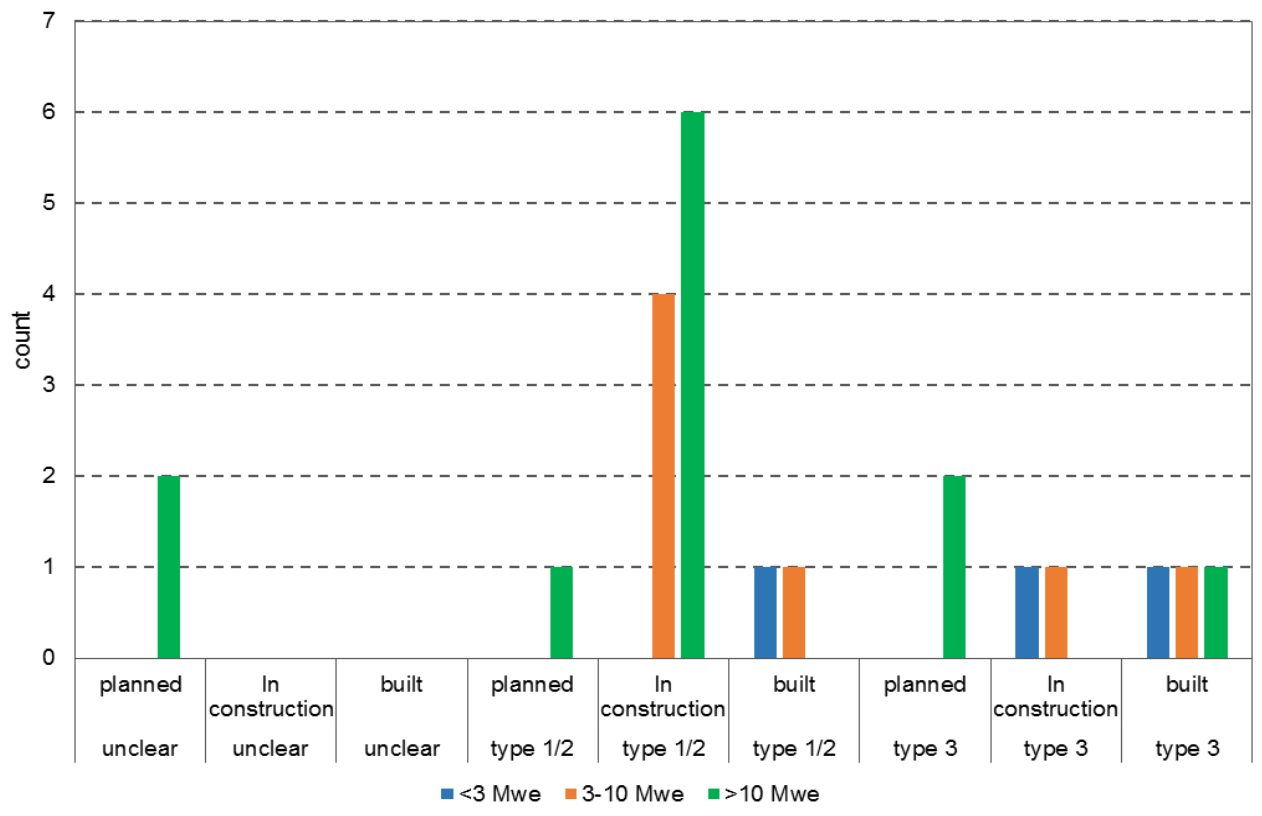
- High temperature treatment
  - >1200°C for set residence time
  - Risk of soot formation
  - e.g. Adv. Plasma Power
- Controlled condensation & stripping
  - Set of columns
  - Tars recycled to gasifier
  - e.g. Royal Dahlman



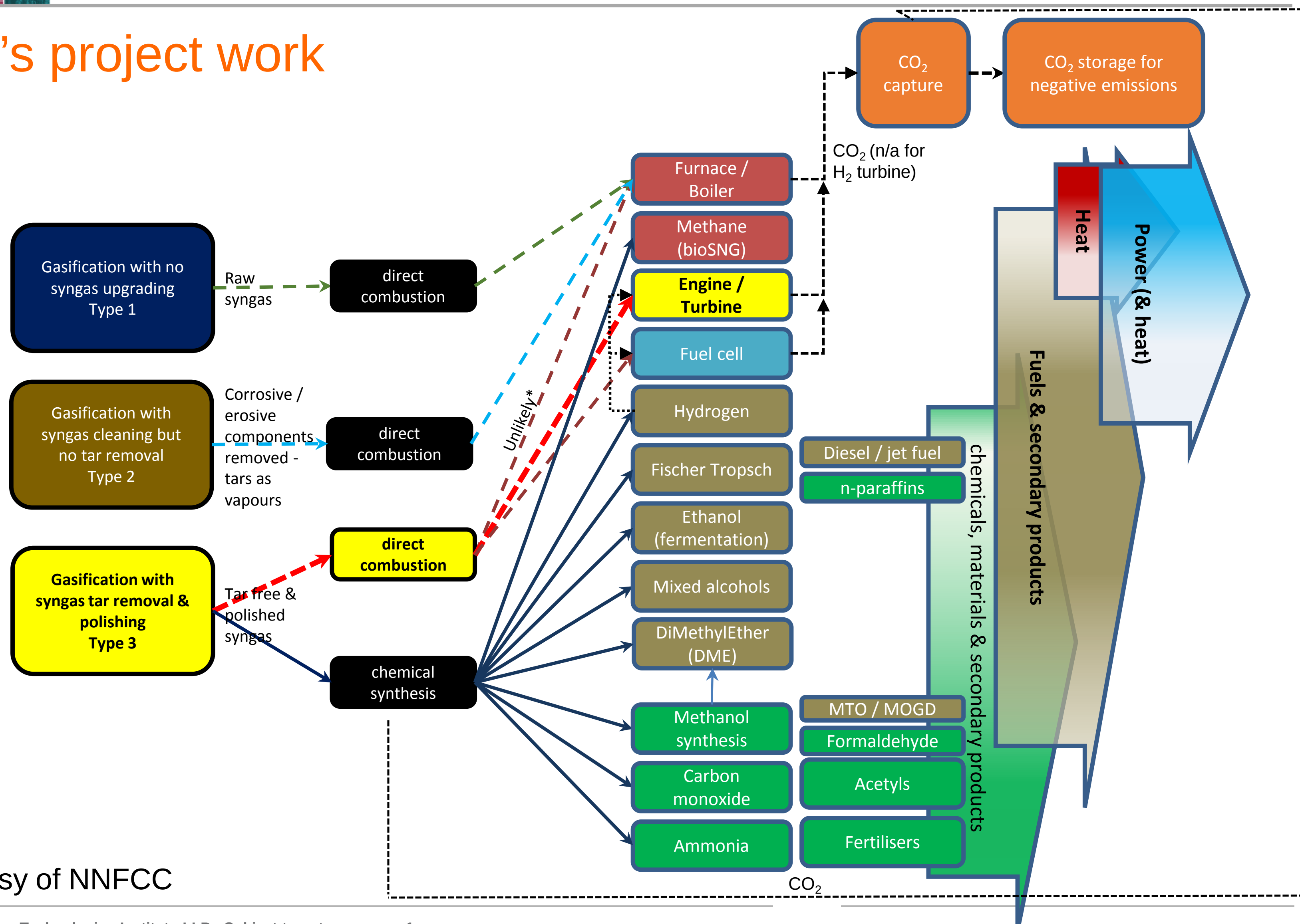


Current gasification landscape in UK

- Type 1
  - No gas cleaning
- Type 2
  - Gas cleaning but no tar removal
  - Improved steam boiler efficiency & reliability
- Type 3
  - Gas cleaning & tar removal
  - Allows syngas use in engines, gas turbines, chemical synthesis

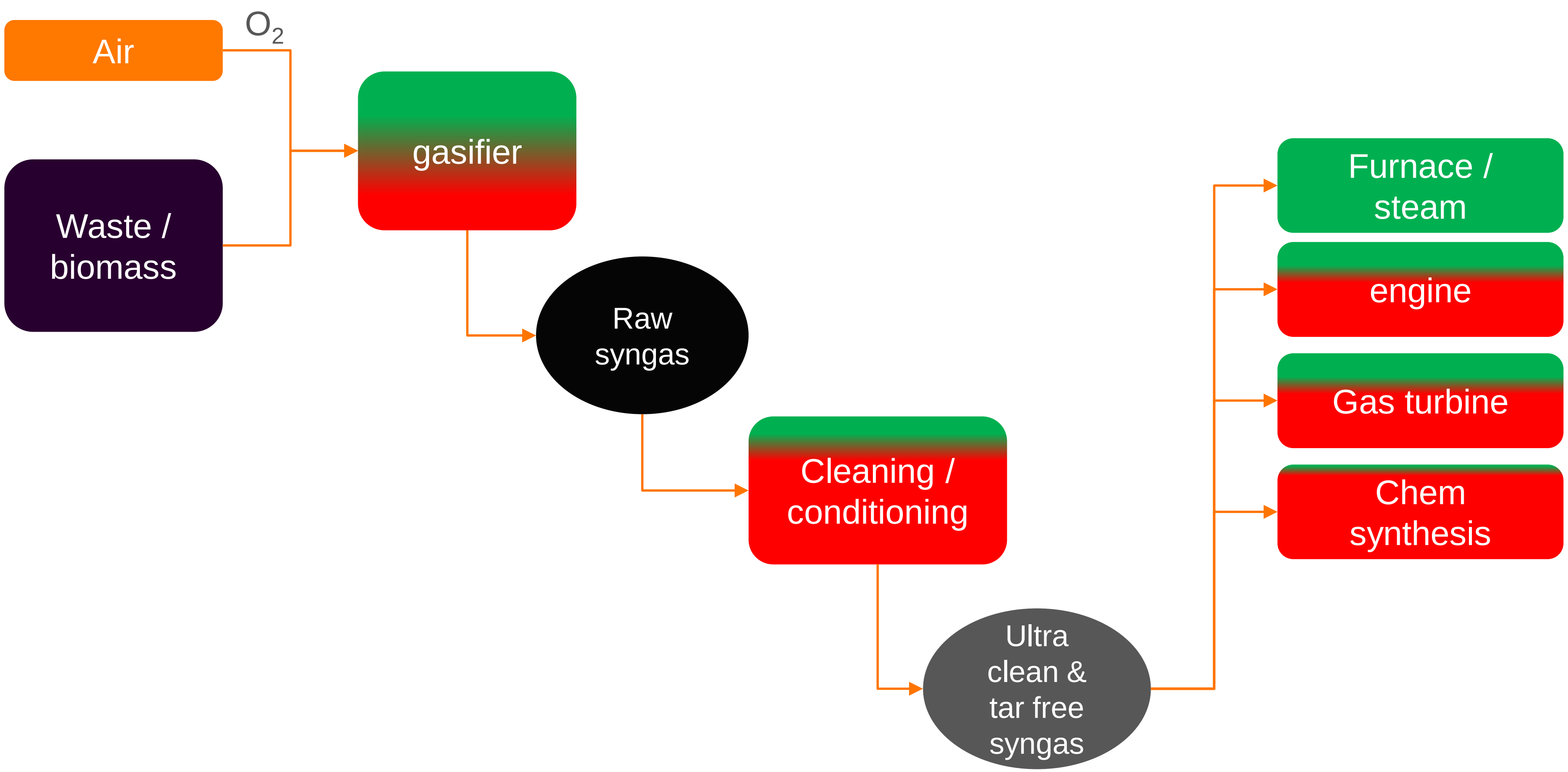


ETI's project work



Courtesy of NNFCC

A set of steps which must all be made to work together – key risks are at the interfaces



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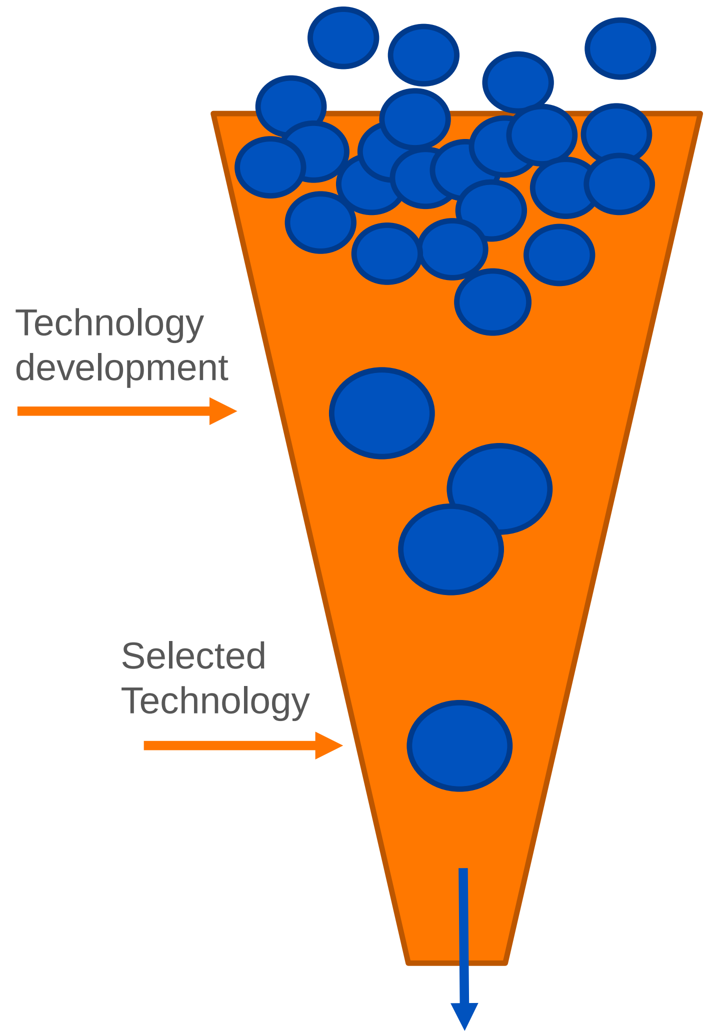
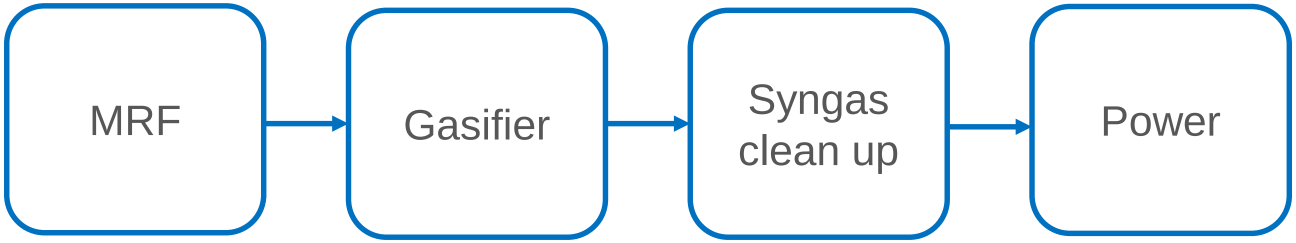
Waste Gasification Programme

Projects		Support
EFW project	Appraise (2009-11)	**Members** BP Shell Cat RR EDF E-On BEIS
WG Phase 1	Select (2012-13)	**ETI staff**
		External reviewers
Contract shaping	Define (2014-16)	**Professional DD**
WG demo project	Execute (2017-19)	**Professional Services** e.g. MACE OSL



Scope (Phase 1 to Phase 2)

- Commissioned three FEED (Front End Engineering Design) studies and business plans for specific sites.
- >25% net electrical efficiency over the whole system (from MRF to electricity production)
- Availability >80%
- Designs were tested through modelling and laboratory testing to understand how performance may change using different waste feedstocks (MSW, C&I and waste wood) and at different scales.



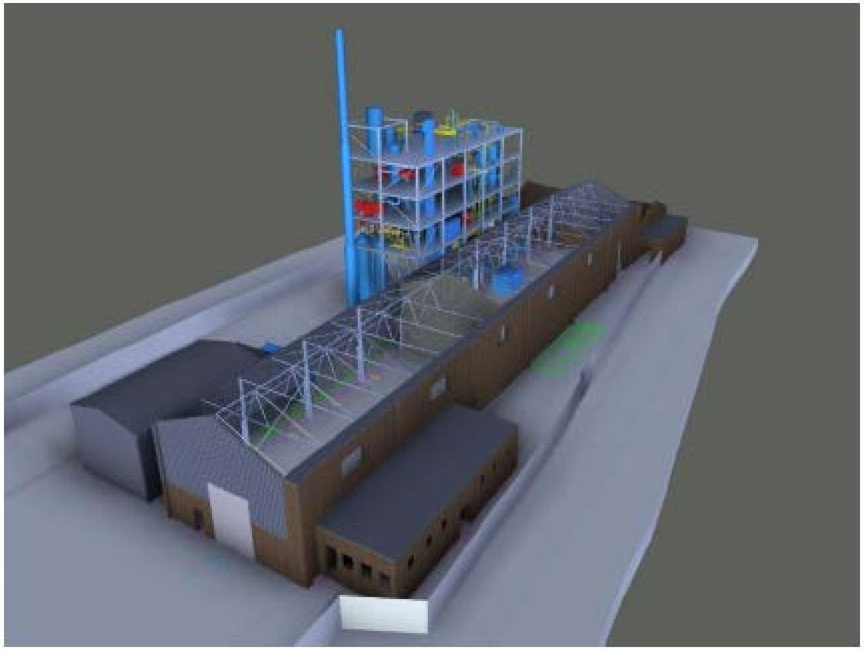
Waste gasification demonstrator (£5M ETI investment; £10.5M total)

- Construction & demonstration of a 1.5 MWe power station incorporating gasification with syngas clean up to deliver an “ultra-clean” tar free syngas for use in a gas engine
- Project announcement 25th Apr 2017
  - anticipated finish Sept 2019
  - construction in hand

- Feed will be a mix of C&I and MSW based feedstocks.
- Uses Fluimax - pressurised fluidised bed technology with a high temperature treatment to produce a high quality, H_2 rich syngas.
- Power generation via a specially adapted syngas engine.
- Site will include a unique syngas testing facility.
  - First use will demonstrate an innovative high yielding methanol synthesis process

Currently looks like…

Going to look like…



Conclusions and next steps

- Gasification offers a number of benefits in the UK setting
  - Flexible in feedstock and outputs - resiliance
  - Comparable/better efficiencies compared with other technologies, especially at smaller scales: cleaned syngas permits the use of higher efficiency generating processes such as engines
  - Scalable, especially down to the “town scale” of around 5-10 MWe
  - Ability to integrate with CCS to deliver negative emissions
- Gasification of wastes and use of syngas in an engine is technically feasible - ETI’s targets are achievable
- Potential to be cost competitive with other sources of renewable power - scope to reduce costs as experience is gained (especially procurement costs).
- To build confidence in financing and delivering, UK policies should be designed as an integrated programme of stages
- Careful and considered approach to scale up is needed
- ETI’s work in gasification is now culminating in its partnership with Syntech to build a 1.5 MWe gasification power project in Wednesbury, north west of Birmingham.
- Insights paper: Targeting new and cleaner uses for biomass and wastes using gasification - Publication Mid June from www.eti.co.uk

Registered Office
Energy Technologies Institute
Holywell Building
Holywell Park
Loughborough
LE11 3UZ

For all general enquiries telephone the ETI on 01509 202020

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