Integrated assessment of feasibility of coal-to-chemical projects

Dr Nikolai Kinaev
Dr Alexey Belov
Dr Geoff Bongers
Igor Grebenyuk
Ilya Vinichenko
Coal-to-chemicals Overview

The production of chemicals or fuels from coal (CtX) may be carried out directly or indirectly. Here we are considering indirect pathway only.
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The production of chemicals or fuels from coal (CtX) may be carried out directly or indirectly. Here we are considering indirect pathway only.
CtX project feasibility Overview

Feasibility of CtX project depends on the number of factors, and they none of these factors could be excluded.

CtX project is feasible when:

• There are available coal resources; and
• Technology is mature enough to deliver; and
• It could be done economically (e.g. LCOP is equal or less than market price of the product;)
• The environmental risks are understood and could be managed;
• And it provides a positive socio-economic impact on the region.
Coal resources availability

Type of available coal resources determines the choice of surface gasification technology.

- Fixed bed and fluidised bed gasifiers are most suited to lower rank coals.
- Entrained flow gasifiers are most suited to higher rank coals.
- Dry fed entrained flow gasifiers has the widest range of preferred coal types based on rank.
- Although entrained flow gasifiers can process all ranks of coal the existing commercial gasifiers all show a marked increase in cost and reduced performance with low rank and high ash coals.
Coal resources availability

- A wide variety of coals are amenable to the UCG process. Main factors to be taken into account in selecting appropriate locations for UCG are:
  - Ash content less than 50% - including any dirt bands, as coal gasification maybe impeded
  - Low rank high volatile coals preferred, but may also work for some non-coking bituminous coal
  - Adjacent aquifers contain poor quality water and have minimal permeability
  - Coal resource for long term operation (>5Mt)
  - Seam thickness not less than 1 m for bituminous and 2 m for sub-bituminous and brown coals
  - Seam depth should be >100 m (preferably 300-600 m for horizontal drilling, and 300 -1000 m for vertical wells) with minimum faulting and no dips/sills. Thicker coal seams required higher depth.
  - Roof thermally stable with minimal permeability, preferably structured to encourage even caving.
  - Population density is important, as high population density may result in serious public perception issue.
  - Infrastructure available for the product transport.
  - Availability of skilled workforce.
# Technology availability – technology readiness levels

<table>
<thead>
<tr>
<th>Development Stage</th>
<th>TRL</th>
<th>DOE Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Operation</strong></td>
<td>TRL 9</td>
<td>Actual system operated over the full range of expected mission conditions.</td>
</tr>
<tr>
<td><strong>System Commissioning</strong></td>
<td>TRL 8</td>
<td>Actual system completed and qualified through test and demonstration.</td>
</tr>
<tr>
<td></td>
<td>TRL 7</td>
<td>Full-scale, similar (prototypical) system demonstrated in relevant environment</td>
</tr>
<tr>
<td><strong>Technology Demonstration</strong></td>
<td>TRL 6</td>
<td>Engineering/pilot-scale, similar (prototypical) system validation in relevant environment</td>
</tr>
<tr>
<td><strong>Technology Development</strong></td>
<td>TRL 5</td>
<td>Laboratory scale, similar system validation in relevant environment</td>
</tr>
<tr>
<td></td>
<td>TRL 4</td>
<td>Component and/or system validation in laboratory environment</td>
</tr>
<tr>
<td><strong>System Operations</strong></td>
<td>TRL 3</td>
<td>Analytical and experimental critical function and/or characteristic proof of concept</td>
</tr>
<tr>
<td><strong>Basic Technology Research</strong></td>
<td>TRL 2</td>
<td>Technology concept and/or application formulated</td>
</tr>
<tr>
<td></td>
<td>TRL 1</td>
<td>Basic principles observed and reported</td>
</tr>
</tbody>
</table>
Technology availability – commercial readiness levels

- **CRL 6**
  - Bankable asset class driven by same criteria as other mature energy technologies
- **CRL 5**
  - Market competition driving widespread deployment in context of long term policy settings
- **CRL 4**
  - Multiple commercial applications becoming evident locally and globally driven by policy/subsidies
- **CRL 3**
  - Commercial scale up occurring driven by specific policy
- **CRL 2**
  - Commercial trial: Small scale, first of a kind underway funded by equity and government project support
- **CRL 1**
  - Hypothetical Commercial Proposition: Technically ready - commercially untested and unproven

Source: ARENA (NASA for TRL)
Technology availability – current status

- Coal gasification
  - Syngas
  - Syngas conditioning and shift reaction
  - Chemical plant
  - Products

- Natural gas reforming
  - Syngas
  - Shift reaction
  - Chemical plant
  - Products

CO₂
Economic assessment – LCOP

Definition of Levelised Cost of Product

\[
LCOP = \frac{\text{Normalised money spent through the project life}}{\text{Normalised product obtained through the plant life}} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + V_t + F_t}{(1 + r)^t}}{\sum_{t=1}^{n} \frac{P_t}{(1 + r)^t}}
\]

- \(LCOP\) is the levelised cost of product
- \(I_t\) is the investment expenditure in the year \(t\), calculated with the WACC that takes into account tax depreciation using straight linear depreciation method.
- \(M_t\) is the fixed O&M expenditure in the year \(t\)
- \(V_t\) is the variable O&M expenditure in the year \(t\)
- \(F_t\) is the feedstock (fuel) expenditure in the year \(t\)
- \(P_t\) is the product output in the year \(t\)
- \(r\) is discount rate
- \(n\) is the life of the plant
## Economic assessment – LCOP

### Financial Assumptions – typical Australian set

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Nominal</th>
<th>Real</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset book life</td>
<td>30 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset tax life</td>
<td>30 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation Rate (CPI Escalation)</td>
<td>2.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corporate Tax Rate</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property Tax / Insurance</td>
<td>2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debt Financing Percentage</td>
<td>70%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Equity</td>
<td>11.50%</td>
<td>8.78%</td>
<td></td>
</tr>
<tr>
<td>Cost of Debt</td>
<td>8.00%</td>
<td>5.37%</td>
<td></td>
</tr>
<tr>
<td>WACC before tax</td>
<td>10.53%</td>
<td>7.83%</td>
<td></td>
</tr>
<tr>
<td>WACC after tax</td>
<td>7.37%</td>
<td>4.75%</td>
<td></td>
</tr>
</tbody>
</table>
## Economic assessment – LCOP

### Plant Cost – typical Australian set

<table>
<thead>
<tr>
<th>Product</th>
<th>Plant Capacity</th>
<th>Total Capital Required $ B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syngas</td>
<td>49,000 GJ/hour</td>
<td>12.00</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>320,000 kg/hour</td>
<td>12.00</td>
</tr>
<tr>
<td>FT products</td>
<td>80,0000 bbl/day</td>
<td>14.20</td>
</tr>
<tr>
<td>Methanol</td>
<td>500 Tonnes/hour</td>
<td>13.10</td>
</tr>
<tr>
<td>Ammonia</td>
<td>470 Tonnes/hour</td>
<td>13.10</td>
</tr>
<tr>
<td>Urea</td>
<td>830 Tonnes/hour</td>
<td>13.65</td>
</tr>
</tbody>
</table>
## Economic assessment – LCOP

Average Market Costs on Global Market

<table>
<thead>
<tr>
<th>Product</th>
<th>Midpoint LCOP</th>
<th>Market price</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syngas</td>
<td>10.7</td>
<td>8</td>
<td>$/GJ</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>4.7</td>
<td>5</td>
<td>$/kg</td>
</tr>
<tr>
<td>FT products</td>
<td>124</td>
<td>90</td>
<td>$/bbl</td>
</tr>
<tr>
<td>Methanol</td>
<td>673</td>
<td>430</td>
<td>$/tonne</td>
</tr>
<tr>
<td>Ammonia</td>
<td>674</td>
<td>580</td>
<td>$/tonne</td>
</tr>
<tr>
<td>Urea</td>
<td>363</td>
<td>360</td>
<td>$/tonne</td>
</tr>
</tbody>
</table>
Economic assessment – LCOP

LCOP – typical Australian set

**CtX LCOP  Standard Australian set of assumptions**

- Raw syngas
- F-T products
- MeOH
- Ammonia
- Urea

**Commercially Viable**
Economic assessment – LCOP

LCOP – Structure

![Bar chart showing the cost breakdown for different products: Raw syngas, H2, F-T products, MeOH, Ammonia, Urea. The chart indicates the percentage contributions of Cost of Carbon, Fuel Costs, Variable Operating & Maintenance, Fixed Operating & Maintenance, and Finance Charges to the Normalised LCOP for each product.](image-url)
Economic assessment – LCOP
LCOP – typical Australian set

CtX LCOP  Stanadard Australian set of assumptions

- Raw syngas
- F-T products
- MeOH
- Ammonia
- Urea

Commercially Viable
Economic assessment – LCOP

LCOP – typical Australian set

CtX LCOE  Cost of Debt down to 4%

Raw syngas
H2
F-T products
MeOH
Ammonia
Urea

Commercially Viable
Economic assessment – LCOP

LCOP– typical Australian set

![Diagram showing CtX LCOP 30% project cost reductions](attachment:diagram.png)

- MeOH
- F-T products
- Ammonia
- Urea

Commercially Viable

LCOP (AUD/Production unit)/market price

- Raw syngas
- H2
Economic assessment – LCOP

LCOP – decrease of debt and project costs

Diagram showing the combined decrease of project and debt costs for different products:
- MeOH
- Raw syngas
- F-T products
- Ammonia
- Urea

The diagram indicates that H2 and Ammonia are commercially viable.
# Environmental impact

## CO₂ footprint

<table>
<thead>
<tr>
<th>Product</th>
<th>Syngas</th>
<th>H₂</th>
<th>F-T products</th>
<th>MeOH</th>
<th>NH₃</th>
<th>Urea</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production unit</strong></td>
<td>GJ</td>
<td>kg</td>
<td>bbl</td>
<td>tonne</td>
<td>tonne</td>
<td>tonne</td>
</tr>
<tr>
<td><strong>CO₂ intensity</strong></td>
<td>N/A</td>
<td>74</td>
<td>115</td>
<td>3,000</td>
<td>2,500</td>
<td>680</td>
</tr>
</tbody>
</table>

![Graph showing LCOP increase vs. Carbon price](chart.png)
Social economic impact

Direct job creation

- CtX plant is a large infrastructure project:
  - Large number of construction jobs is created once the project started.
  - Significant amount of qualified long term jobs are created once construction is over.

<table>
<thead>
<tr>
<th>Product</th>
<th>Approximate Staffing Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial Levels</td>
</tr>
<tr>
<td>Syngas</td>
<td>450</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>500</td>
</tr>
<tr>
<td>Oil</td>
<td>600</td>
</tr>
<tr>
<td>Methanol</td>
<td>500</td>
</tr>
<tr>
<td>Ammonia</td>
<td>500</td>
</tr>
<tr>
<td>Urea</td>
<td>550</td>
</tr>
</tbody>
</table>
Social economic impact

Indirect impact

• Secondary jobs creation
  • Typical multiplier for secondary jobs creation is between 2.5 to 3.5.
  • CtX project can generate more them 1,500 long term secondary jobs

• Ability to save workplaces at coal mines that otherwise would be closed.

• Sustainability of the region economy
  • Ability to sustain industry in the region, even if the coal export prices makes thermal coal mining unprofitable (traditional business model)
  • Ability to replace export of raw resources with value added products
Conclusion
Opportunities of CtX

• Sustainable Industry
  • Independence from NG and oil price volatility
  • Value added product
  • Job creation
  • Social-economic development
  • Environmentally safe
Conclusion

Opportunities of CtX

- Sustainable Industry
- Independence from NG and oil price volatility
- Value added product
- Job creation
- Social-economic development
- Environmentally safe

IF IT IS SO GOOD, WHY THERE IS NOT MUCH HAPPENING??
Conclusion
CtX Challenges

• PUBLIC PERSEPTION
  • Public does not like coal (mostly)
  • Politicians does not like coal (mostly)
• Coal industry does not want to change
  • Business model – dig it of the ground, on a boat, and sell to the customer – no added value products
• NO GOVERNMENT SUPPORT
  • It should be done by the industry, but...
  • Industry often can not afford it
Conclusion
Solution (or at least part of it)

• CHANGING THE PARADIGMA IN FEASIBILITY ASSESSMENT
  • Holistic view, considering the balance of
    • Resources availability
    • Technology availability
    • Techno-economic availability
    • Social-economic impact
    • Environmental impact
  • To achieve this, a methodology for integrating all of those estimates is required – and it is a long journey
Thank you for your attention.