Gasification at the Crossroads

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Just What Do We Do With Gasification?

• It’s well established – but there’s extensive development and progress ongoing
• There is significant potential to improve gasification project economics through the application of new technologies – but is this enough?
• It’s such a flexible process but is it the process of last resort?
• Is it a subsidy junkie?
• If it’s not broadly competitive now, will it ever be and just what do we have to do gain a wider investor acceptance for the technology?
• If “unburnable carbon” is real (i.e. CO₂ emissions will be restricted) how does this affect gasification?

*Unburnable carbon refers to fossil fuel energy sources which cannot be utilized if the world is to adhere to a given carbon budget; refer to:
http://www.carbontracker.org/resources/
Just What Is Happening Out There With Gasification?

- Significant investments in coal based chemicals and SNG in China using Western (& increasingly Chinese) technology
  - The vast majority of gasification investment is in China which reflects a hugely advantaged cost position for local coal
  - Indonesia, India & Pakistan also show potential for investments

- There’s a lot of focus on gasification of opportunistic fuels in other locations – petcoke, commercial & industrial waste, MSW, biomass. Waste & biomass gasification require technology to be commercialised with significant scale assets

- Gasification of coal in N America is in trouble with advent of cheap gas

- Power from gasification of fossil fuels really struggles to make sense. IGCC is no longer the focus of gasification – chemicals and SNG are.

- Technology is being improved but only slowly
### Target Markets – where the added value is

The commercial attractiveness of a project is indicated by its end-product market pricing.

<table>
<thead>
<tr>
<th>Gasification</th>
<th>Product/Volume/Prices*</th>
<th>Revenue / t of coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 t coal (sub-bituminous)</td>
<td><strong>420 Nm³ SNG</strong> (@ 3.5 USD/mmBtu)</td>
<td>50 USD</td>
</tr>
<tr>
<td>1,600 Nm³ Syngas (CO + H₂)</td>
<td><strong>2.4 MWhel Power</strong> (@ 60 USD/MWh)</td>
<td>145 USD</td>
</tr>
<tr>
<td><strong>420 Nm³ SNG</strong> (@ 15 USD/mmBtu)</td>
<td><strong>0.19 t Polypropylene</strong> (@ 1,580 USD/t)</td>
<td>225 USD</td>
</tr>
<tr>
<td></td>
<td><strong>0.72 t Methanol</strong> (@ 450 USD/t)</td>
<td>300 USD</td>
</tr>
<tr>
<td></td>
<td><strong>95 gal Gasoline</strong> (@ 3.5 USD/gal)</td>
<td>325 USD</td>
</tr>
<tr>
<td></td>
<td><strong>0.98 t Ammonia</strong> (@ 450 USD/t)</td>
<td>330 USD</td>
</tr>
</tbody>
</table>

* Applied end-product market prices may differ to actual prices  ** SNG... Substitute Natural Gas

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- Polypropylene, SNG and gasoline are relative recent developments for Syngas. This underlines the scale of change in industry.
Gasification Has Driven Technology Innovation In Chemicals

- Naphtha is an overpriced feedstock for chemicals in real danger of being edged out by alternative feedstocks and processes
- The overwhelming cost advantage of coal over gas and oil in China has driven a series of technology innovations in petrochemicals; this has enabled a much broader range of petrochemicals to be produced which have been traditionally sourced from gas and naphtha feedstocks
- Methanol-to-olefins is now a proven and established process and enjoying considerable investment
- New routes from syngas to mono-ethylene glycol (MEG) have been recently commercialised
- Potentially other chemicals such as aromatics are opening up a range of new opportunities for syngas conversion
- Transport fuels are also increasingly targeted

All the above is great news for gasification – or is it?
Great News for Gasification? Yes!

- Gasification
  - Syngas
    - Methanol
      - Dehydration
        - DME
      - Combined Cycle
        - Power
        - Methanol
      - Polymerization
        - Polyolefins
        - Petrochemicals
        - Gasoline / diesel
      - MTO
        - Olefin derivatives
      - Methanol to Gasoline
        - Sulphur/ Sulphuric acid
        - CO₂ sequestration
        - CO
        - Power
        - Hydrogen
  - Substitute Natural Gas
  - Fischer Tropsch Liquids
  - Ammonia/Urea
  - Acetic acid/misc Chemicals
  - MEG /Aromatics

- Biomass
- Coal
- Refinery residues
- Petroleum Coke
- Wastes

- Traditional
- Newly developed

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Great News for Gasification? – No!

- Partial Oxidation
- Steam Reforming
- Autothermal Reforming
- Natural Gas
- Syngas
- Biomass
- Coal
- Refinery residues
- Petroleum Coke
- Wastes
- Gasification
- Syngas
- Methanol
- Hydrogen
- CO
- Power
- CO\textsubscript{2} sequestration
- Sulphur/ Sulphuric acid
- MEG/ Aromatics
- Acetic acid/misc Chemicals
- Ammonia/Urea
- Fischer Tropsch Liquids
- Substitute Natural Gas
- MTO
- Polymerization
- Olefin derivatives
- Methanol to Gasoline
- Ultra Clean Fuels
- DME
- Power
- Methanol
- Combined Cycle
- MEG/ Aromatics
- Petrochemicals
- Gasoline / diesel
Great News for Gasification – No!

Who moved my cheese? Cheap gas

• The problem is called natural gas, or more specifically methane
• The recent and developing technology innovations in China, allowing syngas to be converted to olefins and other products, are equally applicable to reforming and partial oxidation of natural gas
• So who uses gasification in preference to low cost methane? Virtually everyone moves to cheap natural gas when available
• Low cost gas is hugely advantaged over crude oil derived feedstocks
• Low cost gas is THE most efficient and environmentally friendly route to many chemicals and (fossil) power, and outperforms coal conversion at just about every level:
  – Significantly lower capex
  – Higher carbon and thermal efficiency
  – Better environmental performance
  – Easier feedstock logistics
Main areas of interest are:

1. What technology innovations and improvements can we look forward to that will make gasification more competitive?

2. What are the feedstocks for which gasification provides a potential or only route to market?
   - Coal in certain regions
   - Biomass
   - Industrial and municipal waste (C&I, MSW)
   - Hazardous waste
   - Hydrocarbon rich residues and petroleum coke
   - Feedstocks that are either very low cost or even negative value
Gasification is a process that has been developing for many years. It is still regarded by many as being:

- Expensive and complicated
- Less reliable than many alternative processes
- Less thermally and carbon efficient than many competing processes

But in many instances is still in its infancy and many improvements are being made – will this make it competitive?

We’re looking for disruptive and transformative improvements in technology, not evolutionary improvements.

If Gasification is to be widely adopted it has a performance mountain to climb.
First the bad news

- There is a fundamental problem that gasification has to face; major improvements to rival processes come from three main technology areas:
  1. The development and use of catalysts has transformed processes by increasing efficiencies and reducing CAPEX, and has opened up new process routes to product. Catalysts do not look likely for the gasification step. Gasification uses heat to break chemical bonds, catalytic processes have reduced energy demands for bond breaking and higher selectivity
  2. Biotech looks neither appropriate nor possible
  3. “Unburnable carbon” theory is gaining ground; there are far more fossil fuel resources available to burn than the atmosphere can handle; carbon inefficient technologies will be significantly disadvantaged

And some potential good news

- Areas of process improvement for gasification investments that do look interesting are:
  - Oxygen Transport Membrane (OTM) or Ion Transport Membrane (ITM)
  - Warm syngas clean-up
  - SNG technology improvements
- Underground gasification of coal could potentially reduce the capital cost and schedule for projects and open up previously inaccessible coal reserves

Let’s examine these potentials.
OTM

IGCC Integration Concept *(NG+Coal)*

Benefits of OTM-Enhanced IGCC + Coal-to-Liquids vs IGCC
- Smaller cryo ASU
- Smaller shift reactor
- Higher conversion of carbon to CO
- Improved syngas quality for liquids synthesis
- Reduction in carbon footprint by more than 40%

**“Perfect” oxygen separation driven by reaction with coal syngas**

Warm Syngas Clean-Up

Technology being developed by RTI International

• Process being developed to recover all forms of sulphur from syngas
  – Multi-contaminant fixed bed sorbent systems also included
  – Other developments and applications being researched

• Advantages claimed:
  – Potential 2-3% improvement in overall integrated gasification combined cycle (IGCC) thermal efficiency
  – Significant capital cost reduction
  – Will have a more beneficial impact on high S (& therefore low cost) feedstocks

• Status
  – Pilot plant development undertaken with Eastman Chemicals in Kingsport, TN
  – Pre-commercial scale demonstration unit completed in Florida (Tampa Electric Polk County) early in 2014, now operational

Underground Coal Gasification (UCG)

UCG is the gasification of coal in-situ underground

• Advantages
  – Can access un-mineable coal seams and reduce the cost of coal and simplify logistics; developer potentially buys the land not the coal
  – Significant cost reduction potential in eliminating the gasification island (gasification island is about 25% of an IGCC plant)

• Downsides
  – Carbon and thermal efficiencies are not as high as for conventional gasification of coal
  – Issues over public perception (such as underground water contamination) and lack of clarity on permitting guidelines
  – Integration with other processes looks more difficult

• Status:
  – Numerous pilot schemes in place
  – Full commercial operation 10 years away?
Foster Wheeler’s VESTA SNG Process

*Targets SNG production from low cost coal and distressed refinery residues*

- Developed by Foster Wheeler
- Process patented
- Catalyst exclusively supplied by Clariant
- Advantages
  - Lower process temperatures max. 550°C
  - Simpler metallurgy and cheaper reactors
  - No recycle compressor
  - High quality CO₂ recovery
  - Highly flexible steam export options
  - Lower CAPEX than existing processes (approx. 20%)
- Status
  - Demonstration plant completed mid-2014 in China and now operational for tests
- What is FW offering?
  - Process design package together with license
  - FEED (at Client request)
  - EPC (at Client request)
**What Else Is Happening Out There That Affects Gasification?**

### CO₂ as a carbon source

- Very significant efforts in catalysis are being undertaken to create hydrocarbons and chemicals from CO₂
  - I believe that commercially viable processes will be demonstrated within the next decade – have faith in technology developers – this will happen
  - Potentially of benefit to gasification as CO₂ captured in the gasification process could prove a very competitive CO₂ source
  - A market that values CO₂ as a source of carbon could significantly and positively change economics (no CCS) whilst enhancing the environmental performance of gasification
  - CC is OK but CCS is unlikely ever to be attractive (without significant subsidy or compulsion) except in very specific circumstances. Avoidance at all costs is likely response strategy
  - Competing processes such as reforming and partial oxidation also benefit

### Renewable Power & Energy Storage

- Over the past 5 years levelized costs of power from wind have halved and from solar have more than halved; these two technologies are dominating new power investments in many regions
- Over the next decade energy storage will take meaningful strides in scale and efficiency increasing our ability to manage intermittent generating plant; gasification of fossil fuels for power will not be able to compete
If coal is not a competitive player in most markets then where does the future lie for gasification?

As a technology of last resort for difficult wastes and biomass based products.

- If renewable energy targets (e.g. International Renewable Energy Agency REMap 2030 [http://irena.org/remap/](http://irena.org/remap/)) then surely gasification has a key role to play

- Two examples commercialised at small scale:
  - AlterNRG plasma gasification for WTE (operating plant but current builds significantly scale-up by factor of 10)
  - Foster Wheeler biomass gasification

These processes, whilst representing environmentally the best solution, will typically only progress with subsidies and there is also a scale issue for syngas conversion competitiveness.
Air Products Tees Valley

- 2 x 1000t/d WTE plants based on AlterNRG plasma gasification
- Feedstock – municipal solid waste (MSW) – pre-sorted
- Each plant generates 50MWe with GT combined cycle
- Technology suited for wide variety of industrial, chemical and hazardous waste, tyres, biomass or a mix of the above
- Foster Wheeler is the selected contractor

Foster Wheeler is looking at a number of similar projects
Target Feedstocks

Gasification of Biomass using Foster Wheeler’s CFB technology

- 11 gasifiers built in 1981-2008
- Readiness to offer atmospheric plants for over 100 MWth air-blown applications for various wood and waste based fuels
- Readiness to offer pressurized oxygen-steam blown gasifiers up to ~300 MW for biorefinery applications with wood based fuels
- Development program to increase the plant efficiency further
- Process conditions according to fuels and applications

Long history (originally developed in the late 70s) → Commercial applications → New developments in progress

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In Summary

It’s not going to be easy but there is light ahead

• Gasification is expensive to build and operate so struggles to complete
• There is potential to improve economics of gasification but the majority of this improvement is to be expected in processes around the gasifier and therefore are not unique to gasification
  – Competitor processes (reforming and partial oxidation of gas) have typically benefited equally in the advance of new processes to convert syngas to product
• Significant progress can be made in gasification of difficult feedstocks/fuels for applications such as WTE
• Whilst gasification is under significant long term pressure, particularly from gas-based technologies, developments in the use of CO₂ as a carbon source could be instrumental in wider uptake
• If “unburnable carbon” theory gains global acceptance then the least carbon efficient technologies will be hugely disadvantaged
• Gasification remains the technology of last resort for a number of problematic wastes and currently, in most cases, needs significant incentives/subsidies
• If renewable fuels are to be fully exploited then gasification does have a role
Thank you for your attention

Time for questions
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