A. P. Steynberg
R. Harris – Technology Manager
J. Smit & S. Barry
I. Greeff

Recent Advances in Sasol's GTL Technology

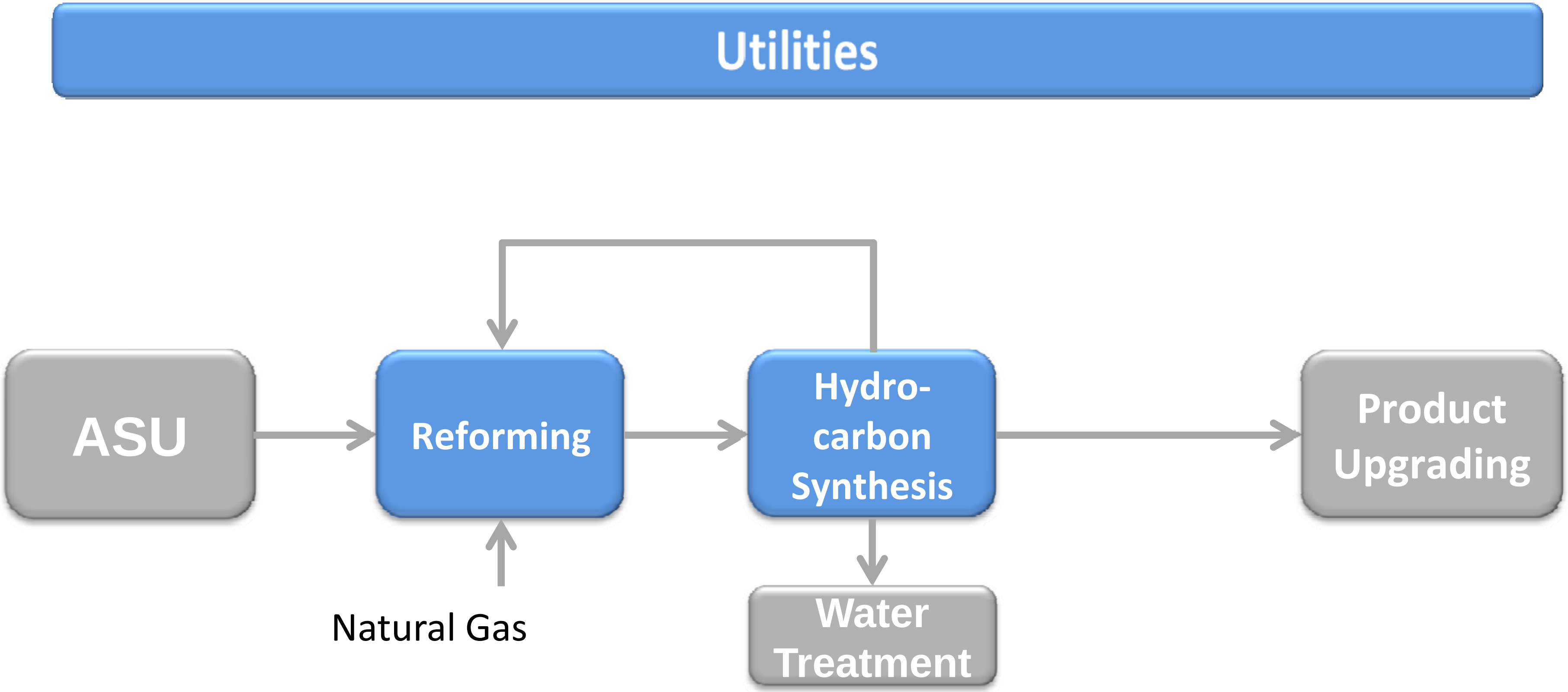
Jan 2013

Key success factors for GTL & technology impact

- Oil to gas price ratio – positive trends due to shale gas technology
  - no real impact on GTL technology selection but improvements will enhance profitability
- Site specific capital costs in offsites and infrastructure are significant
  - tends to drive towards larger scale facilities to get economy of scale
- Intrinsic capital cost based on technology selection is important
- Catalyst cost is important
- Project execution potential impact on capital cost is significant and this creates inertia for taking technology steps
- Plant ramp-up and reliability are also important and contribute to reluctance to change (unless the change is specifically aimed at improved reliability based on lessons learnt)

  - Some important lessons learnt at maximum commercial scale
- Departure point is no negative impact on plant reliability
  - this is achievable with the next generation GTL technology

Key Focus Areas



GTL with Hydrocarbon Synthesis

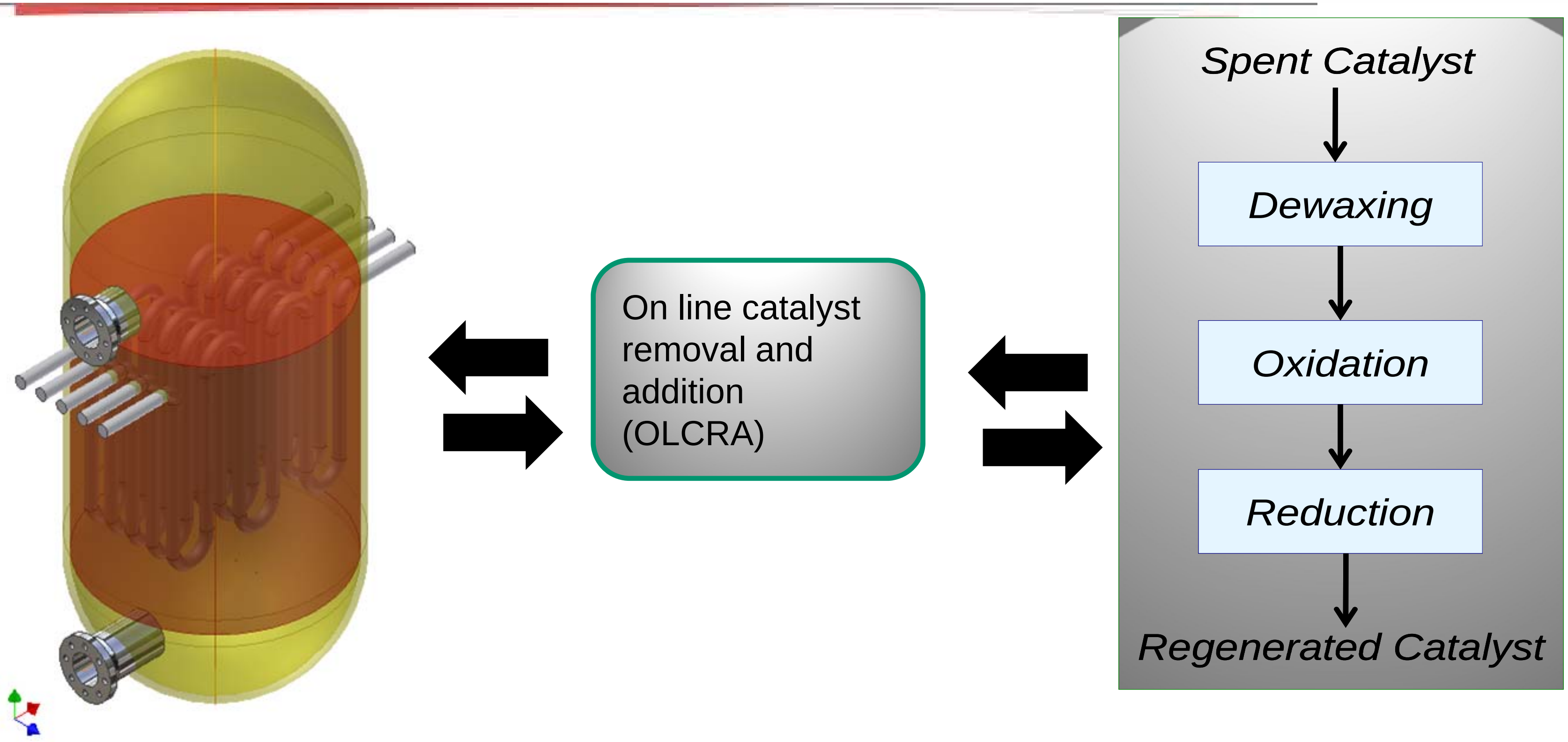
- It has now been more than 10 years since the design basis was set for the first commercial GTL facility using slurry phase reactors

Significant technology developments have occurred
- together with reforming unit developments and improved utility system design now classified as a next generation of gas-to-liquids (GTL) technology.

- Reactor Intensification
  - *Increased volumetric conversion efficiency with same reactor shell*
  - *150% reactor capacity available now*

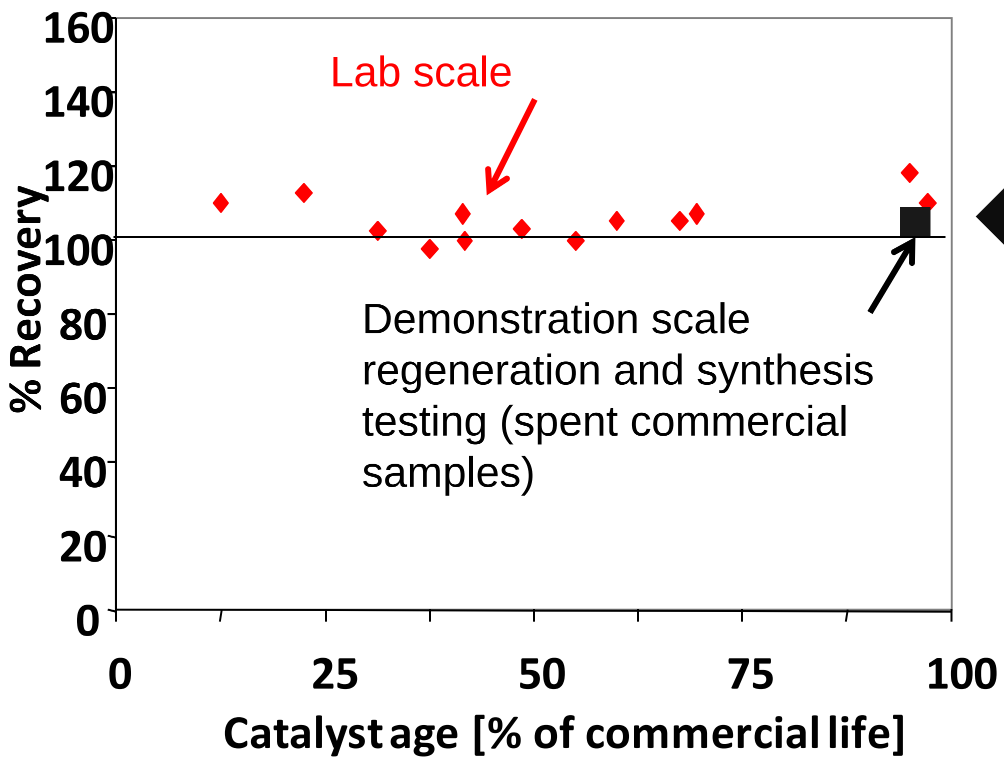
- Catalyst Development
  - *Support*
  - *Cobalt application*
  - *Regeneration – new step at commercial scale*

Regeneration as a Catalyst Management Tool



- **Regeneration reduces effective catalyst cost**
- **Effective catalyst management facilitated by on-line catalyst removal and addition**
- **Allows the process to remain near the optimal operating point**

Successful Demonstration of Regeneration Process



Slurry phase reactor for catalyst demonstration

(100-200 kg scale)

Present Commercial GTL Reforming

- Autothermal reforming (ATR) from Haldor Topsøe is well proven at large capacity

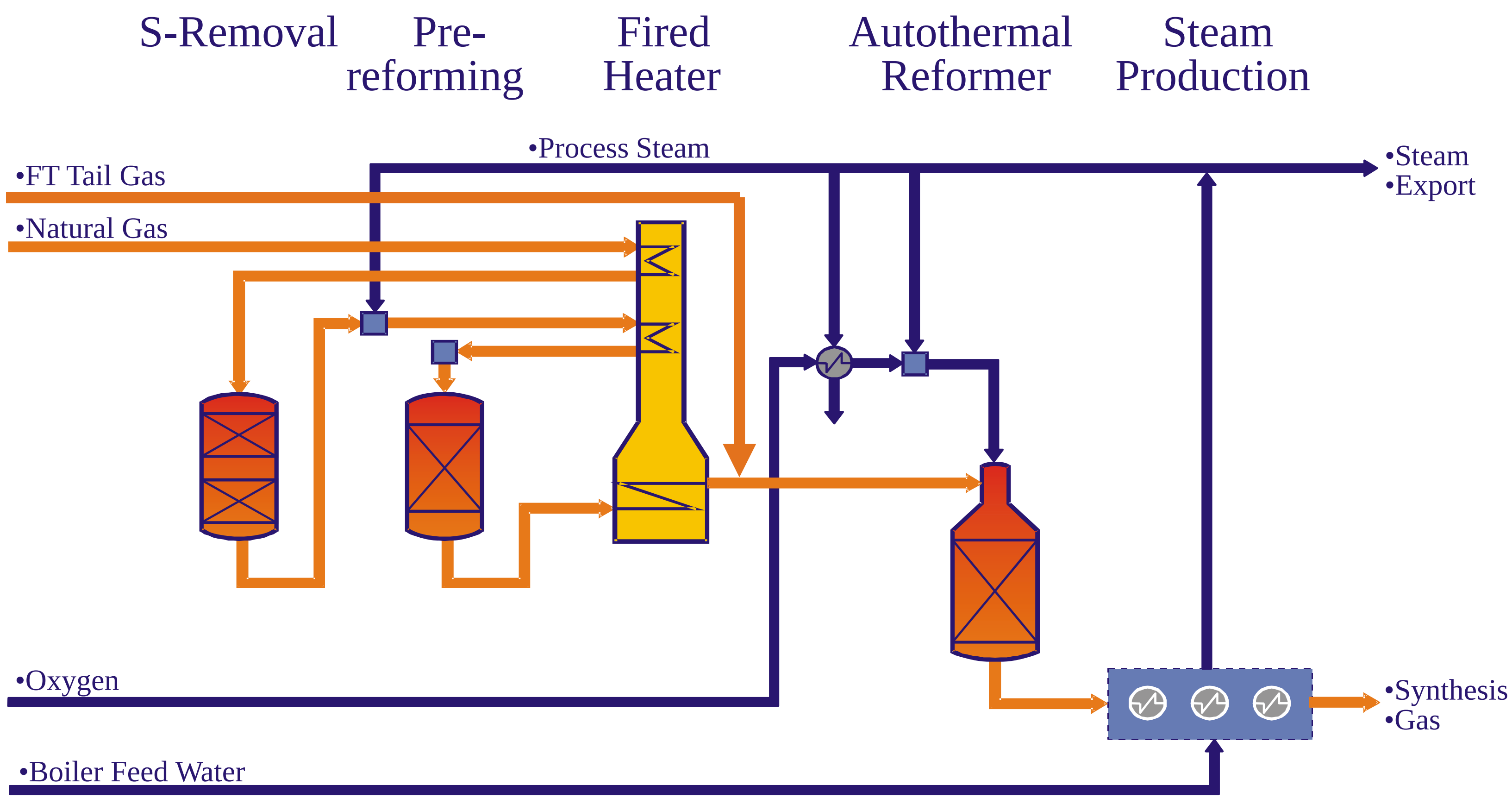
- Highly reliable between planned shut-downs

- Present maximum single train sizes were set by the Air Separation Unit (ASU) but in future 2 or 3 reforming trains using 2 or 3 ASU units will be coupled with 2 larger Hydrocarbon Synthesis units – optimal configuration is selected based on investment and plant operation considerations

- Increased utility system efficiency requires opportunities to use excess steam

Joint Synthesis Gas Developments for GTL

Sasol demonstrated features for Haldor Topsøe ATR technology using industrial reformers at Secunda

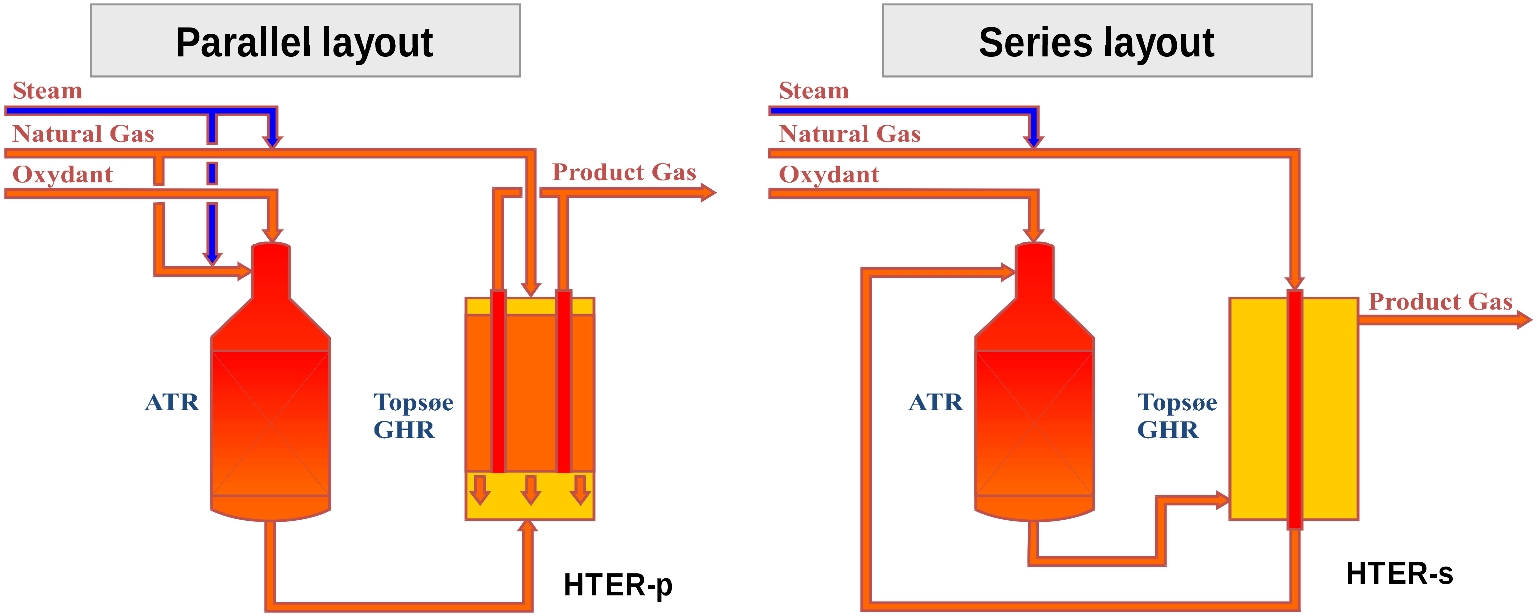


- **Next step is to add heat exchange reforming into the flowsheet**

Synthesis Gas Generation Improvement

- Haldor Topsøe Exchange Reforming in series (HTER-s)

	Base Case	HTER-s
Plant-wide GTL carbon efficiency (%)	**73-75**	**80 +**



- **Increase in synthesis gas capacity from the same O_2 capacity**
- **Increase in plant-wide carbon efficiency**

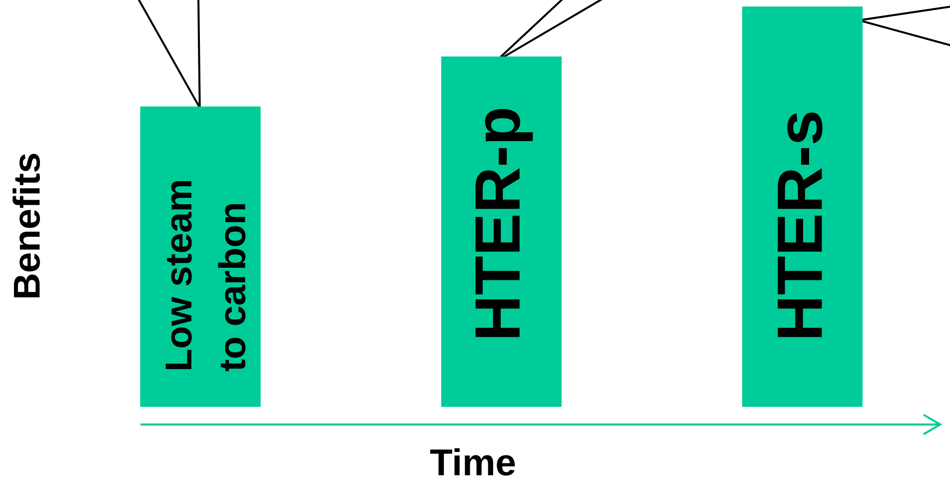
Sasol & Haldor Topsøe:
Re-cap of Reforming Technology Advances

sasol
reaching new frontiers

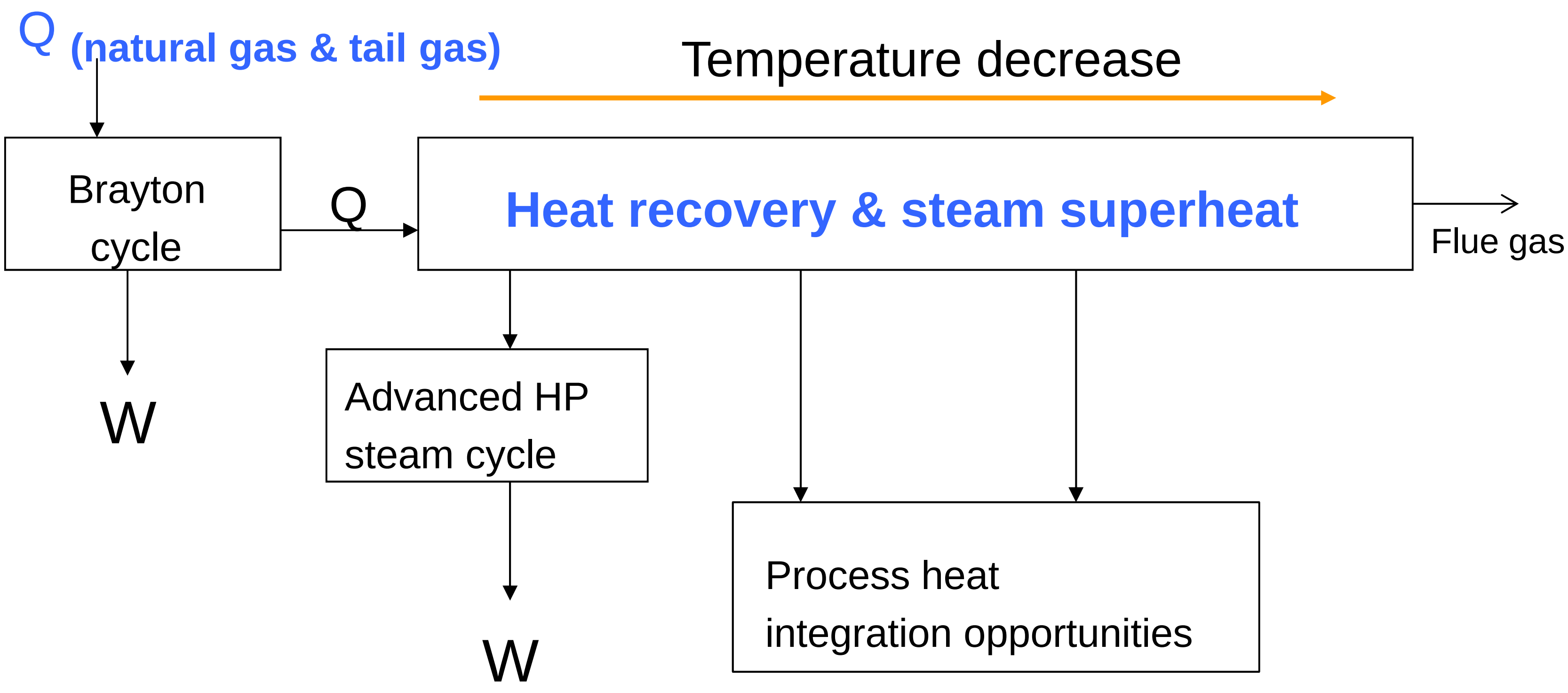
- Low steam to carbon operation (0.6) was a step change in ATR efficiency & capex
- Necessary in GTL for suitable syngas H_2:CO
- Demonstrated in Secunda.
- Operating in Sasolburg and ORYX GTL
- Significant advances in burner design and scale-up

- Major efficiency improvement retrofit
  – adds steam reforming without requiring a fuel gas.
- Commercialized successfully in Secunda.
- 4x additional units being installed
- Subsequently used to retrofit methanol and hydrogen plants

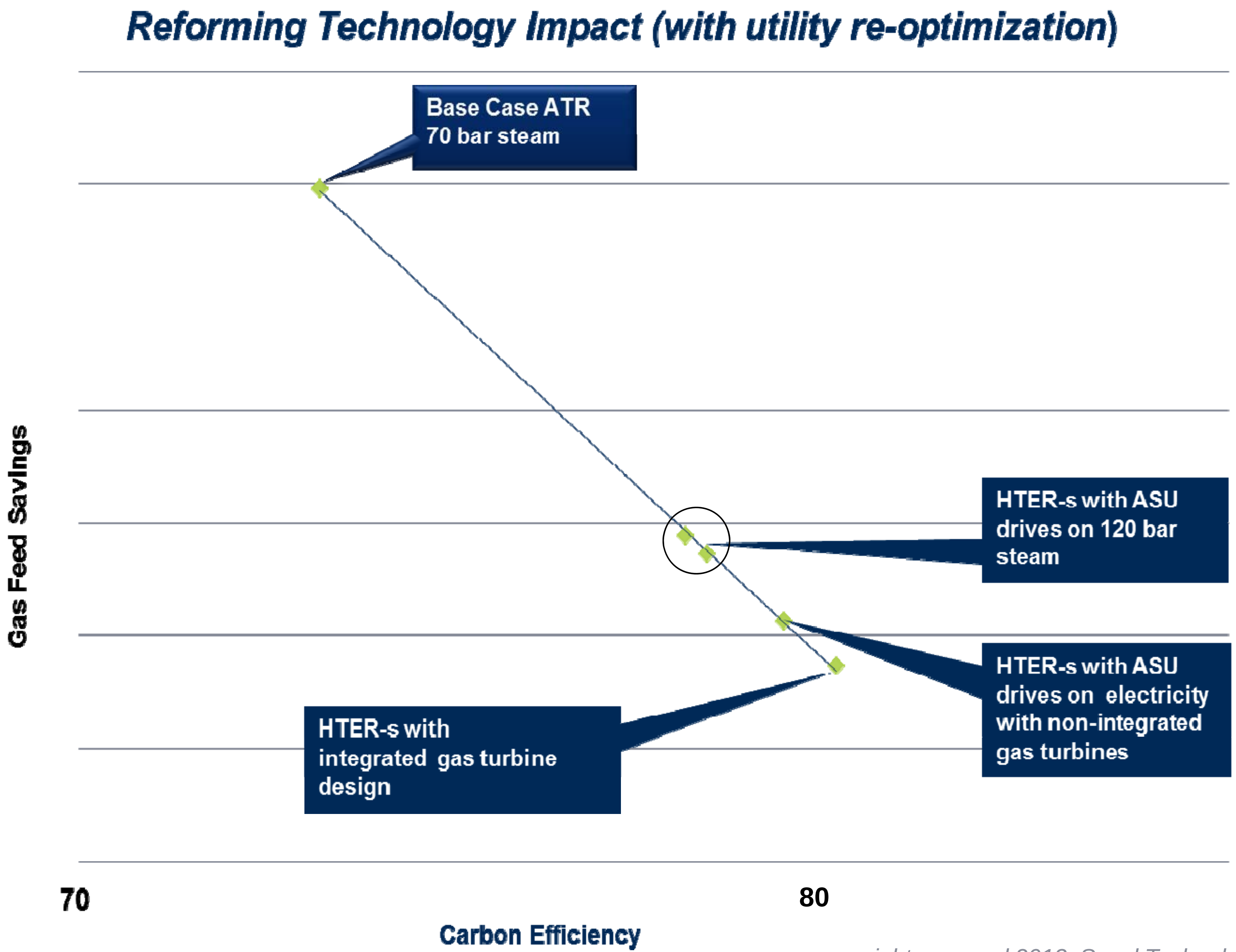
- Next major step-change in reforming technology.
- Builds on HTER-p technology, but inherently more efficient.
- Simple mechanical design.
- Metallurgical challenges are manageable



Gas Turbine Integration



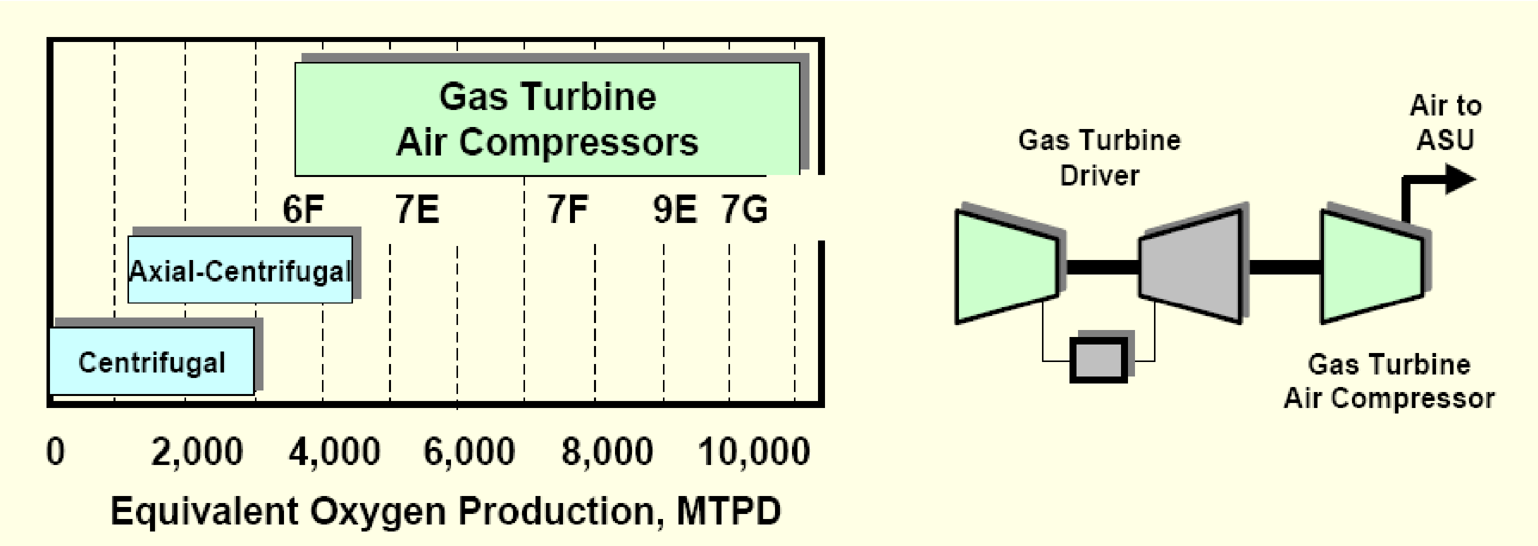
Brayton Cycle integrated efficiency is between 50% and 60% and is far more efficient than the simple steam Rankine cycle



Reforming Technology Impact (with utility re-optimization)
Base Case ATR
70 bar steam
HTER-s with ASU
drives on 120 bar
steam
HTER-s with ASU
drives on electricity
with non-integrated
gas turbines
HTER-s with
integrated gas turbine
design
Gas Feed Savings
70
80
Carbon Efficiency

Further Scale Benefits for GTL

- Ingredients for single ASU supporting up to 40 000 bbl/d GTL capacity
  - *New axial-centrifugal compressors potentially also with a gas-turbine driven ASU: enables larger ASU capacity*



(From an Air Products presentation)

- *Further Hydrocarbon Synthesis intensification beyond 24 000 bbl/d is possible (Intrinsic advantage for slurry phase reactors)*
- *Facility target capacity of 120 000 bbl/d supported by 3 or 4 FT & ASU trains (Currently use 6 ASU trains for 100 000 bbl/d plant)*

Some USA Feasibility Study Results

- The next generation results were compared to present generation technology for a US Gulf Coast site location
- Various next generation technology options were considered:
  - most benefits from a combination of HTER-s with an integrated gas turbine power block together and Hydrocarbon Synthesis reactor intensification with catalyst regeneration
- Significant capital cost saving in the hydrocarbon synthesis unit, the heart of the GTL process. 50% scale-up of the downstream product recovery and product work-up units to a nominal capacity of about 50 000 bbl/d still allows single units to be connected to two hydrocarbon synthesis units which gives significant economy of scale. All the associated utility units also benefit from this scale-up
- The air separation unit (ASU) only requires about 20% scale-up because of the reduced oxygen consumption with HTER-s

Carbon Efficiency Improvements

Case/Comparison parameter	Present Generation	Next Generation (HTER-s with non-integrated gas turbine)	Next Generation (HTER-s with integrated gas turbine)
Facility carbon efficiency	73 to 75 %	77.5 to 78.5 %	80.5 to 81.5 %
Achievable relative improvement s in CO_2 emissions		20 %	30%

Conclusions

- The next generation GTL plant design has now reached "ready for commercialization" status
- The improved plant design is more or less Capex neutral on the same capacity basis & significantly more efficient
- Carbon dioxide emissions per unit of product are around 30% lower
- Hydrocarbon synthesis technology improvement has enabled a single train capacity increase of 50% - even more upside potential
- Improved GTL economics (per bbl) due to: lower capital cost & lower operating cost (due to catalyst & efficiency improvements) and/or more product can be made from the available natural gas
- This also comes with about a 10% smaller plot & improved operating flexibility/reliability based on previous learning
- Some new features will be demonstrated in the USA project in a manner which avoids potential negative impact on plant reliability