ARCHER HTR in support of a Coal-to-Liquids process. An economic feasibility view
Weihai, 28 October 2014

Prof Pieter Stoker
HTR/CTL An economic feasibility view

Overview

• Introduction
• Financial feasibility modeling
• Results & findings
• Further work – NC2I
Introduction

• RSA- case study: Coupling of the European HTR to a typical CTL process
• Baseline: Sasol Secunda – West Plant
• Approx. 80,000 bpd Syncrude
• In operation since 1995
HTR/CTL: An economic feasibility view

Introduction Secunda West Plant
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Introduction

• Plant cost baseline 2012 – based on numbers reported for project Mafutha
• Mafutha is a new 80,000 bpd CTL plant
• Mafutha is currently on hold, due to uncertainty iro carbon taxation, CCS and high capital cost
Overview

- Introduction
- Financial feasibility modeling
- Results & findings
- Gap and SWOT analysis
- Further work – NC2I
Financial feasibility modeling - philosophy.
Most important KPIs: IRR>6%
          : CO2 emission savings >30%

Secunda Plant is an assembly of BUSINESS UNITS

Input: commodity streams at purchase prices
Business Unit #1
• Convert input to output according to process requirements.
• **Account for externalities** - e.g. carbon tax
• Determine selling price to meet IRR>6%
Output: value add commodity streams at selling prices
BU #2
BU #3
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Financial Feasibility Modeling supported by extensive process modeling:

Financial Feasibility modeling: First Principles

Mass and Energy Balances of intermediate products & utilities streams

Nuclear & Coupling - FLOWNEX  Chemical Process Modeling: ASPEN
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Three scenarios were modelled:

- **Scenario S0**: Baseline. Secunda West Plant as is
- **Scenario S1a**: Baseline + replace electricity from the grid with electricity from NSSS (Nuclear Steam Supply System)
- **Scenario S1b**: Baseline + replace electricity from the grid and supply the 40bar CTL steam need from NSSS

* ARCHER NSSS “plug-and-play” building block:
  Two x $265\text{MW}_{\text{th}}$ pebble bed reactors
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Results and findings: Scenario S0. Baseline
### Plant level mass balance

<table>
<thead>
<tr>
<th></th>
<th>ton/h simulation</th>
<th>mton/Y simulation</th>
<th>mton/Y Analyst book/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>2163</td>
<td>18.95</td>
<td>18.95</td>
</tr>
<tr>
<td>O2</td>
<td>2578</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>5795</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10536</strong></td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Outputs</th>
<th>ton/h simulation</th>
<th>mton/Y Simulation</th>
<th>mton/Y Analyst book/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refined product</td>
<td>209</td>
<td>1831</td>
<td>1790</td>
</tr>
<tr>
<td>Heating fuels</td>
<td>36</td>
<td>313</td>
<td>340</td>
</tr>
<tr>
<td>Gasification products</td>
<td>32</td>
<td>281</td>
<td>280</td>
</tr>
<tr>
<td>Alcohols and ketones</td>
<td>32</td>
<td>285</td>
<td>280</td>
</tr>
<tr>
<td>Chemical feedstocks</td>
<td>91</td>
<td>795</td>
<td>820</td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
<td>79</td>
<td>80</td>
</tr>
<tr>
<td><strong>Total saleable products</strong></td>
<td><strong>409</strong></td>
<td><strong>3583</strong></td>
<td><strong>3590</strong></td>
</tr>
</tbody>
</table>

| CO2       | 3306             |                   |                        |
| Ash       | 587              |                   |                        |
| Process waste water  | 5336             |                   |                        |
| Other     | 891              |                   |                        |
| **Total waste streams** | **10121**      |                   |                        |
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Results and findings: Scenario S0. Baseline. Operating cost

<table>
<thead>
<tr>
<th>vs. Analyst Book</th>
<th>Material Coal</th>
<th>Operating cost Material Other</th>
<th>Manpower</th>
<th>Electricity</th>
<th>Water</th>
<th>Maintenance O/heads</th>
<th>other</th>
<th>sub-total</th>
<th>Balance to Corporate Overhead</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,323</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5016</td>
<td></td>
<td>1718</td>
</tr>
<tr>
<td>6734</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Allocation to BUs

- STB (Steam Boiler): 1,333, 136, 38, 214, 84, 28, 241, 2073
- GEN (Power Station): 29, 0, 46, 18, 6, 52, 151
- ASU (Air Separation Unit): 97, 733, 153, 60, 20, 172, 1235
- LGG (Lurgi Gasifier): 2,666, 243, 52, 383, 150, 50, 429, 3973
- ASH (Ash Handling System): 39, 38, 61, 24, 8, 69, 238
- WDS (Water Distribution System): 19, 75, 177, 31, 12, 4, 34, 352
- REC (Rectisol Plant): 58, 90, 92, 36, 12, 103, 391
- SAS (Gasol Advanced Synthesis): 325, 68, 60, 107, 42, 14, 120, 736
- CSU (Cold Separation unit): 58, 188, 92, 36, 12, 103, 489
- SMR (Steam Methane Reforming): 39, 60, 61, 24, 8, 69, 261
- Product Workup Systems (PWS): 185, 203, 291, 114, 38, 326, 1157

|                      | 3998 | 325 | 972 | 1537 | 177 | 1530 | 600 | 200 | 1718 | 11057 |

Proof: 0
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Results and findings: Scenario S0. Baseline.

Validating the Economic Feasibility Model

• Cash operating margin (2012) for Secunda West Plant is available from Analyst book (EBITA = Earnings Before Interest, Tax, Amortization)
• Overnight cost to build SWP in 2012 based on escalated Mafutha cost
• Overall IRR was thus easily calculated: 8.1%

EBITA for each BU’s was calculated; IRR then follows; Consolidation of BUs Income and Expenses should reveal plant EBITA and IRR:
Results and findings: Scenario S0. Baseline.

Conclusion. We now have:

- An accurate mass balance for SWP, and
- A validated Economic Feasibility Model for the plant

....which enables us to:

- Do sensitivity analysis
- “Plug-and-play” alternative technology solutions and compare their performance with the status quo
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Results and findings: HTR electricity as a function of nuclear plant overnight cost and IRR hurdle rate:
Results and findings: Scenario S1a). Replace power from grid. Given Nuclear high and low cost – what is the effect on CLT IRR? (Divide by 8 to get USc/KWe)

<table>
<thead>
<tr>
<th>Power scenario</th>
<th>Cost of O2 (R/ton)</th>
<th>CTL Plant IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eskom</td>
<td>580</td>
<td>8.1%</td>
</tr>
<tr>
<td>Nuclear low</td>
<td>727</td>
<td>6.8%</td>
</tr>
<tr>
<td>Nuclear high</td>
<td>908</td>
<td>4.8%</td>
</tr>
</tbody>
</table>

NSSS = a marginal proposition

NSSS = not a viable proposition
Results and findings: Scenario S1b). S1a) + nuclear steam – what is the effect on CLT IRR?

Plug-and-play assumptions
- 8 NSSSs (16 reactors)
- Fuel cost 1$/GJ
- IRR NSSS project = 6%
- All-in operating cost 8% of O/night cost
- Coal saved by CTL plant sold at 80% of FOB price
- CTL O/night cost reduced (STB)
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Results and findings: Scenario S1b). S1a) + nuclear steam –

Conclusions

It is concluded that the economic feasibility challenge for large scale deployment of nuclear energy in a Coal-to-Liquid application - where steam and electricity are to be generated from nuclear energy, is to construct such a facility at an all-inclusive overnight cost not exceeding $3400/kWe.

• CO₂ emission of the Secuda West Plant (Baseline) is 29 million ton/year
• CO₂ emission of Scenario S1b) is approximately 14.2 million ton/year
• A 51% saving in CO₂ emission.
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- Nuclear Hydrogen and Oxygen
- Alternative gasification technology
- Alternative methane reforming technology

We are investigating the above as part of FP7 project NC2I (European Nuclear Cogeneration Industrial Initiative)
Thank You