

# Clean coal thermal power cycles

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Stephen B. Harrison, Managing Director, sbh4 consulting  
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# Clean coal thermal power cycles

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- 1) Coal offers the Asia Pacific region an abundant and affordable local energy source
- 2) CO<sub>2</sub> emissions from power generation must be mitigated to ensure clean and sustainable use of coal
- 3) Retrofitting existing coal-fired power plants with CO<sub>2</sub> capture equipment is technically viable and proven at scale
- 4) When combined with oxygen-fed coal gasification, innovative thermal power generation technologies, such as the Allam-Fetvedt Cycle can result in low-cost, CCS-ready thermal power generation from coal
- 5) The potential for large scale permanent CO<sub>2</sub> storage exists in many locations in South East Asia

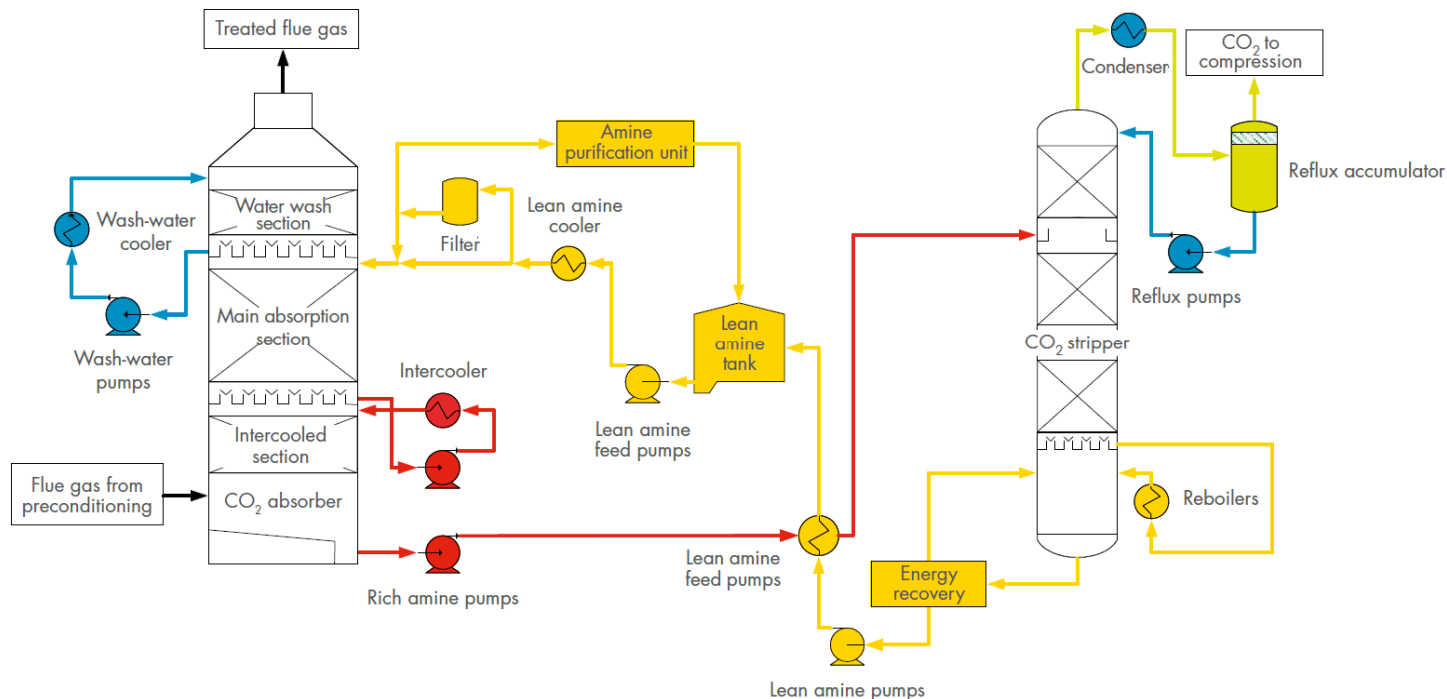
# 1) Mitigating CO<sub>2</sub> emissions from coal fired power generation with post combustion CO<sub>2</sub> capture

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# Coal-fired thermal power generation with retrofitted Shell CANSOLVE post-combustion CO<sub>2</sub> capture. SaskPower, Boundary Dam Canada.

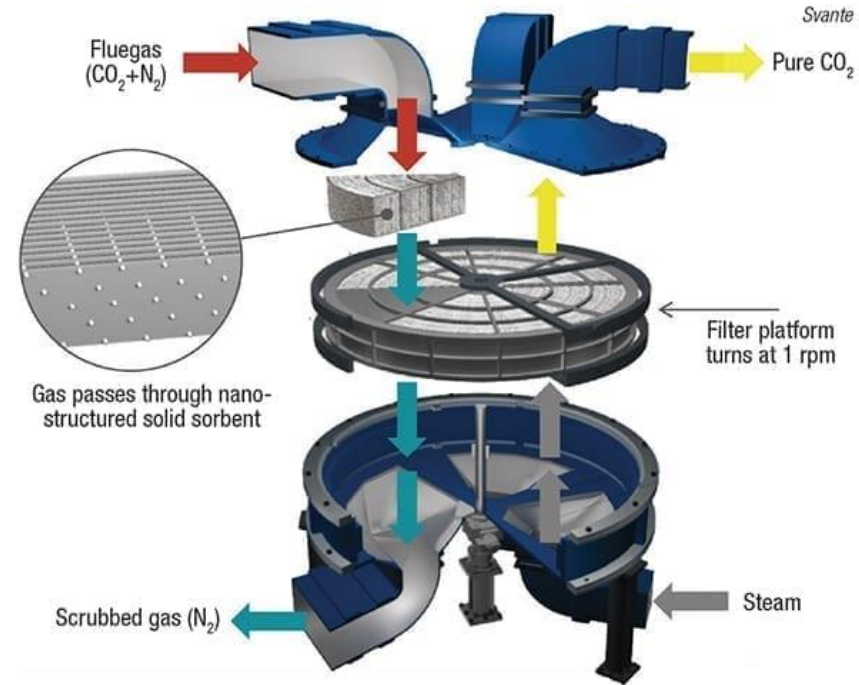


Amine-wash is the most used CO<sub>2</sub> capture technology in post-combustion applications. Other solvents can be used. Heat is the main input for solvent regeneration.



- Various amine blends (Shell, CANSOLVE; BASF, OASE Blue)
- Chilled ammonia process (Baker Hughes, CAP)
- Hot potassium carbonate (UOP, Benfield)
- Chilled methanol (Linde / AL, RECTISOL)
- Mixed MEG / PEG (Dow, SELEXOL)
- Carbonic anhydrase enzyme / potassium carbonate, CO<sub>2</sub> Solutions / SAIPEM)

# Svante – Temperature Swing Adsorption (TSA) CO<sub>2</sub> capture using solid amine or Metal-Organic Framework (MOF) adsorbents.

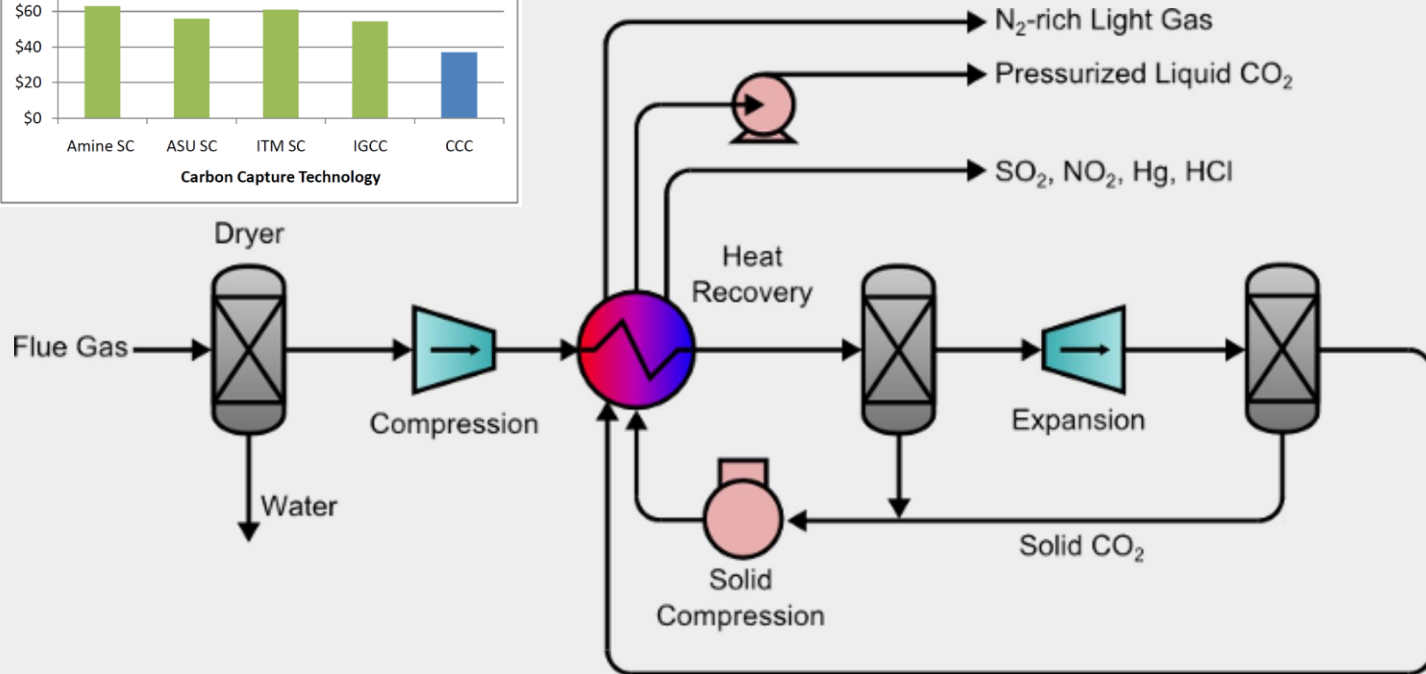
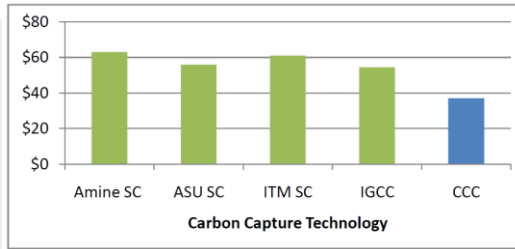




Vacuum Swing Adsorption (VSA) proven for CO<sub>2</sub> capture at Air Products SMR, Port Arthur for high-pressure, high-concentration, pre-combustion CO<sub>2</sub> capture. Power is the main input for regeneration, not heat.



# Chart Industries (SES innovations) Cryogenic Carbon Capture (CCC). Successful demonstration projects completed. As with VPSA, power is the main input, not heat.



The CCC process uses power whereas solvent wash processes use heat.

Use of heat for CO<sub>2</sub> capture could potentially utilise waste heat to minimise the parasitic load of CO<sub>2</sub> capture.



# CO<sub>2</sub> capture technology selection – points for consideration.

- Availability of heat vs power
- Scale of operation
- TRL requirement for investment
- Available space
- CO<sub>2</sub> concentration in the gas stream
- Pressure of the gas stream
- Need for SO<sub>2</sub> reduction to protect the solvent?
- Solvent emissions to air and water
- Required CO<sub>2</sub> purity
- CO<sub>2</sub> to be produced as liquid or gas?

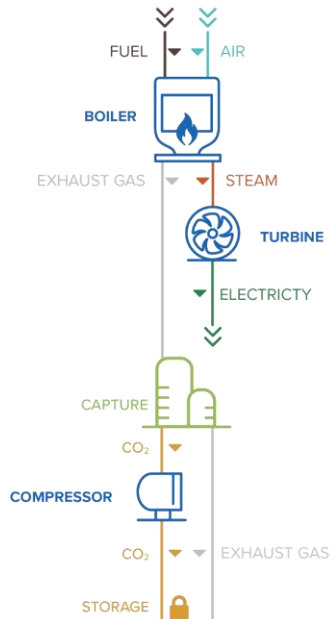


## 2) Simplification of CO<sub>2</sub> capture using IGCC with oxygen-fed coal gasification

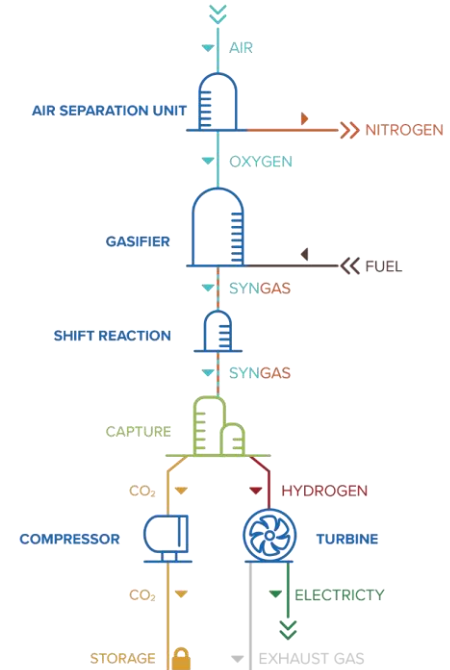
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Pre-combustion CO<sub>2</sub> capture from oxygen-fed gasification does not need to treat nitrogen from combustion air and can operate at high pressure.

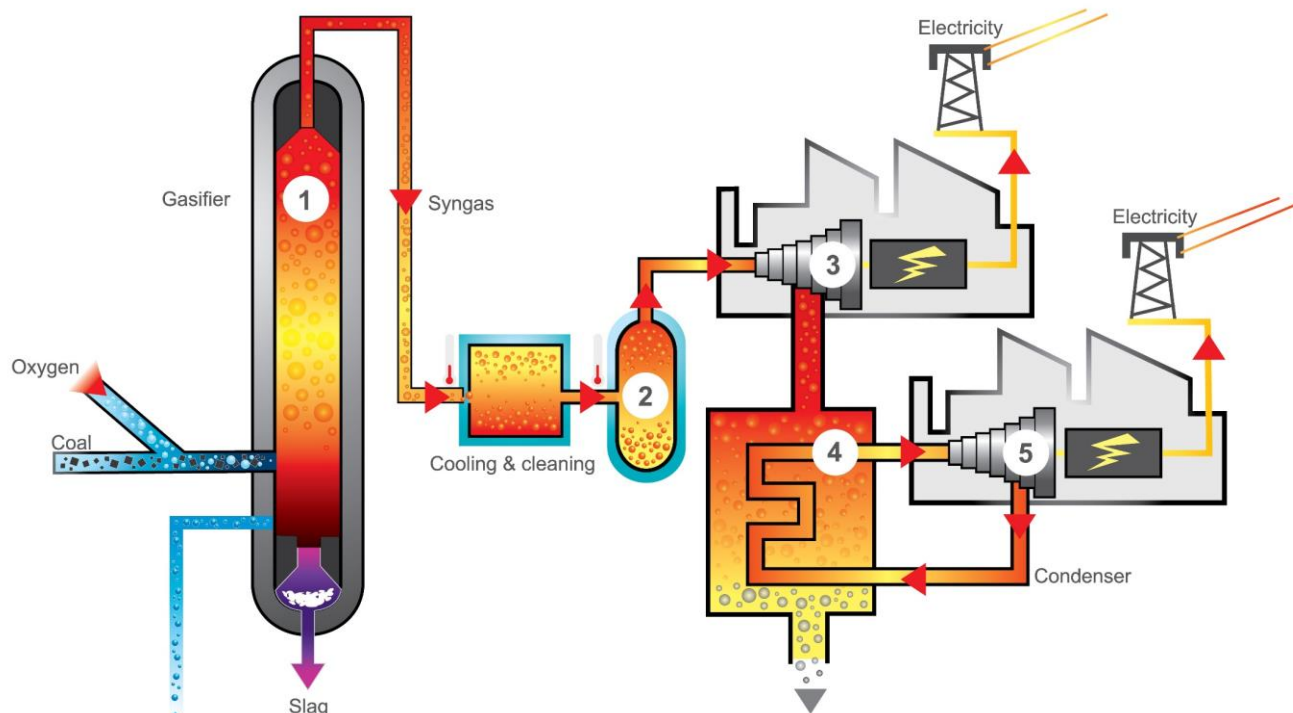
POST-COMBUSTION CO<sub>2</sub> CAPTURE



PRE-COMBUSTION CO<sub>2</sub> CAPTURE



Syngas can be used for thermal power generation in the Integrated Gasification Combined Cycle (IGCC). Oxygen feed simplifies CO<sub>2</sub> capture by avoiding nitrogen ballast gas flow.



- 1) Oxygen-fed coal gasifier
- 2) Syngas clean up
- 3) Syngas-fired gas turbine
- 4) Heat recovery loop
- 5) Steam turbine

Flue gas to Carbon Capture unit

# Elcogas oxygen-fed coal gasification IGCC thermal power plant, Puertollano Spain.



### 3) The Allam-Fetvedt cycle: Oxy-fuel process with integrated CO<sub>2</sub> capture to achieve clean power from coal

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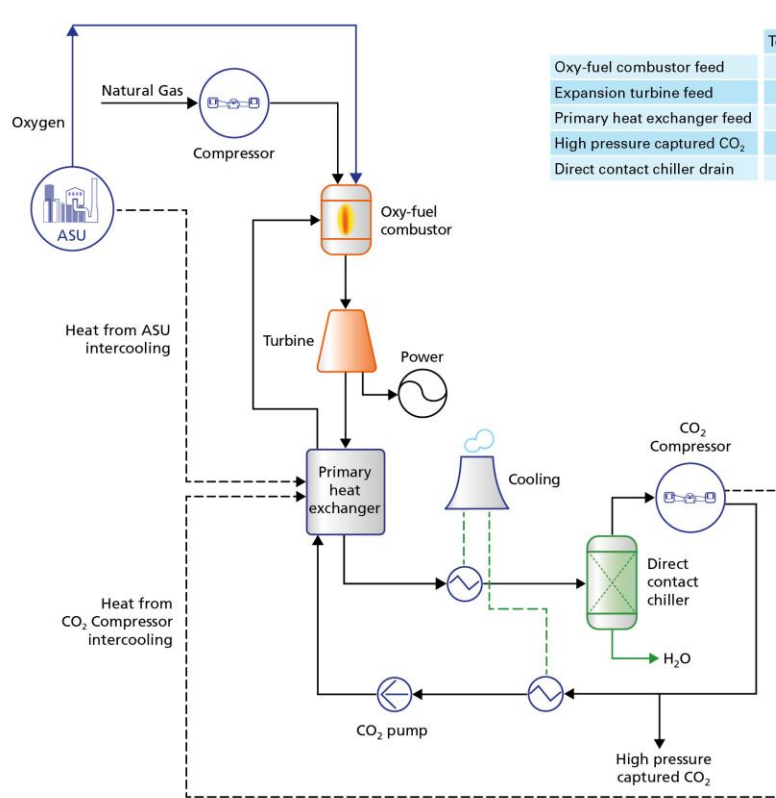


# Allam-Fetvedt cycle demonstration facility, La Porte USA.

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# The Allam cycle for natural gas: oxy-fuel thermal power generation with integrated CO<sub>2</sub> capture



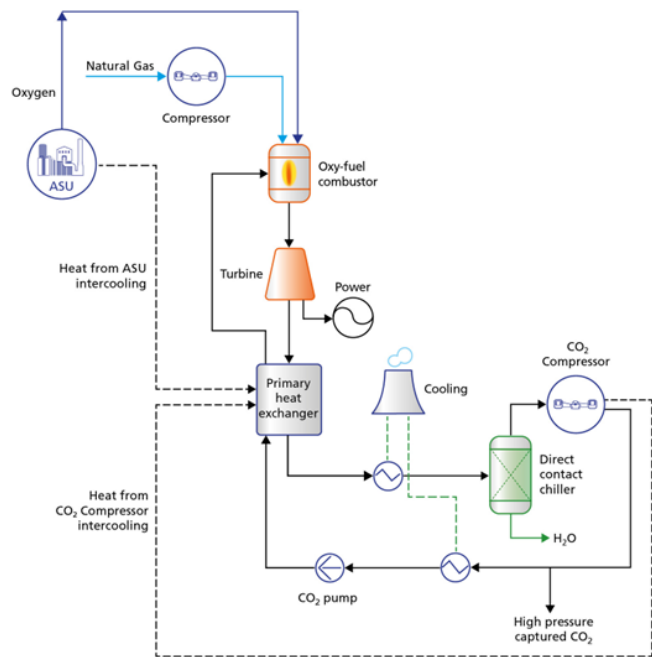
	Temperature °C	Pressure bar	Stream composition, referenced to combustor feed			
			CO <sub>2</sub> wt%	Natural gas wt%	Oxygen wt%	H <sub>2</sub> O wt%
Oxy-fuel combustor feed	700	300	94	1,25	4,75	0
Expansion turbine feed	1150	300	97,25	0	0	2,75
Primary heat exchanger feed	720	30	97,25	0	0	2,75
High pressure captured CO <sub>2</sub>	60	80	100	0	0	0
Direct contact chiller drain	20	30	0	0	0	100

- 1) Air separation plant for oxygen production
- 2) Oxygen compression
- 3) Natural gas, or syngas fuel compression
- 4) Oxy-fuel burner
- 5) Supercritical CO<sub>2</sub> turbine operating with some moisture
- 6) Heat exchange of CO<sub>2</sub>-rich working fluid leaving turbine against turbine inlet gases
- 7) Moisture removal from CO<sub>2</sub> working fluid through cooling and condensation
- 8) CO<sub>2</sub> recompression for working fluid recycle
- 9) CO<sub>2</sub> bleed for CCS

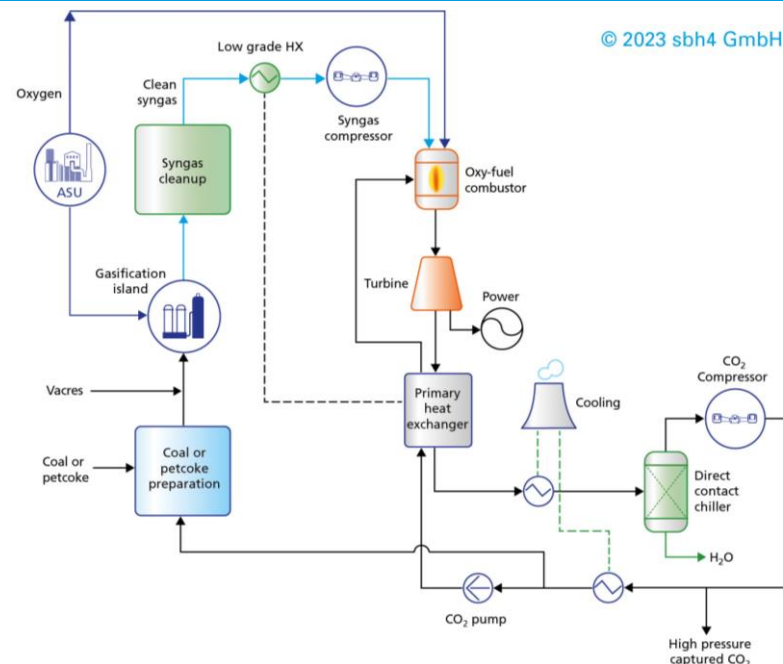
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# The Allam-Fetvedt cycle: for use with natural gas or syngas from coal gasification.

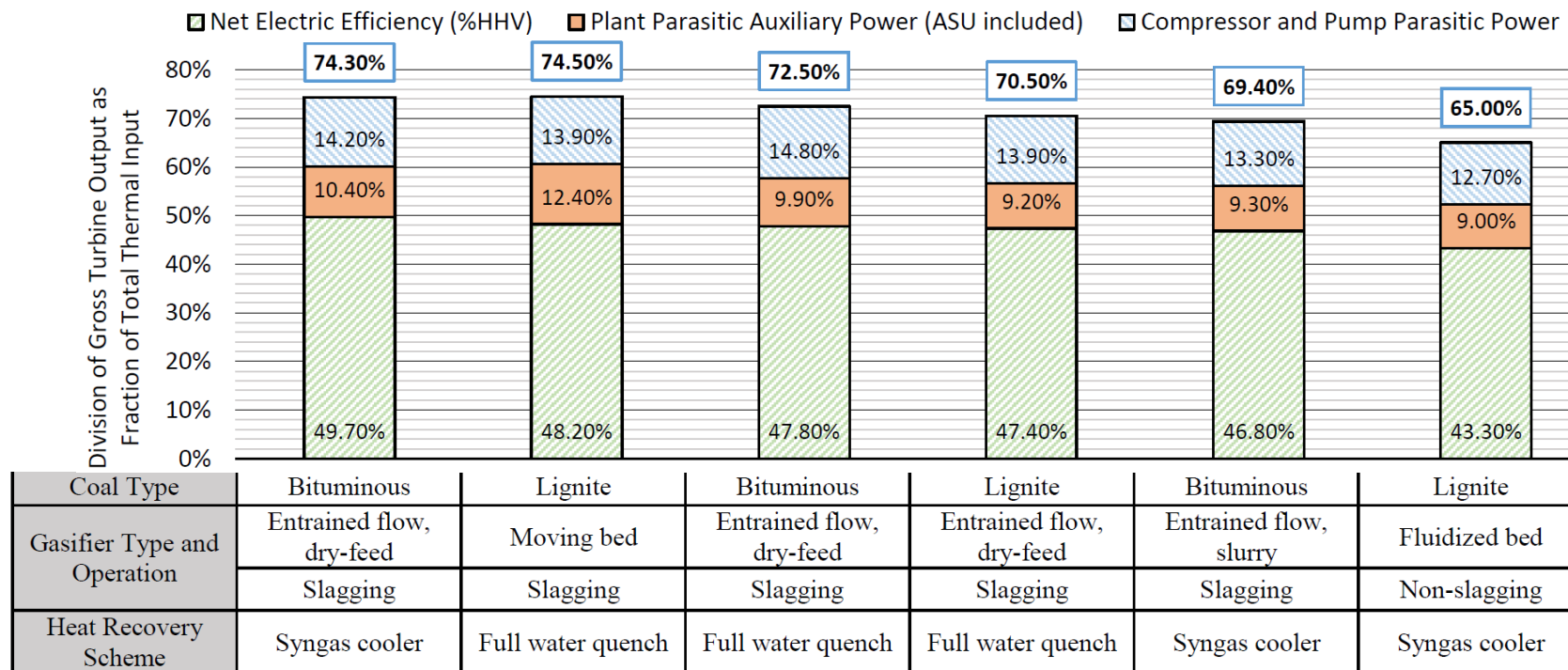


Classic Allam cycle for natural gas



Adapted Allam cycle for syngas from vacres, petcoke or coal gasification

# Modelled efficiencies of the Allam-Fetvedt cycle for various coal types and gasification regimes.

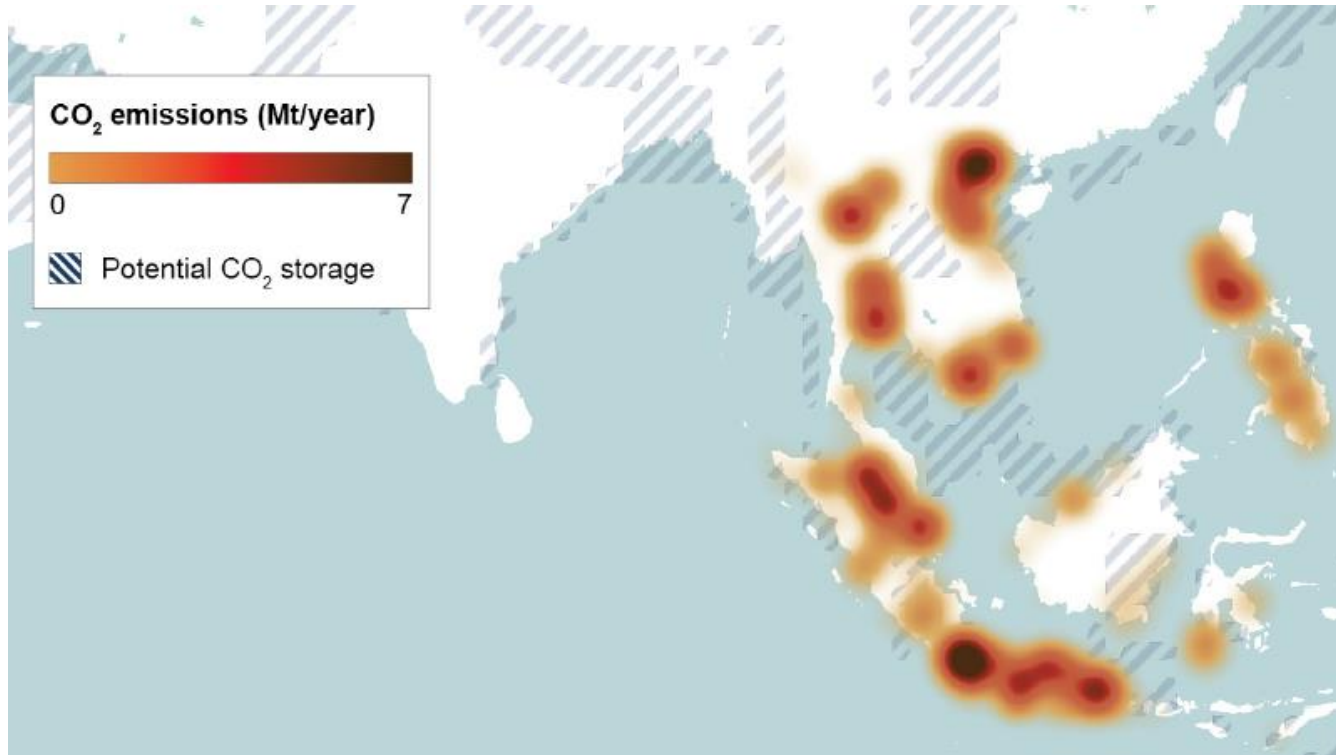


## 4) CO<sub>2</sub> Source / sink matching and concluding remarks

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Permanent CO<sub>2</sub> storage is integral to CCS and clean power from coal. South East Asia has huge CO<sub>2</sub> storage potential in locations close to major CO<sub>2</sub> emissions sources.





# Clean thermal power from coal is possible.

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- 1) CCS can help to decarbonise thermal power generation from coal
- 2) Post-combustion CO<sub>2</sub> capture is the simplest retrofit option to existing power plants
- 3) Amine wash is the dominant CO<sub>2</sub> capture technology, but many other carbon capture technologies are emerging and will challenge its dominance
- 4) IGCC with CO<sub>2</sub> capture can be more cost-effective than post-combustion CO<sub>2</sub> capture for new-build thermal power generation due to CO<sub>2</sub> capture at higher pressure and higher concentration
- 5) Oxygen-fed gasification for IGCC can further reduce the cost of CO<sub>2</sub> capture by further increasing CO<sub>2</sub> concentration in the flue gas
- 6) Advanced thermal cycles, also with oxy-fuel combustion, such as the Allam-Fetvedt Cycle are likely to be cost-effective clean technologies for thermal power generation from both coal
- 7) CCS scheme infrastructure for CO<sub>2</sub> transmission and utilisation or sequestration (eg with underground injection) is a critical enabler for all of the above



# Introduction to Stephen B. Harrison

**Stephen B. Harrison** is the founder and managing director at sbh4 GmbH in Germany. His work focuses on decarbonisation and greenhouse gas emissions reduction. Hydrogen and CCS are fundamental pillars of his consulting practice and he supports many industrial clients with their decarbonisation programmes.

Private Equity firms, investment fund managers and hydrogen start-ups are also regular clients. Stephen has accumulated extensive M&A and investment due diligence experience in the clean-tech sector.

Stephen served as the international hydrogen and CCS expert for multiple World Bank, IFC and ADB projects in Namibia, Pakistan, Palau and Viet Nam. His background is in industrial and specialty gases, including 27 years at BOC Gases, The BOC Group and Linde Gas. For 14 years, he was a global business leader in these FTSE100 and DAX30 companies.

As a member of the H2 View and **gasworld** editorial advisory boards, Stephen advises the direction for these leading hydrogen and CO<sub>2</sub> focused international publications.

Stephen is a member of the scientific committee for CEM 2023 in Barcelona. He also served on the Technical Committee for the Green Hydrogen Summit in Oman in December 2022 and the Advisory Board of the International Power Summit in Munich in September 2022.

