Concept

• Combine:
  – Coal or natural gas conversion
  – Nuclear energy
  – Wind or solar

• Products:
  – Electricity
  – Liquid fuels
  – Chemicals
Synergies

- No effective grid scale energy storage

- $(\text{Power produced}) = (\text{Power consumed})$

- Balancing production and consumption becomes difficult with increasing production from renewables, nuclear.

- *Low cost power available for coal/gas conversion off-peak.*
Coal to liquids

Air separation Unit (ASU)

$\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$

Water –gas shift

Acid gas removal

$\text{H}_2\text{S}$, $\text{CO}_2$

Hydrocarbon Liquids

Fischer – Tropsch synthesis

Coal

Air

$\text{N}_2$

$\text{O}_2$

Steam

$\text{H}_2$

Ash or slag
High Temperature Steam Electrolysis (HTSE) Using Nuclear Power

- Steam electrolysis (HTSE)
- Electric power
- Steam
- Oxygen ($O_2$)
- Coal
- Steam
- Gasifier
- Acid gas removal
- $H_2S$
- $H_2$
- Hydrocarbon liquids
- Fischer–Tropsch synthesis
- Ash or slag
HTSE Results

With HTSE

• 95 % reduction in CO$_2$ production
• 65 % reduction in coal consumption
• 2.3 gigawatts of power for 50,000 bbl/day
• Southern Company constructing 2 nuclear power plants: 2.5 gigawatts total, $14 billion

Without HTSE

• $5.9 billion capital construction cost for 50,000 bbl/day
• Economics dominated by capital construction cost.
• Steady state operation (both cases).
• Steady state HTSE approach not economically feasible.

• Smaller scale, off-peak use of electric power still possible.
Use off-peak nuclear heat, instead of electric power, for coal or natural gas conversion.
Temperatures for coal or natural gas conversion

Coal gasification or natural gas reforming: 750 – 1,600 °C

Syngas processing and conversion: 20 – 300 °C

Fuels and chemicals
Heat for coal gasification or natural gas reforming

(1) Raise feeds to reaction temperature
(2) Endothermic syngas formation reaction
(3) Slagging (heat of melting)

• Part of feedstock burned to provide heat with conventional system

• Heat from external source could reduce oxygen consumption and increase product yield.
# Heat from nuclear reactors

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Delivery</th>
<th>Return</th>
<th>Heat type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light water*</td>
<td>300 C</td>
<td>300 C</td>
<td>latent</td>
</tr>
<tr>
<td>Molten salt</td>
<td>500 C</td>
<td>450 C</td>
<td>latent</td>
</tr>
<tr>
<td>High temperature gas</td>
<td>700 – 800 C</td>
<td>300 – 400 C</td>
<td>sensible</td>
</tr>
</tbody>
</table>

*Conventional technology, others require development.

Nuclear heat temperatures are too low for conventional coal gasification or natural gas reforming.

For syngas processing and conversion, heat provided by hot syngas, conversion reactions.
Nuclear steam to feed natural gas reforming

- Nuclear energy
  - 4000 MW heat
  - Time-varying heat 1229 MW max
  - Steamed fuel
  - Carbon

- Steam generation
  - Steam reforming
    - Methane synthesis
      - 25,000 tonnes/day
      - Synfuel* (~98,000 bpd equiv)

- 1267 MW elec max
- Load-following intermediate power
Possible future work

• Lower temperature gasification
  – Laboratory evidence
  – Reactor development needed.
  – Pair with high temperature gas nuclear reactor.

• Opportunities for using off-peak electricity.
Challenge: Non-steady state operation of a large chemical plant

• Need good control and efficient operation.

• Financial: Increased capital cost per unit of production because not operating at full capacity.

• Research, design and development: Need to change software to model time response.
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