Compact GTL as an Associated Gas Solution
Pilot Plant & Commercial Factors

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Iain Baxter
CompactGTL plc
GTL as an associated gas solution

- Market background & alternatives
- Technical & commercial factors
- CompactGTL technology description
- Pilot Plant – UK
- Pilot Plant – Brazil
- Commercial plant studies
Associated gas is a huge global problem

- **Re-injected**
  - 14 TCF

- **Flared**
  - 6 TCF
  - = 27% of annual US gas consumption!

- ~4 TCF
  - Not used to enhance oil recovery

- > 10 TCF (= 4.6 mmboe per day)

Satellite image of gas flaring in Nigeria
Distressed Gas – an increasing E&P challenge

**Environmental Issues**
- New fields not allowed to flare
- Existing fields risk shut-in or financial penalties

**Gas Re-injection**
- High cost – wells in deepwater can cost $200 to $250 million
- Gas breakthrough risks, limits production, threat to reserves

**Wasted Hydrocarbon ‘Asset’**
- Gas un-bookable as “reserves”
- Governments concerned by national resource issues

**Gas Infrastructure Issues**
- High cost of pipelines in remote or deepwater areas
- Multi-party, complex infrastructure projects take time
Current offshore gas management options

- Employ gas as FPSO fuel source
- Pipe gas to onshore infrastructure
- Re-inject gas into reservoir
- Flare gas
Emerging gas utilization options

• **CNG**
  – High infrastructure cost
  – Economics favourable at 200+ MMscfd
  – Concepts being developed
  – Economics dependent on distance to shore

• **FLNG**
  – High infrastructure cost
  – Economics favourable at 400+ MMscfd
  – Project studies underway

• **Gas to Wire**
  – High cost for deep water and remote fields
  – Needs local market for power
  – Economics dependent on distance to shore
Integrate the GTL plant with the production facility
Convert the associated gas into syncrude
Co-mingle and transport with the natural crude
Workable solution - technical factors

• **Safety**
  – No oxygen supply required
  – Offshore certification

• **Operability & Reliability**
  – No catalyst handling on facility
  – Exchangeable 25 tonne reactor modules
  – Handles high CO2 gas
  – Handles variable gas composition & flow-rate

• **Seaworthiness**
  – Low liquid inventory
  – Low C.O.G.
  – Motion insensitivity

• **Scaleability**
  – Accommodates production decline over field life
Commercial factors – field development

- **Time**: Acceleration….
  - Avoid multi-party gas infrastructure negotiations
  - Overcome flaring restrictions

- **GTL Capex**: Offset by….
  - Savings in gas re-injection wells & equipment
  - Savings in gas pipeline infrastructure

- **Revenue**: Increased….
  - Additional syncrude revenue
  - No additional storage / transport / market costs

- **Reserves**: Increased….
  - Distressed gas now bookable as reserves

**Project Enabler**
**Enhanced Oilfield NPV**
## Indicative economics

### PRE-TAX Incremental Economics – Oilfield FPSO Project

GTL module replaces $250 MM Re-injection well

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed gas at first oil</td>
<td>20 MMscfd</td>
</tr>
<tr>
<td></td>
<td>[converts to 2,000 bpd syncrude]</td>
</tr>
<tr>
<td>Feed gas at end of field life [15 years]</td>
<td>5 MMscfd</td>
</tr>
<tr>
<td></td>
<td>[converts to 500 bpd syncrude]</td>
</tr>
<tr>
<td>Incremental capex</td>
<td>$ 50 MM</td>
</tr>
<tr>
<td>Oil price [assume natural crude]</td>
<td>$ 75 / bbl</td>
</tr>
</tbody>
</table>

**PRE-TAX Incremental Oilfield NPV** $ 150 MM

### Pre-TAX IRR Sensitivity

![Pre-TAX IRR Sensitivity Diagram](image)
Process overview

**Gas Treatment**
- Gas feed
  - Pre-wash
  - Mercury removal
  - Heating
  - Sulphur removal

**Syngas Production**
- SMR 1 reactor modules
- SMR 2 reactor modules
- Steam generation (WHB)
- Synch gas compressor
- Steam
- Water treatment

**FT Synthesis**
- FT 1 reactor modules
- FT 2 reactor modules
- FT cooling system
- Product flash
- HC rich tail-gas
- GT drivers
- H₂ rich tail-gas
- Syncrude

*No Oxygen Required!*

*High CO₂ Possible!*
Compact mini-channel reactors are key

- High heat transfer plate & fin reactor construction
- High specific heat input to SMR reaction
- High specific heat removal from FT reaction
Process intensified mini-channel SMR

Compact SMR Reactor

- SMR catalyst foil inserts
- Combustion catalyst foil inserts

SMR Stream

Combustion Stream

High heat transfer from Combustion stream into SMR process stream
SMR mini-channel reactor layout

- Fuel & Combustion Air
- Combustion Layer
- Combustion Exhaust
- Methane & Steam
- Reforming Layer
- Complete SMR Reactor Block
- Syngas
Process intensified mini-channel FT

Compact FT Reactor

FT catalyst foil inserts

High heat transfer from FT process stream into coolant stream
FT mini-channel reactor layout

SYNGAS IN

FT PROCESS LAYER

COOLANT IN

COOLANT LAYER

COOLANT OUT

COMPLETE FT REACTOR BLOCK

FT PRODUCT OUT

FT PRODUCT OUT
Mini-channel reactor benefits

**Catalysts :**
- Removable inserts
- Coated foil inserts based on established automotive mass production techniques

**Reactors :**
- High specific heat transfer
- Based on established plate-fin heat exchanger mass production techniques
- High reactor 'voidage' using pressed fin plates, minimising metal content, cost & weight

Technology Partners

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Modular plant design gives scaleability, inherent redundancy and operability

- Modules can be removed as production falls
- Modules re-furbished and catalyst replaced onshore
- Modules can go on-line and off-line to accommodate production variability
- Methanol or ethanol used as supplemental and start-up SMR fuel

The number of active reactor modules can be adjusted to match the associated gas production profile over time.
UK Pilot plant achievements

Installation at Wilton, NE England

Plant commissioned July 2008

- Confirming catalyst & reactor performance from manufacturers
- Integrated operation – ‘gas in to liquids out’
- Operational stability, start-up & shut down procedures
- Variable feed gas composition & CO₂ content
- Operator training for larger plants
Inside the UK pilot plant

SMR process equipment

FT process equipment
Brazil pilot plant

- 200,000 scf gas (20 bpd)
- FATs Completed
- Shipping in stages – Commissioning commences July
- Joint testing with Petrobras at commercial process conditions
- Commercial scale reactor blocks and catalyst inserts
- All aspects of process, gas treatment, steam generation etc
Brazil pilot plant

Under construction in Canada [Nov 2009]
Pilot plant reactors

Completed brazed pilot reactor block in Japan [Dec 2009]

Building block for commercial reactor modules
Commercial plant studies

Conceptual designs completed:
• 50 MMscfd plant
• 10 MMscfd plant
• 2 MMscfd plant

Client offshore projects:
• 2 MMscfd plant feasibility (completed)
• 10 MMscfd plant pre-FEED (commenced)
Commercial plant layout

- 10 MMscfd gas feed
- 1,000 bbl/d syncrude production
- 2,400 T operating weight
- Configurable for:
  - Aframax
  - Suezmax
  - VLCC

SMR modules

FT modules

Dimensions:
- 29 m
- 48 m
Summary

• True ‘standalone’ solution
• Strong economics where gas infrastructure or re-injection are avoided
• Key engineering aspects identified & addressed by pre-FEED studies
• Technology verified by major independent groups
• Operability & complete process verified by UK pilot plant
• Manufacturing route & partners established
• Large scale testing imminent at Brazil pilot plant

CompactGTL solution @ 2-50 MMscfd integrated with FPSO
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