Proven reserves of fossil fuels will sustain the world for just over 300 years at current production rates:

- Crude Oil: 42 years
- Natural gas: 62 years
- Coal: 224 years

Source: Chiyoda

Energy content of coal in US more than oil in Middle East.
**King Coal: master of energy security?**

![Graph showing cumulative % of world reserves for Coal, Oil, and Natural Gas across different countries.](image)

**Source: BP Energy Statistics**

<table>
<thead>
<tr>
<th>Energy Reserves</th>
<th>Countries</th>
<th>World Population</th>
<th>GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>80% Coal</td>
<td>6</td>
<td>45%</td>
<td>46%</td>
</tr>
<tr>
<td>80% Gas</td>
<td>13</td>
<td>12%*</td>
<td>26%*</td>
</tr>
<tr>
<td>80% Oil</td>
<td>9</td>
<td>5%</td>
<td>5%</td>
</tr>
</tbody>
</table>

*Includes USA*
Coal-to-Liquids can provide energy security to countries with large coal and small oil reserves.

- **United States**: imports 14 million bbl/d of oil.
- **Russia**: imports 3.2 million bbl/d of oil.
- **China**: imports 1.7 million bbl/d of oil.
- **India**: imports 0.3 million bbl/d of oil.
- **Australia**: imports 0.7 million bbl/d of oil.
- **Iran**, **Saudi Arabia**, **Azerbaijan**, **South Africa**, **Kazakhstan**, **Qatar**, **Ukraine**, **United Arab Emirates**, **Iraq**, **Kuwait**, **Venezuela**: imports significantly lower than others.
GTL/CTL enablers

Common Drivers

- Abundant, inexpensive hydrocarbon reserves (coal, natural gas, biomass)
- Global drive for cleaner transportation fuels

Additional CTL Drivers

- Diversity of energy supply
- Reduced dependence on crude oil
Countries with access to:

*large reserves of low cost gasifiable coal (a minimum of approximately 1 billion tons) at proposed location*

  *Reserves to support further expansions*

  *Adequate water resources close to proposed site*

Suitable partners – Coal supplier, product marketer, power utility & other technology providers

Low construction cost countries

  *with good infrastructure (roads, railway, etc.)*

Countries where suitable sites are close to large attractive markets

Countries with the ability and will to provide enabling support
effective transportation fuels need to meet certain requirements

- Easily stored
- Easily transported
- Easily converted

Alternatives that can integrate into an existing infrastructure will have an advantage

Alternatives that are fungible to end user and provide environmental benefits will have an advantage
synthetic fuels hold significant environmental benefits

- Emissions benefits vary depending on vehicle type & technology level
- Synthetic diesel has cetane >70
- Synthetic diesel contains
  - < 1ppm sulphur,
  - < 1% aromatics

<table>
<thead>
<tr>
<th>Emissions</th>
<th>NOx</th>
<th>PM</th>
<th>HC</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinery diesel</td>
<td>100%</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
</tbody>
</table>

NOx: oxides of nitrogen
PM: particulate matter
HC: hydrocarbons
CO: carbon monoxide
Sasol’s processes convert “locked-in” resources to easily transportable liquid fuels.
Sasol’s technology can be applied to multiple feedstocks.

- Coal
  - Coal to Liquids (CTL)
- "Heavy" Oil
- Natural gas
- Biomass
  - Gas to Liquids (GTL)
  - Biomass to Liquids (BTL)

Similar products:

- Renewable hydrogen
- Clean Diesel
Coal utilization in South Africa

Run-of-Mine Production 307 Mt

- Stocks 23.5 Mt
- "Washing" 180 Mt

"Washing" 180 Mt

- Discards 65 Mt
- "Screening" 127 Mt

"Screening" 127 Mt

- Local Use 27.4 Mt
- Export 67.9 Mt
- Synfuels 41 Mt
- Electricity 110 Mt

Xavier M Prévost, Chief Mineral Economist, MINERALS BUREAU, Coal and Hydrocarbons, e-mail: xavier.prevost@dme.gov.za
Coal usage per sector in South Africa

- **62%** for ELECTRICITY
- **23%** for INDUSTRIES
- **8%** for MERCHANTS AND DOMESTIC
- **4%** for METALLURGICAL
- **4%** for SYNTHETIC FUELS
- **0.01%** for MINES

Xavier M Prévost, Chief Mineral Economist, MINERALS BUREAU, Coal and Hydrocarbons, e-mail: xavier.prevost@dme.gov.za
South Africa CTL history and drivers

- Initial driver to commercialize CTL in RSA...fuel independence on crude imports

- Secondary objective to convert low grade coal to petroleum products and chemical feedstocks

- Today Sasol produces >150,000 barrels per day

- In excess of 40% of SA’s liquid fuels requirements (includes PetroSA)

- Manufactures >200 fuel and chemical products

- Syngas production increased ±15% over the last 10 years
  - 60% due to increased gasifier throughput
  - 20% due to the reduction of CO₂ produced in gasification
  - 10% due to the recovery of coal lock off gas
  - 10% due to increased gasifier availability / reliability
Influence of oil price

Escalating oil price….caused by supply constraints and increased demand resulting in….

*Increased emphasis on alternatives*

*Renewed interest in coal use*

CTL likely to be viable at crude oil prices > USD 35/bbl (China based)
the Sasol process

**Raw Materials**
- Natural gas production
- Propane crude oil
- Coal mines
- Energy

**Operations**
- Gas transmission & marketing
- Oil refining & fuel marketing
- Synfuels production

**Products**
- Automotive fuels
- Pipeline gas
- Automotive fuels
- Steam coal

**Southern Africa**
- Chemical intermediates

**International**
- Chemicals: olefins & surfactants, solvents, polymers, nitrogen products, waxes

**Chemicals**
- Coal
- Natural gas
- Oil products
- Natural gas

South African chemical operations

International chemical operations
Sasol is continuously improving our GTL/CTL technology

**High temperature processes**
- Gas phase reactions and products
- Products - gasoline and light olefins

**Original 1950’s to 1980’s technology**
- The Sasol Synthol reactor
  - 1950 to 1987
  - 2,000 – 6,500 bbl/d

**Advanced 1990’s technology**
- The Advanced Synthol reactor
  - 1989 to present
  - 11,000 – 20,000 bbl/d

**Low temperature processes**
- Liquid phase reactor products
- Products - mostly diesel

**Original 1950’s to 1985**
- The Arge tubular reactor
  - 1950 to 1985
  - 500 – 700 bbl/d

**1989 to present**
- The Sasol Slurry Phase reactor
  - 1993 to present
  - 2,500 – 17,000 bbl/d
3 different Sasol technologies

- Cobalt low temperature Fischer-Tropsch (Co-LTFT)
- Iron low temperature Fischer-Tropsch (Fe-LTFT)
- Iron high temperature Fischer-Tropsch (Fe-HTFT)

The 3 technologies produce fundamentally different types of hydrocarbons and thus ultimately have the potential to produce different chemical products.
iron-based FT: a historical perspective

- **First generation (1920’s to early 1970’s)**
  - Strategic considerations
  - Mainly fuel value
  - Limited chemical value

- **Second generation (1970’s to late 1990’s)**
  - Economic considerations
  - Reactor technology developments (SAS, Slurry bed)
  - Chemical value significant
  - Expensive and complex separation processes

- **Third generation (2000 - )**
  - Greater product flexibility between fuels / chemicals
  - Direct production of high value chemicals
  - Minimize separation costs
  - More effective catalyst / reactor systems
### Effect of Temperature on Iron-based FT

#### Product distribution (per 100 carbon atoms)

<table>
<thead>
<tr>
<th>Product</th>
<th>Low Temperature 220 - 250°C</th>
<th>High Temperature 330 – 350°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>C₂-4 olefins</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>C₂-4 paraffins</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Gasoline</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Distillate</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>Oils and waxes</td>
<td>48</td>
<td>9</td>
</tr>
<tr>
<td>Oxygenates</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
low temperature Fe-based operation
Slurry Phase Reactor

- 200-240°C
- Precipitated Iron-based catalyst
- 5m diameter
- 100 kt pa
- Capital cost is less of multi-tubular train
- More isothermal
- Lower dP across catalyst bed
- Online catalyst replacement possible
Sasol’s 2500 bbl/day commercial Slurry Phase reactor
Product characteristics:

- wax chain growth probability = 0.95
- 55 mass% \( \text{C}_{20+} \) selectivity
- SBR product more olefinic than TFB product

Niche applications

- exploitation of low \( \text{H}_2/\text{CO} \) synthesis gas
- suitable for synthesis gas produced through gasification:
  - *no need to remove sulphur and other impurities to extreme levels from synthesis gas*
**high temperature process**

Sasol Advanced Synthol reactor

Simple construction
High conversions
Large single reactor capacity
60% lower capital cost (vs. CFB)
Ease of operation
Lower operating cost

85% less maintenance

Circulation of catalyst is eliminated
All the catalyst is working all the time
Less catalyst consumption
Sasol’s 11 000 bbl/day Advanced Synthol reactor
recommendations for CTL applications:

- **Power export (co-production) should be a feature from the outset**

- **Each potential site should consider the business case for a footprint plant and the eventual targeted product spectrum**

- **Starting with fuel value products and gradually phasing in the high value products is a successfully proven business model**

- **Alternative approaches only making high value products from the outset will be complex leading to start-up delays and difficulties in placing products in the market**

- **Message: look for a simple starting scheme that allows the ultimate business objective to be achieved with a phased approach**
Sasol’s Fe-LTFT technology – the footprint plant

- Sasol’s Iron low-temperature technology is ideally suited for the production of diesel from Coal (CTL technology).
- Very high quality Naphtha is produced -- ideal for steam crackers.
- Best option for a simple footprint plant.
- Need a use for the FT tail gas.
Sasol’s Fe-HTFT technology – footprint plants

- **HTFT products are highly olefinic and these olefins are ideal building blocks for producing high value products.**
- **A simple initial product offering is possible.** Various options exist and an example here illustrates a propylene, diesel and naphtha footprint plant.
- **Propylene volumes that accompany a reasonable scale diesel plant match well with a world scale polypropylene plant.**
- **Major products are aimed at large markets (fuels, propylene & ethylene), to obtain economy of scale with syngas preparation and FT synthesis.**
- **Most capital intensive product upgrading processes but some progress has been made to decrease these costs.**
Sasol’s Fe-HTFT technology with additional chemicals

Complex due to many different products with differed market drivers. Therefore a phased approach has proven to be successful.
Industry challenges
CO₂ & Capital Cost
converting coal to usable energy is capital intensive

Capital cost has increased at a significantly higher rate and has moved in line with PPI. What will the future hold?
achieving economic development while limiting CO₂: a challenge for our industry

Models differ widely in their estimates of contributions to the virtual triangle from structural shifts (toward services), energy efficiency, and carbon-free energy.
Many technology options are available to stabilize emissions.

Sasol is integrating a number of wedges into CTL.
gasification of coal and use in CTL holds advantage for CCS

CTL process and where CO₂ is emitted

- **Coal**
- **Gasification**
- **Gas cleanup**
- **Fischer Tropsch synthesis and product workup**
- **Utilities** (power and steam)

- **CO₂ is dilute and expensive to capture**: < 50% of CO₂
- **CO₂ is more concentrated and less expensive to capture**: > 50% of CO₂

**Liquid products**
Sasol moving beyond setting targets on CO₂

**Targets**

- Voluntary energy efficiency intensity improvement target of 15% on 2005 base year by 2015, agreed with SA Government
- GHG intensity reduction target of 10% on 2004 baseline, by 2015; combined result for all operations

**What we have done**

- 2004/5 introduction of Natural gas at Sasolburg & Secunda reduced GHG by 6 Mtpa
- Secunda energy efficiency improvements expected to remove up to 7 Mtpa
CTL challenges & benefits

Challenges:
- Critical mass of key industry players
- Capital intensive process
- Environmental issues:
  - “Dirty coal” - public perception
  - Permitting – no new refineries in the US since 1984?

Benefits:
- Relatively low operating cost
  - Low feedstock cost: Price of coal = USD 10/t equivalent to ~ USD 0.50/MMBtu (location specific)
- Technologies facing dual challenges of capture and storage of CO₂ – capture not major concern for CTL due to concentration of CO₂ which allows for simple CO₂ sequestration.
- Polygeneration
  - Might improve plant efficiency
What is Sasol Doing?
Sasol is actively pursuing coal-to-liquids footprint opportunities globally and expansion in SA

- **South Africa**: Expanding Secunda through Natural Gas and coal, exploring feasibility of 80,000 bbl/d facility with Government.
- **United States**: Currently evaluating opportunities.
- **China**: Pre-feasibility being conducted.
- **India**: In discussions with private sector and Government.

Sasol focusing on establishing large footprint plants
China CTL project status

Identified 2 sites in coal rich western part of China:

- Ningxia Autonomous region
- Shaanxi province

Plant capacity ~ 85,000 barrels per day per site

Capital cost: US$ 60,000 to 80,000/daily bbl

Feasibility in progress
CTL holds great promise…….

Requires highly integrated chemical facilities

Requires unique technical expertise in gasification, chemical processes and Synthetic fuel properties

Requires an appetite for technology risk

Requires expertise in the execution of large complex projects

.....having 1,5 billion barrels of Synfuels experience helps
Thank you