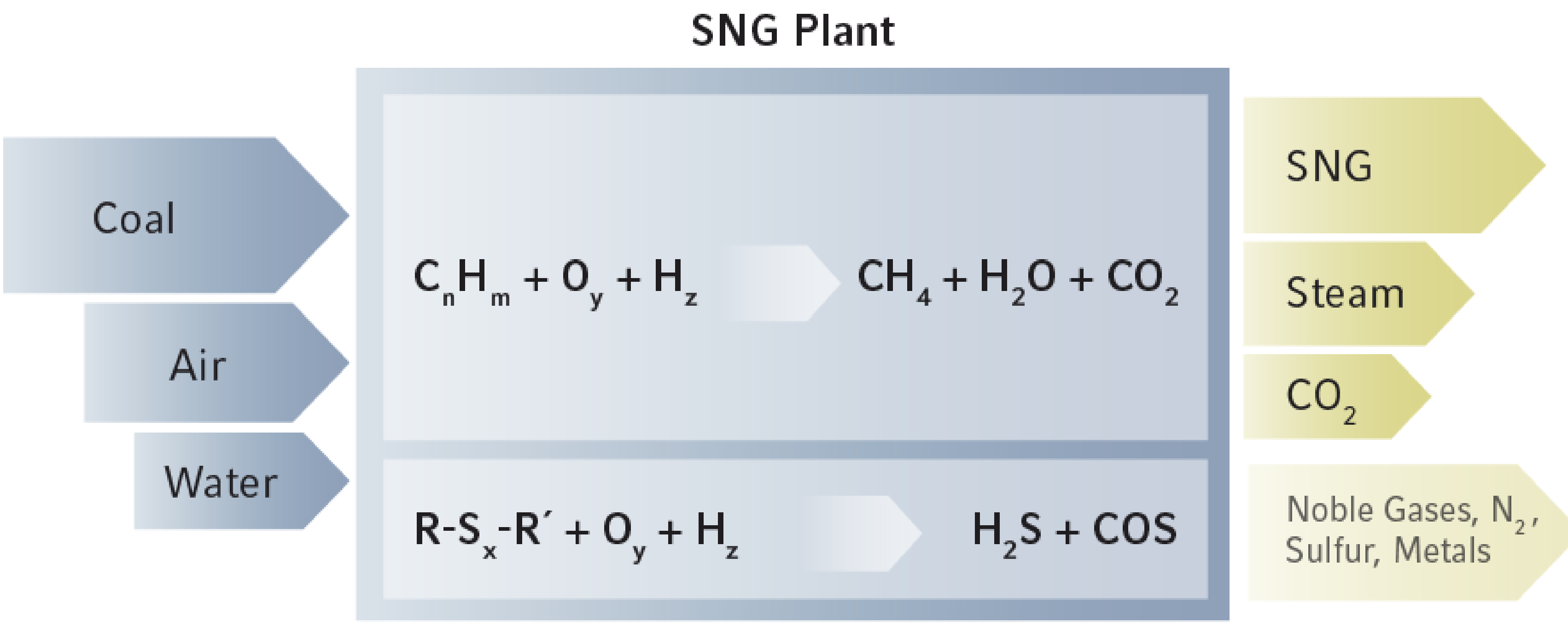


VESTA SNG Methanation Technology

Solid fuels to SNG applications

Amec Foster Wheeler Italiana (a Wood Company)

Solid Fuel to SNG



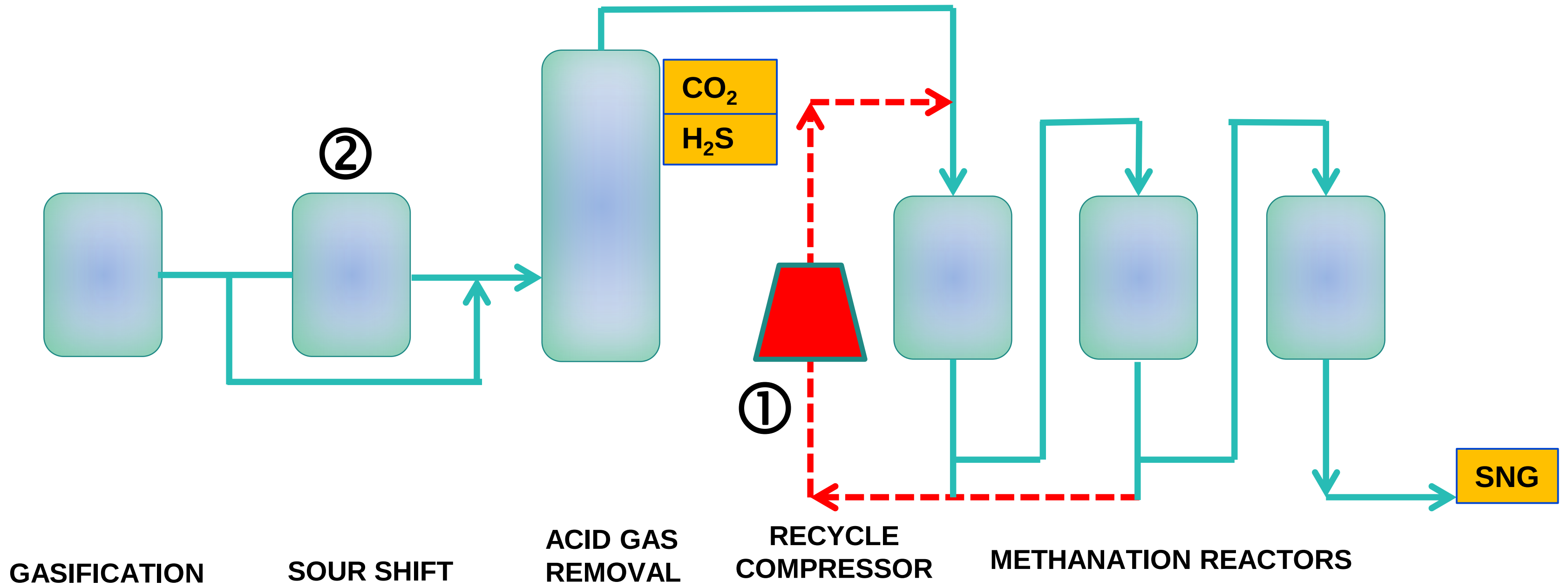
The Methanation Reactions are Highly Exothermic

$CO + 3\ H_2\ \ CH_4 + H_2O$ $\Delta H = -\ 205$ kJ/mole

$CO_2 + 4\ H_2\ \ CH_4 + 2\ H_2O$ $\Delta H = -\ 165$ kJ/mole

Competing technologies review

- The recycle of CH4 product to syngas is the standard process to handle the exothermic reactions <u>for competing technologies</u>



Process characteristics:

① Recycle compressor to handle the exothermic reactions (a lot of product gases go through circulation, as a heat transfer medium)

② Complex adjustment of the feed gas to achieve on-spec SNG

Solid Fuel to SNG - Competing technologies

SOLID FUEL → Gasification Block → Adjustment of H_2/CO Ratio 3:1 → CO_2 Removal H_2S Removal → SNG Process → **SNG**

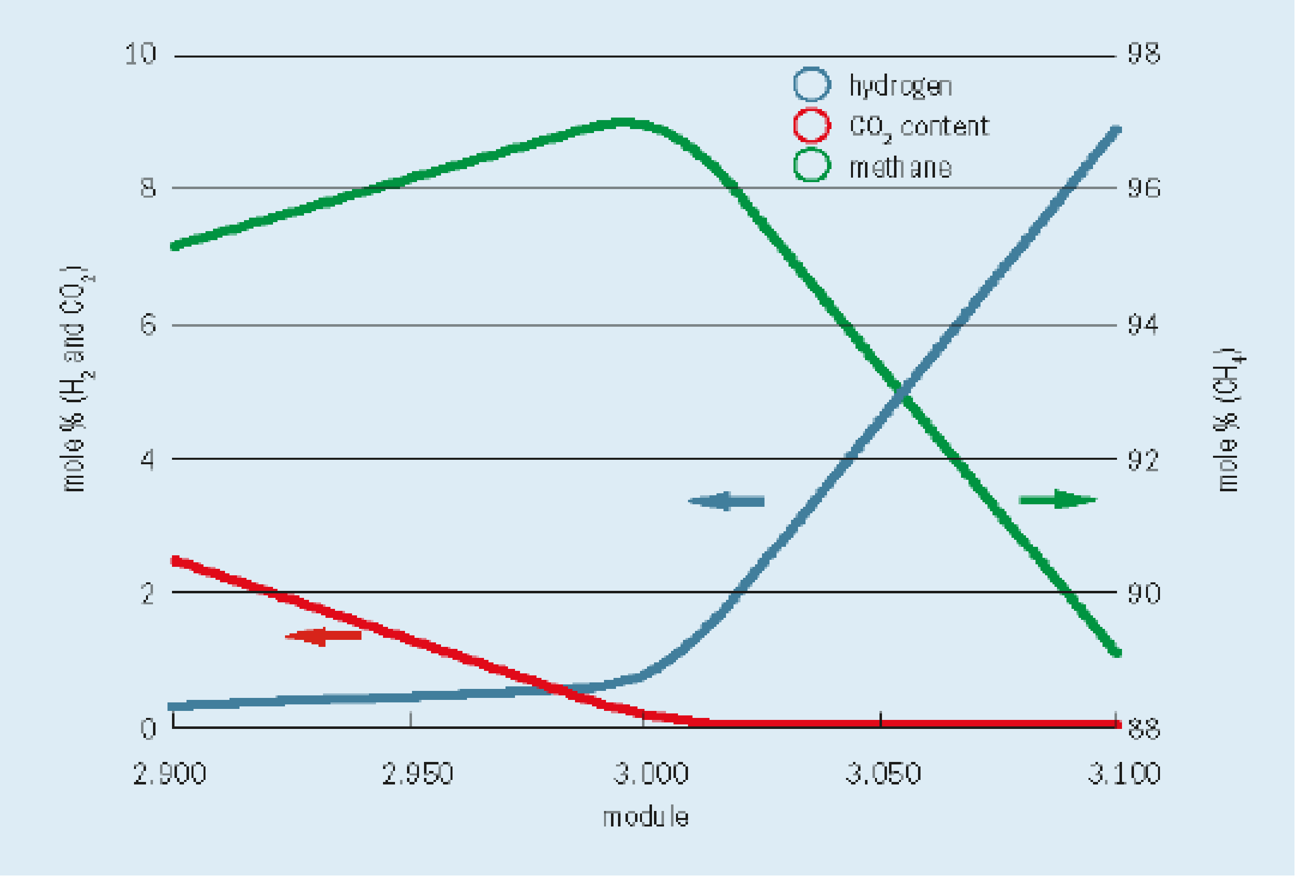
Gasification	**CO Conversion**	**Purification**	**SNG Process**
Different Technologies Differences in H_2/CO Differences in CH_4	Sour Gas Shift	Physical Solvent Complex scheme to separate H_2S from CO_2	Exothermic Reaction Expensive Reactors Material High temperature Superheater Recycle at high temperature Recycle Compressor

Solid Fuel to SNG - Competing technologies

SOLID FUEL → Gasification Block → Adjustment of H2/CO Ratio 3:1 → CO2 Removal H2S Removal → **SNG Process** → **SNG**

SNG Process		**Criticalities**
Exothermic Reaction Expensive Reactors Material High temperature Superheater Recycle at high temperature Recycle Compressor	→	H2/CO Ratio Coke formation Recycle mandatory Temperature runaway Brick lined reactors Unsafe Operation Metal dusting risk Limitation in train size

Effect of H2/C ratio in competing technology on SNG product quality

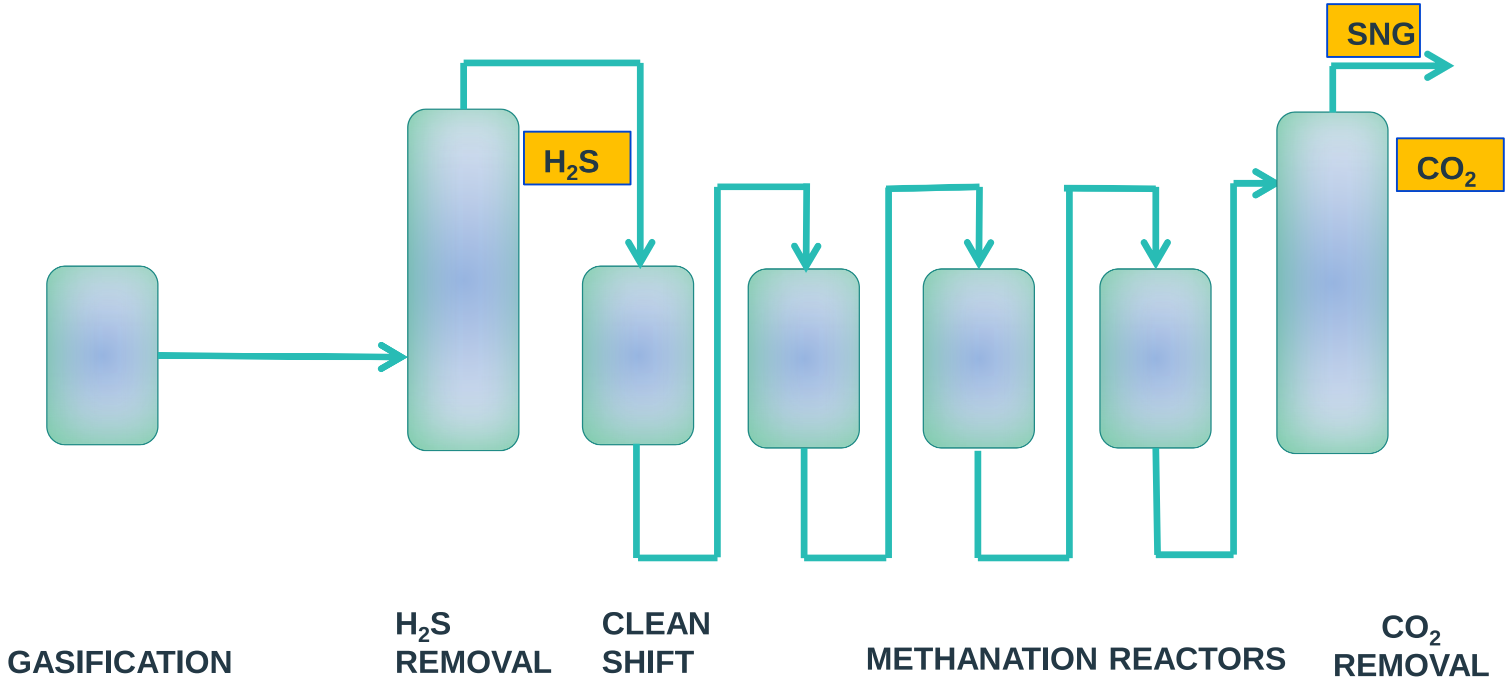


Solid Fuel to SNG – VESTA Technology

- **VESTA - Can we do more for you?**
  - Can we avoid high temperatures?
  - Can we avoid recycle compressors?
  - Can we avoid brick lined vessels?
  - Can we avoid high alloyed steel?

VESTA technology review

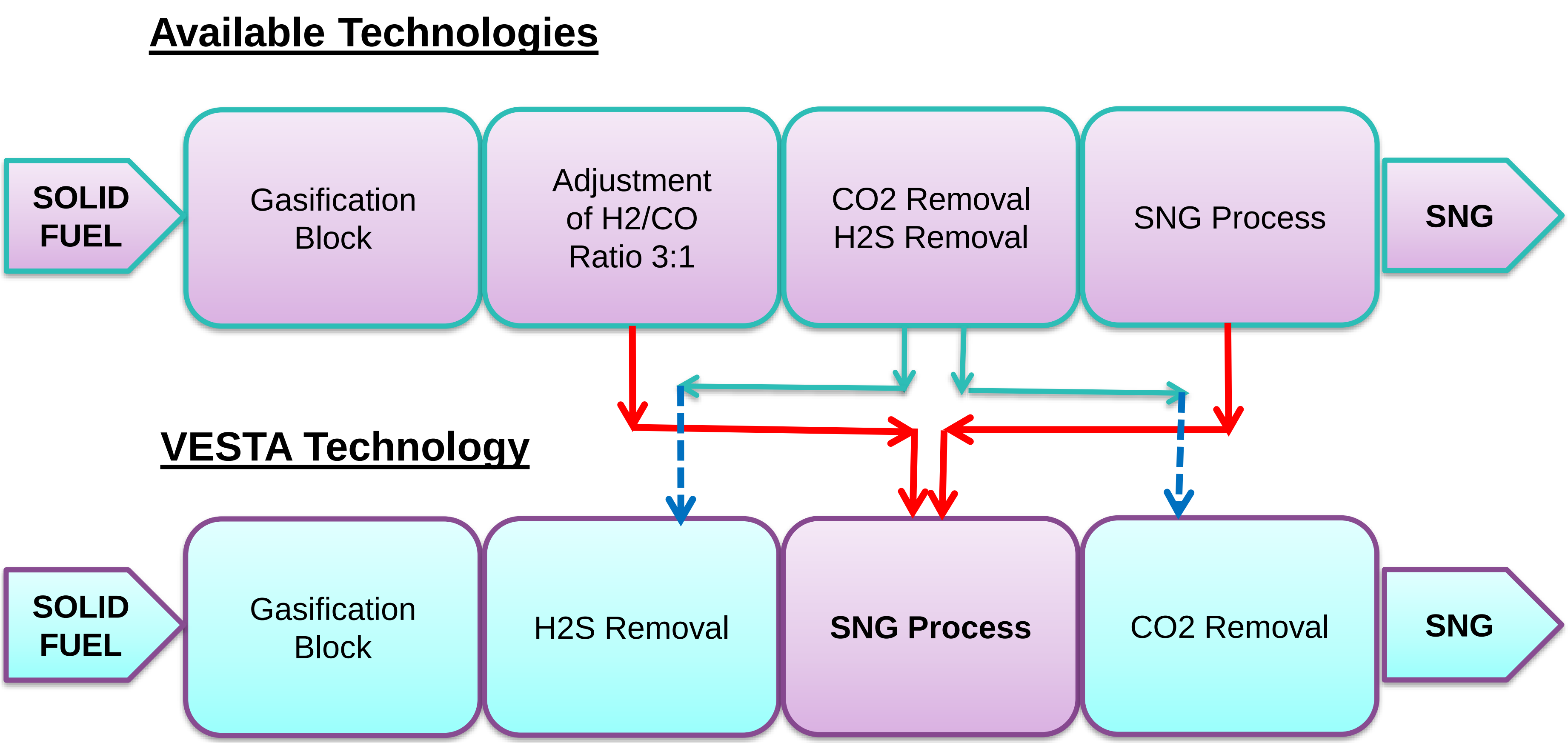
- The VESTA technology is a **once-through operation**



Process characteristics:

- No recycle compressor
- CO_2 and H_2O control heat of reaction
- Easy to control

Solid Fuel to SNG – Technologies comparison

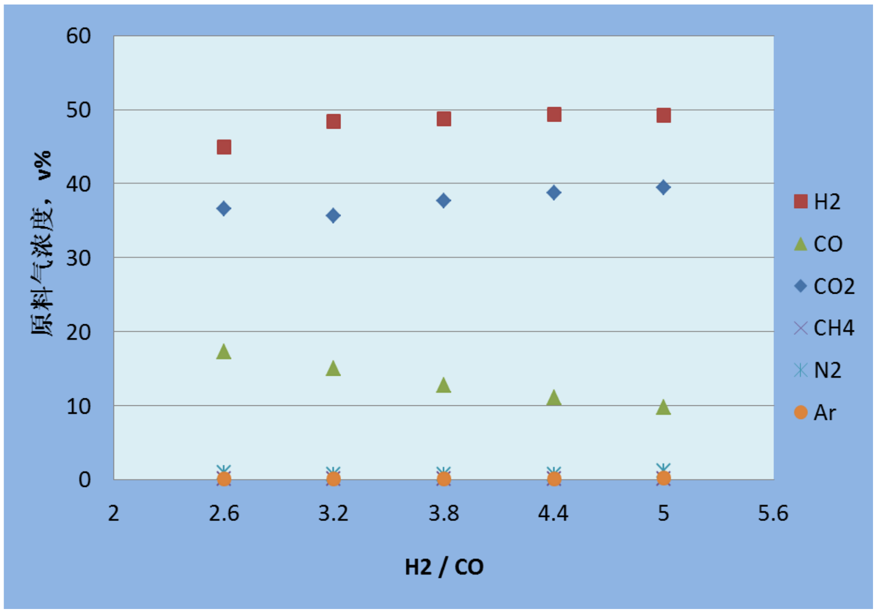


Solid Fuel to SNG - VESTA technology

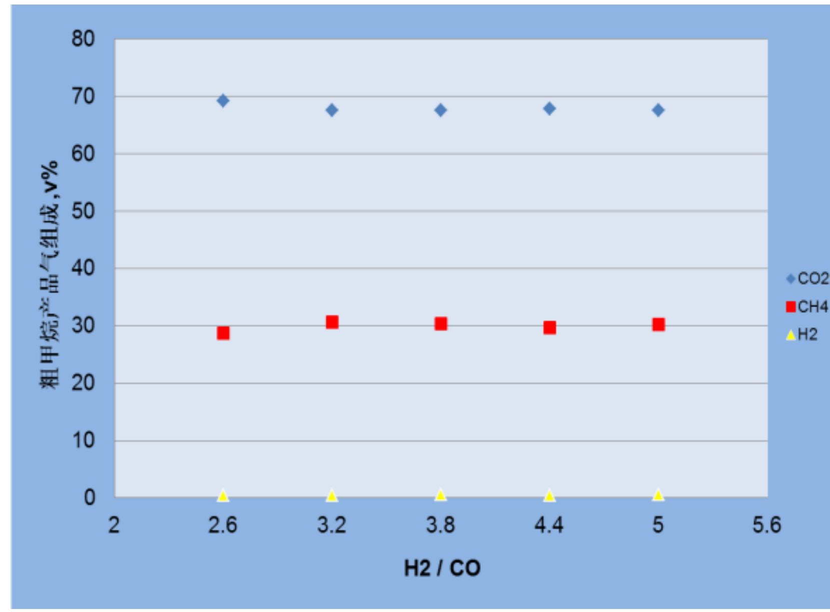
SOLID FUEL → Gasification Block → H2S Removal → **SNG Process / CO2 removal** → **SNG**

Gasification	**Purification**	**SNG Process / CO2 removal**
All gasification technologies are compatible with the Novel VESTA Process High efficiency / WHB / dry type are more beneficial	H2S removal Carbonyl removal Fine Purification No H2/CO ratio adjustment	No limitations of H2/CO ratio Neither coke formation nor metal dusting risk Low alloyed steel reactors Low severity WHB No Recycle Compressor Final CO2 removal (high quality)

Effect of H2/C ratio in VESTA technology on SNG product quality



The feed composition under different H_2/C conditions



Effect of feed gas with different H_2/C ratio on crude SNG composition

VESTA technology - catalyst

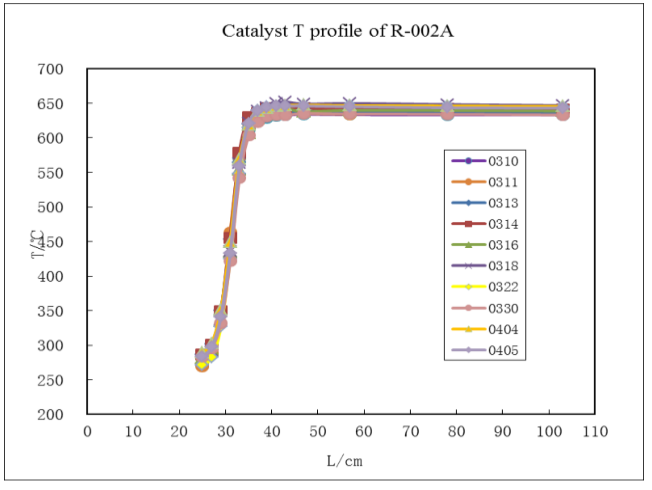
Catalyst (high temperature methanation)

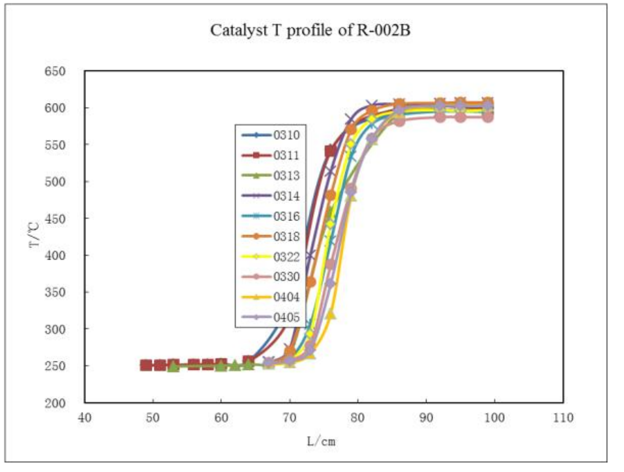
- Methanation reactors filled with proprietary Clariant catalyst
- High stability, robust under different conditions
- Suitable for the operating range 230-700 °C (higher than conventional methanation catalysts)
- High CO and CO_2 conversion
- No carbon deposition
- Long operational history and industrial references
- Available as pre-reduced catalyst for simple start-up

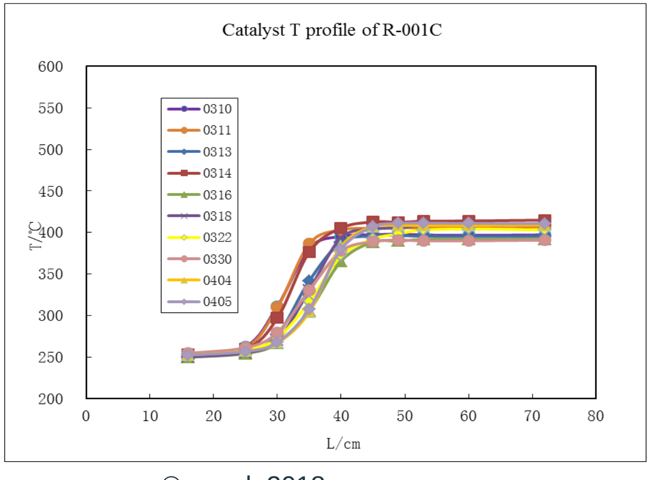
Name	SNG 5000
Shape	Tablet
Size (mm)	4.7 x 4.7
NiO%	53.5~59.5
Bulk Density (g/ml)	1.15 ± 0.10
Particle Density g/ml	1.93
Crush Strength (Newtons)	>75
BET Surface Area (m2/g)	140
Pore Volume (ml/g)	0.22
Operation Temperature, ^{0}C	250~550

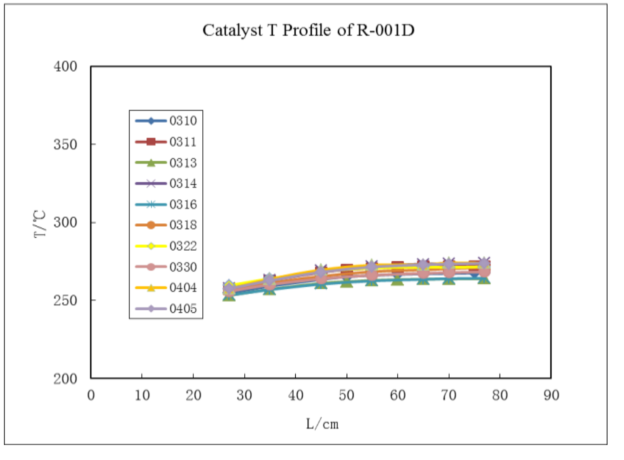
VESTA technology - catalyst

▶ Catalyst (high temperature methanation)









The temperature profile of VESTA methanators, running for 4000 hours

VESTA technology - catalyst

▶ Catalyst (high temperature methanation)

Clariant experience in methanation

2015

SNG 5000 at **Dakota Gasification;** catalyst start-up in 2015; *1.6 bn Nm3/a*

2014

CO2 to SNG (Audi): Clariant Catalyst > 2 year on-stream; *1.4 m Nm3/a green CH4*

SNG5000 at Wison pilot plant, 100 Nm3/h SNG

2013

2010

1980-2000: SNG pilot plant in Louisville/US; Basic Development of SNG 5000 catalyst, 10 Nm3/h

2000-2010: development of SNG 5000 improved SNG catalyst, R&D center Louisville/US

1990

1980

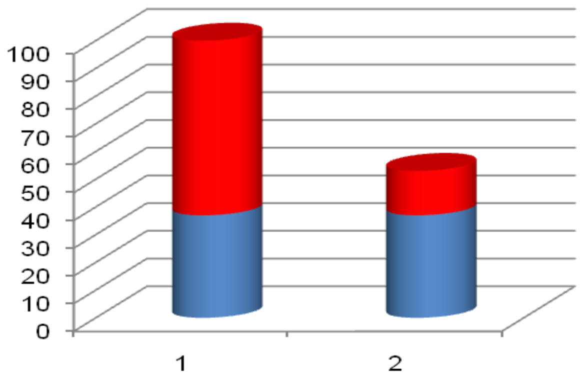
1977-1990: first commercial COG to SNG plant in JP operated with Clariant catalysts COG inlet: 25.000 Nm3/h

1975

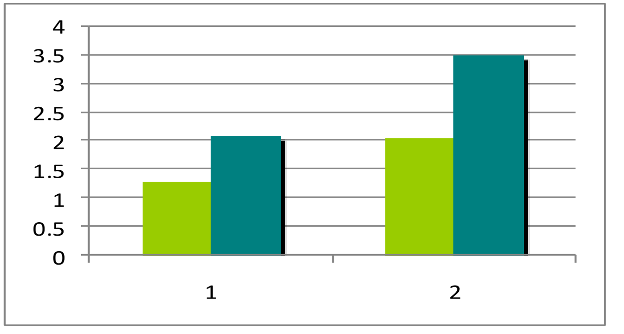
1970: Lurgi/Sasol SNG process in South Africa: isothermal + adiabatic,

VESTA technology - lower CAPEX/OPEX

- **VESTA technology reduces the investment and energy consumption of purification devices**



Gas volume changes before and after methanation



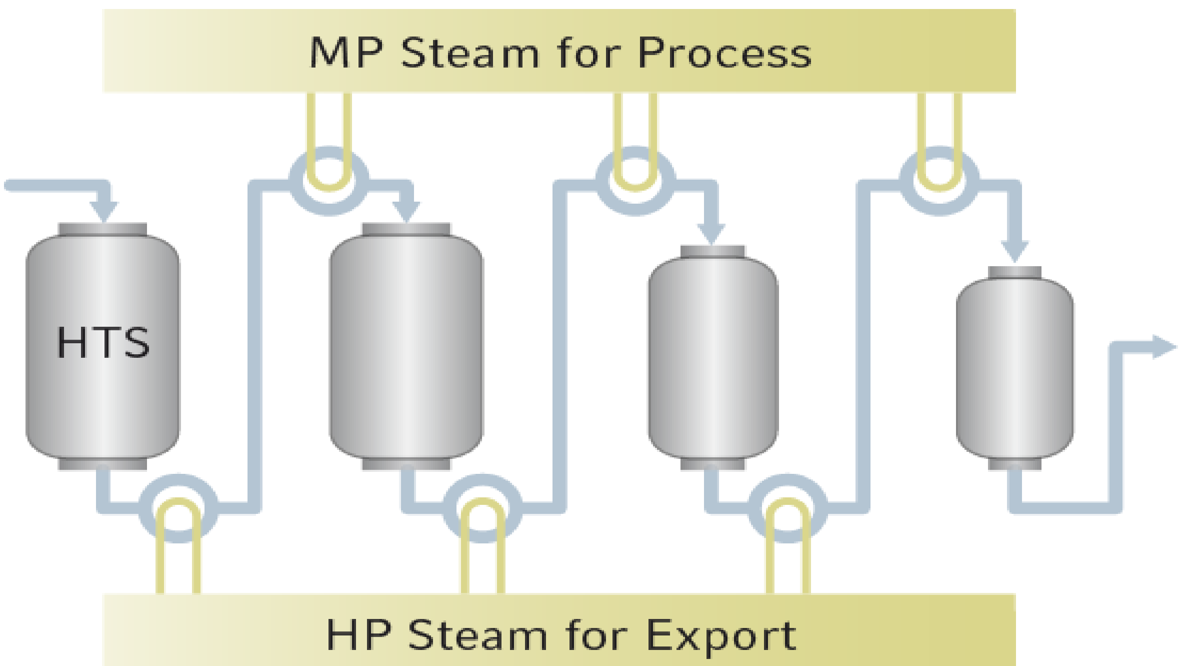
Partial pressure change of CO2

Tower diameter	Conventional	VESTA
	m	m
Wash Column	6.5	4.6/5.2
CO_2Production Column	4	4.4
H_2S Enrichment Column	6.5	5.2
Hot Regeneration Column	6.6	5
Tail Gas Wash Column	5.8	5

Comparison of main towers

VESTA technology - steam flexibility

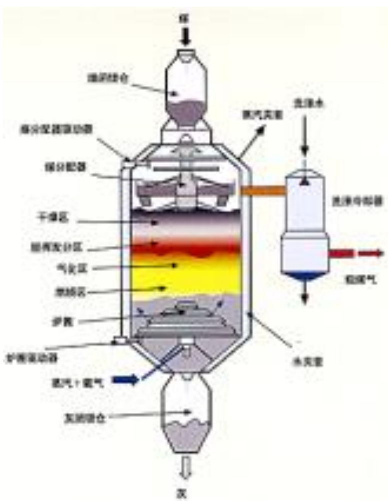
- **VESTA provides full flexibility of steam quality**
  - Temperature: 450 to 500°C
  - Pressure: For all industrial applications



VESTA technology evaluation

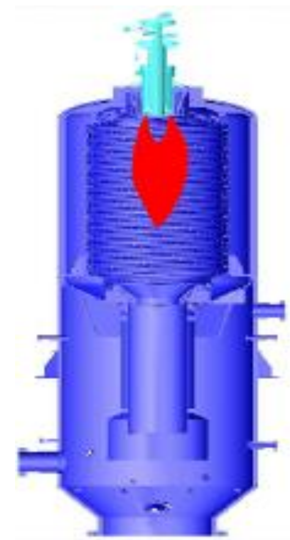
- **VESTA is suitable for all types of gasifiers**

Fixed Bed



Dry Feed WHB

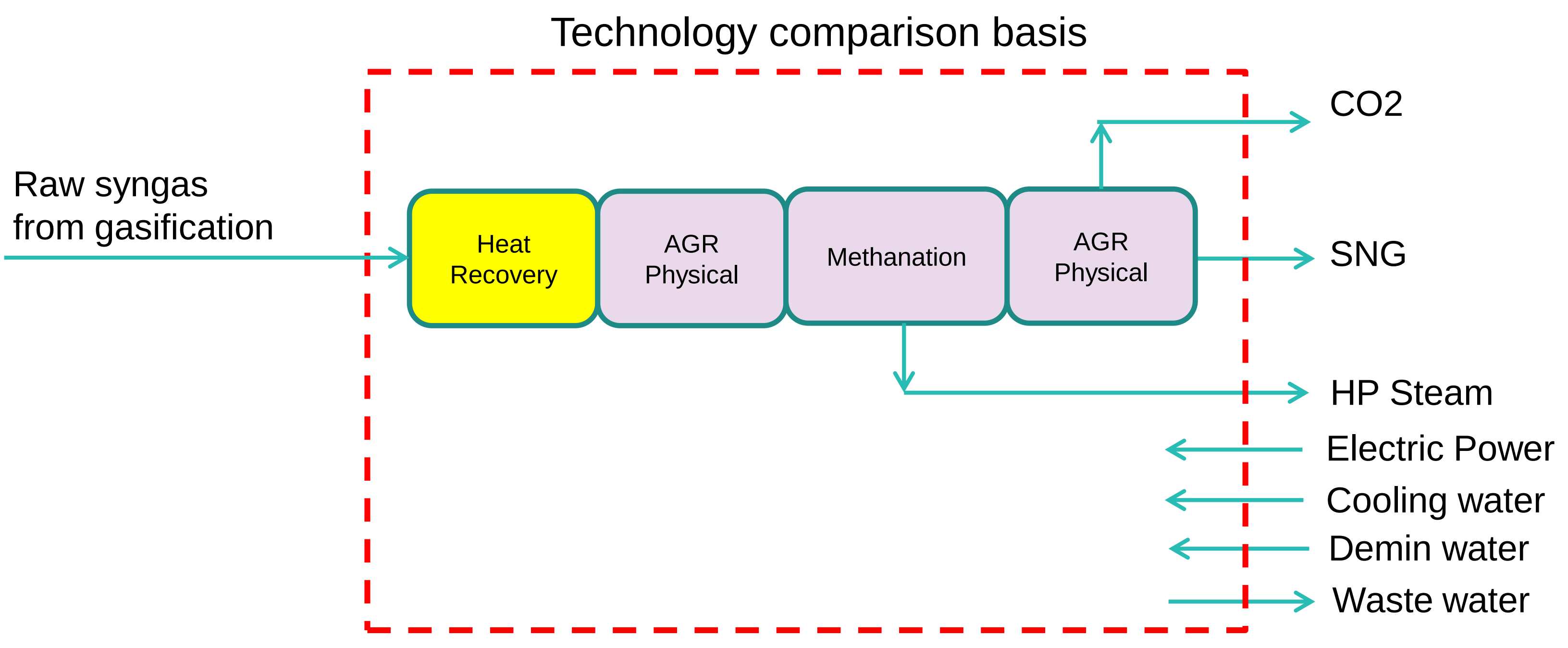
Dry Feed Quench



- The following comparison is based on Dry Feed WHB gasifier

VESTA technology evaluation

▶ Worth to include all the sections downstream the gasification scrubber up to the CO_2 removal



▶ We can offer an integrated SNG / Acid Gas Removal solution with suitable process guarantees

VESTA technology evaluation

VESTA has lower CAPEX

Equipment cost comparison		
	Competing Technology	VESTA
SAVING ON EQUIPMENT COST %	BASE	-20 %

- The comparison accounts for the acid gas removal (H_2S and CO_2), the CO Shift and Methanation.
- Syngas from Dry feed WHB gasification

VESTA technology evaluation

VESTA has lower Energy Consumption (OPEX)

Production / Consumption figure (GB30179-2013)		
	Competing Technology	VESTA
TOTAL %	BASE	15 % better

- Comparison according to the Norm GB30179-2013
- Comparison based on integrated SNG Acid Gas Removal scheme

VESTA Pilot Plant

- Wood has signed a cooperation agreement with Clariant International AG ("Clariant") and Wison Engineering Ltd ("Wison Engineering") to build a pilot plant to demonstrate the Wood VESTA SNG technology. All the parties have a large experience in the coal industry.

Pilot plant:

- Designed for a production capacity of 100 Nm^3/h of SNG and includes all reactors and control system in order to completely demonstrate a real plant in addition to the verification of the chemical reactions
- Erected in Nanjing, China
- Two test campaigns have been carried out in 2014 and 2015/2016 to successfully demonstrate a continuous operation at 100% SNG production meeting the Chinese natural gas grid specification, and to test different operating parameters.

VESTA Pilot Plant



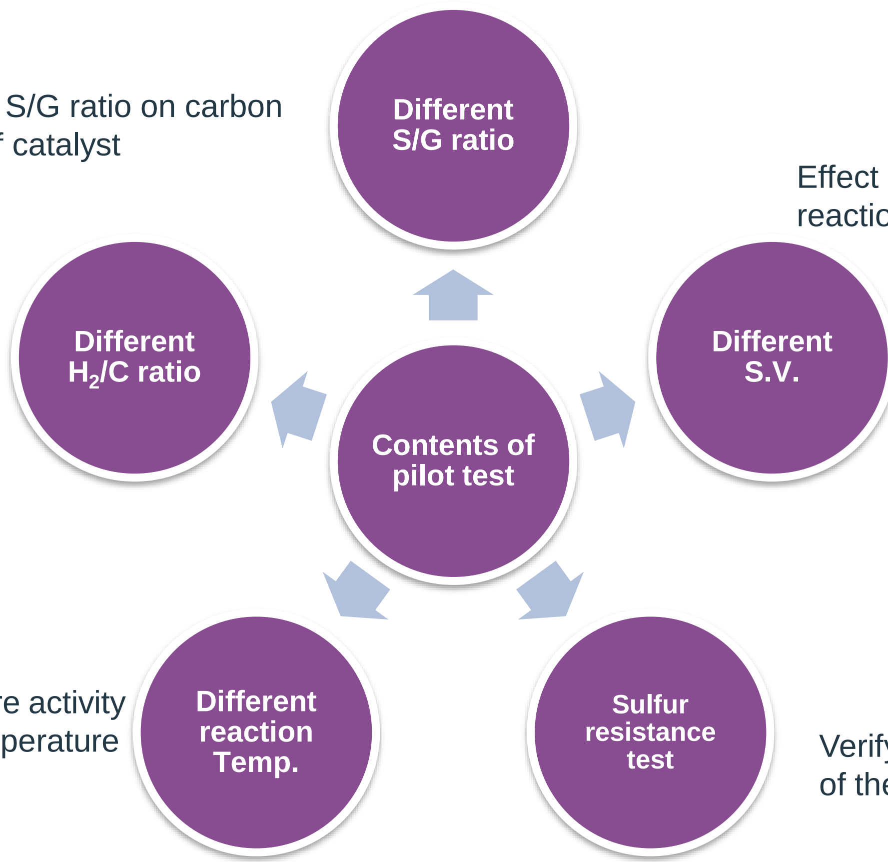

Design drawing and real pilot plant with methanation reactors

Full range of pilot test for VESTA SNG technology

Effect of low S/G ratio on carbon deposition of catalyst

Effect of different S.V. on reaction equilibrium

Effect of different feed composition on reaction



To verify the low temperature activity of the catalyst and high temperature stability

Verify the anti-toxic ability of the catalyst

Examples of VESTA Technology application

- Coal to SNG
- Petcoke to SNG

Coal to SNG – VESTA Technology application

In some areas of the world, natural gas demand cannot be satisfied by import with the consequent requirement to exploit coal reserves to produce fuel by means of SNG.

TECHNICAL DATA

Feedstock: Bituminous coal: LHV equal to 25,870 kJ/kg and sulphur content of 1.1% wt (dry, ash free)

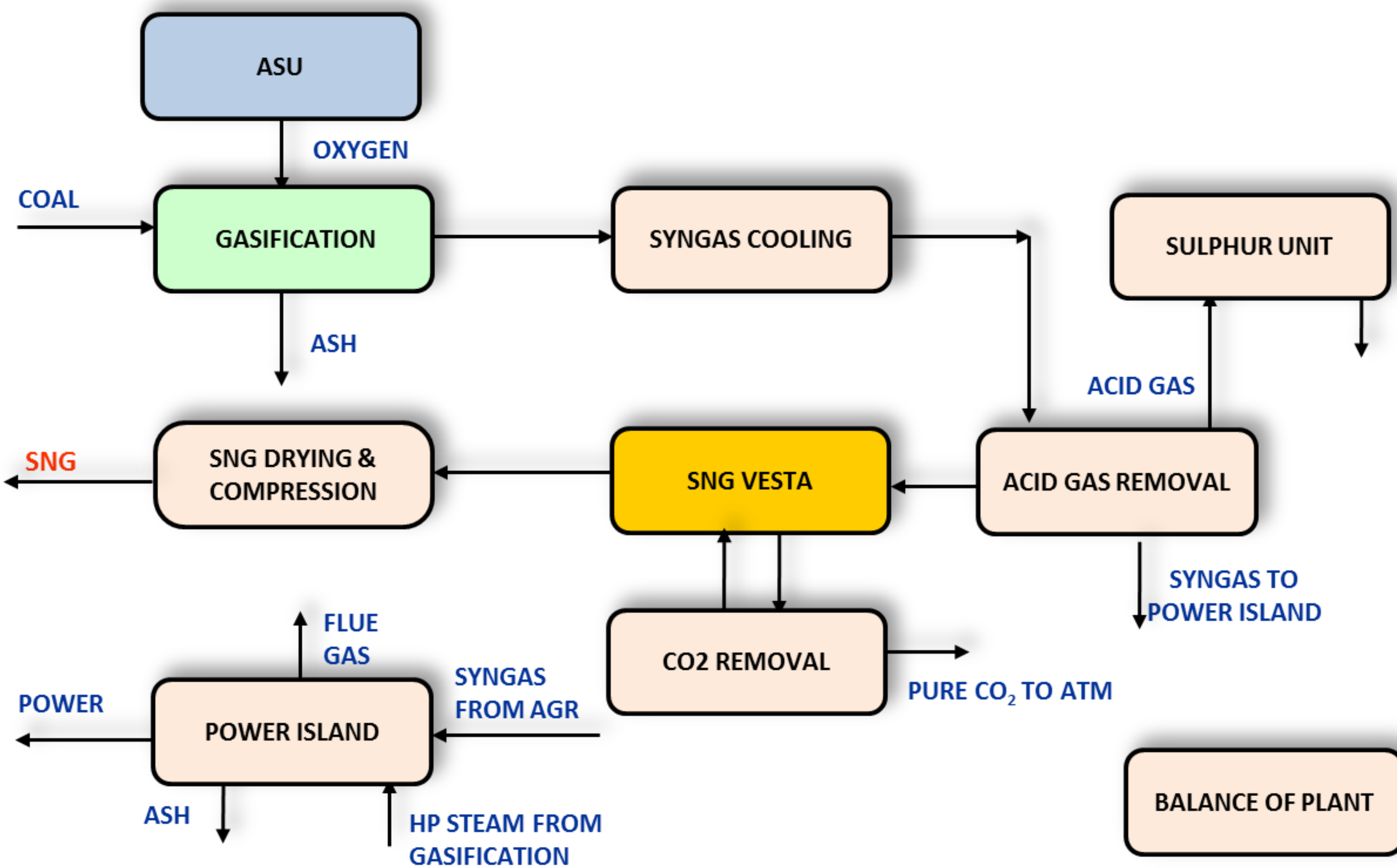
Flowrate: 100 t/h

SNG production: 34,800 Nm^3/h

Electrical power production: 0 MWe net (*)

(*) Gross electrical power production 53 MWe

Coal to SNG – VESTA Technology application



Petcoke to SNG – VESTA Technology application

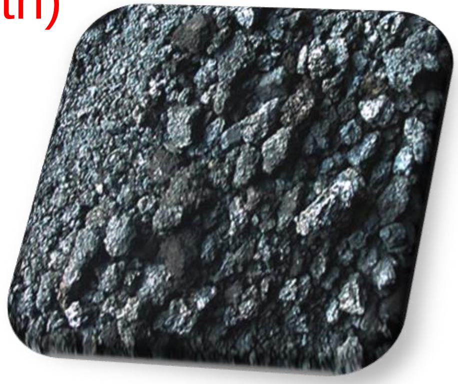
Considering a 200,000 BPSD refinery processing an average crude, 100 t/h of petcoke are produced.

TECHNICAL DATA

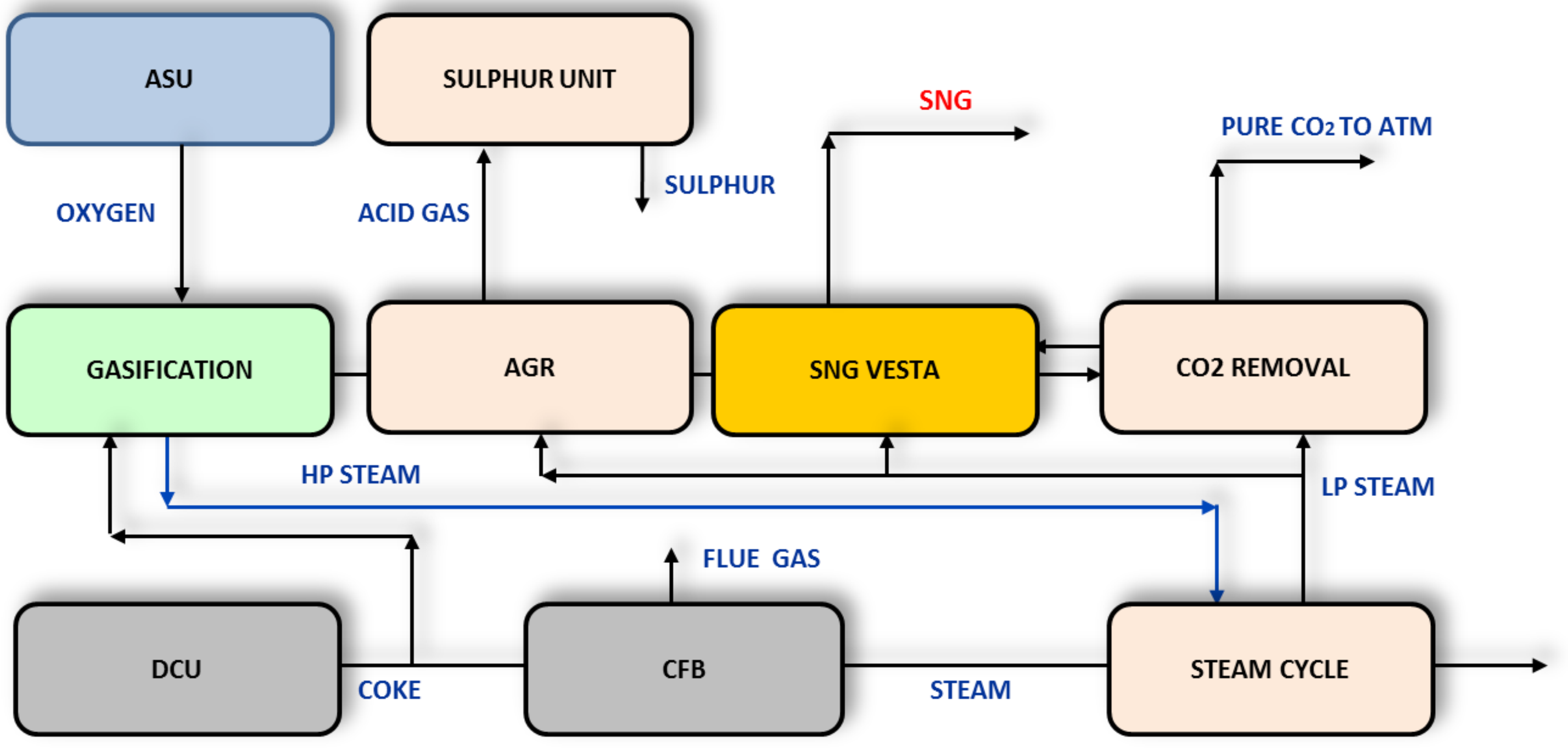
Feedstock: petcoke from a DCU, LHV equal to 32450 kJ/kg and sulphur content of 6.7% wt (dry, ash free)

Flowrate:	100 t/h (*)
SNG production:	37,800 Nm^3/h (362 MWth)
Electrical Power production:	60 MWe net suitable to satisfy refinery needs

(*) Petcoke : 75 t/h to SNG production and 25 t/h to power station.



Petcoke to SNG – VESTA Technology application



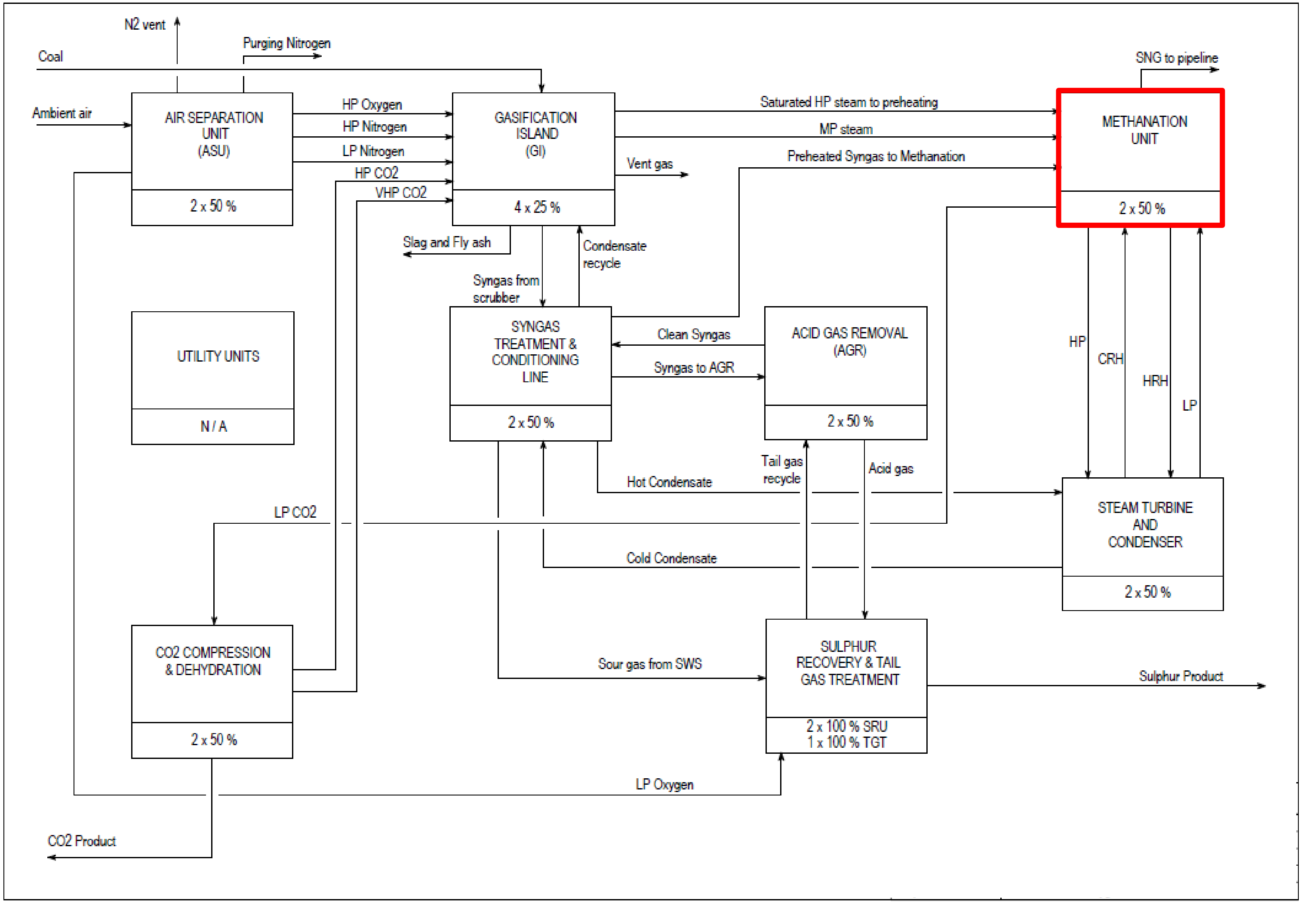
Polygeneration plant application with VESTA

- Wood perfomed a study to assess the performance and costs of two Polygeneration plants, based on the coal gasification process and aimed at the production of Substitute Natural Gas (SNG)
  - Case #1: Medium-pressure (40 barg) Coal Gasification Process, with dryfeed system and Synthesis Gas Cooler.
  - Case #2: High-pressure (85 barg) Gasification Process, quench type and slurry-feed system.

DESIGN BASIS

- Plant capacity: 2,000 MWth SNG min
- Electric power produced by means of dedicated steam turbines
- Coal-fired Circulating Fluidized Bed (CFB) boilers to meet the additional steam production of the plant for power generation
- Methanation unit based on the VESTA technology, producing SNG

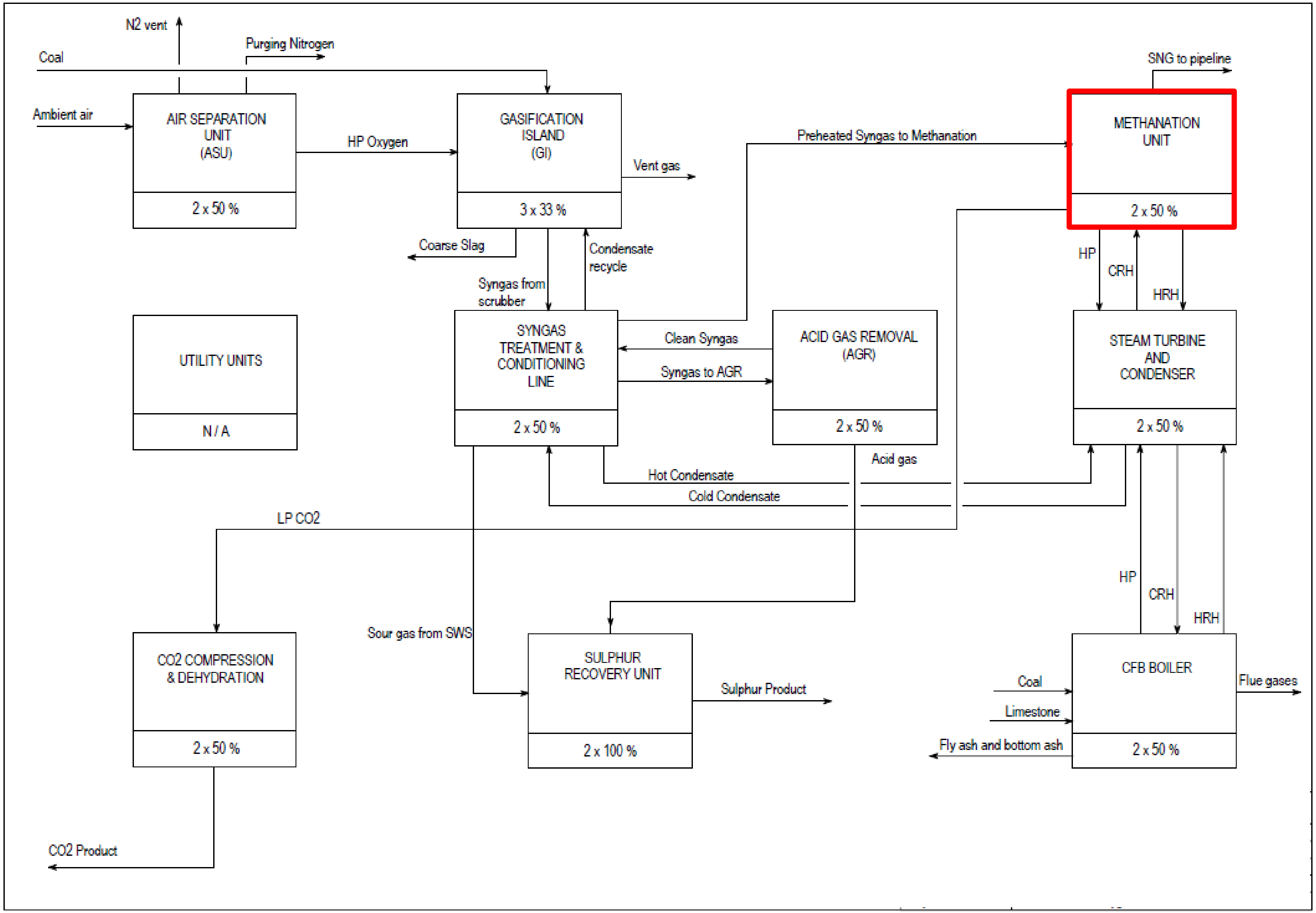
Polygeneration plant application with VESTA (Case #1)



Polygeneration plant application with VESTA (Case #1)

Polygeneration Case #1 Performance Summary		
OVERALL PERFORMANCES		
EABC Flowrate (as received)	t/h	130.1
Indonesian coal Flowrate (as received)	t/h	403.3
Coal Flowrate (as received)	t/h	533.3
Coal LHV (as received)	kJ/kg	23,054
Coal HHV (as received)	kJ/kg	24,369
THERMAL ENERGY OF FEEDSTOCK(A)	**MWth (LHV)**	**3,415**
THERMAL ENERGY OF FEEDSTOCK(A')	**MWth (HHV)**	**3,610**
Thermal Power of Raw Syngas exit Scrubber (B)	MWth (LHV)	2,816
Thermal Power of Clean Syngas to CMD (C)	MWth (LHV)	64
Thermal Power of Clean Syngas to SNG (D)	MWth (LHV)	2742
Syngas treatment efficiency ((C+D)/B x 100)	% (LHV)	99.6
Thermal Power of SNG (E)	**MWth (LHV)**	**2035**
SNG efficiency (E/D x 100)	**% (LHV)**	**74.2**
Gasification to SNG efficiency (E/A x 100)	**% (LHV)**	**59.6**
Steam turbine electric power output	MWe	314.7
GROSS ELECTRIC POWER OUTPUT	**MWe**	**314.7**
Gasification Section units consumption	MWe	52.7
ASU consumption	MWe	137.4
Power Island units consumption	MWe	8.6
CO_2 Compression and Dehydration unit consumption	MWe	81.0
Methanation unit consumption	MWe	22.6
Utility Units consumption	MWe	13.5
TOTAL ELECTRIC POWER CONSUMPTION	**MWe**	**315.9**
NET ELECTRIC POWER IMPORT	**MWe**	**1.1**

Polygeneration plant application with VESTA (Case #2)



Polygeneration plant application with VESTA (Case #2)

Polygeneration Case #2 Performance Summary		
OVERALL PERFORMANCES		
EABC Flowrate (as received)	t/h	0.0
Indonesian coal Flowrate (as received)	t/h	643.4
Coal Flowrate to gasification (as received)	t/h	596.2
Coal Flowrate to CFB boiler (as received)	t/h	47.2
Coal LHV (as received)	kJ/kg	22,336
Coal HHV (as received)	kJ/kg	23,233
THERMAL ENERGY OF FEEDSTOCK to gasification (A)	**MWth (LHV)**	**3,699**
THERMAL ENERGY OF FEEDSTOCK to gasification (A')	**MWth (HHV)**	**3,847**
Thermal Power of Raw Syngas exit Scrubber (B)	MWth (LHV)	2,757
Thermal Power of Clean Syngas to CMD (C)	MWth (LHV)	0
Thermal Power of Clean Syngas to SNG (D)	MWth (LHV)	2748
Syngas treatment efficiency ((C+D)/B x 100)	% (LHV)	99.7
Thermal Power of SNG (E)	**MWth (LHV)**	**2093**
SNG efficiency (E/D x 100)	**% (LHV)**	**76.1**
Gasification to SNG efficiency (E/A x 100)	**% (LHV)**	**56.6**
TOTAL THERMAL INPUT (gasification + CFB boiler) (F)	**MWth (LHV)**	**3991.9**
Coal to SNG efficiency (E/F x 100)	**% (LHV)**	**52.4**
Steam turbine electric power output	MWe	326.1
GROSS ELECTRIC POWER OUTPUT	**MWe**	**326.1**
Gasification Section units consumption	MWe	49.4
ASU consumption	MWe	158.1
Power Island units consumption	MWe	11.1
CO_2 Compression and Dehydration unit consumption	MWe	76.8
Methanation unit consumption	MWe	12.9
Utility Units consumption	MWe	17.8
TOTAL ELECTRIC POWER CONSUMPTION	**MWe**	**326.0**
NET ELECTRIC POWER EXPORT	**MWe**	**0.1**

Experience transfer

- Wood has a great deal of experience in hydrogen plants where syngas is produced, shifted and cleaned-up

- Wood has a great deal of experience in power generation following a gasification unit (designed, engineered, constructed and started-up one of the largest IGCC in the world)

- Wood have a great deal of experience in AGR systems from all available Licensors

- Wood has the capabilities to engineer complex control systems for the simultaneous operation of multi-unit complexes

- Wood completed two BDP relevant to methanation and purification, sold the first license, and is ready to globally commercialize the VESTA technology.

Thank you

For VESTA enquiries, please contact SNG@woodplc.com

Questions and Answers?!