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Clean coal thermal power cycles

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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_2 emissions from power generation must be mitigated to ensure clean and sustainable of coal
3) Retrofitting existing coal-fired power plants with CO_2 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_2 storage exists in many locations in South East Asia

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1) Mitigating CO_2 emissions from coal fired power generation with post combustion CO_2 capture

Coal-fired thermal power generation with retrofitted Shell CANSOLVE post-combustion CO_2 capture. SaskPower, Boundary Dam Canada.

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Amine-wash is the most used CO_2 capture technology in post-combustion applications. Other solvents can be used. Heat is the main input for solvent regeneration.

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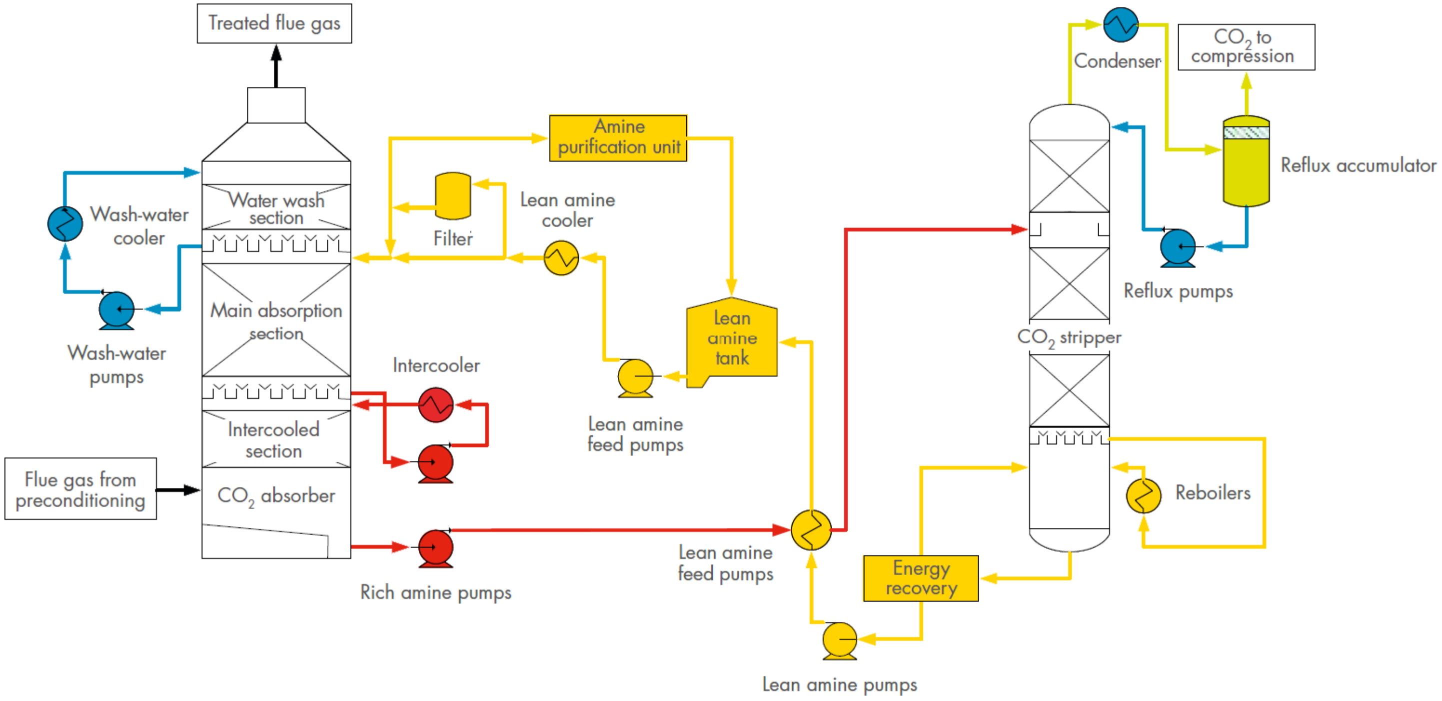

- Various amine blends (Shell, CANSOLVE; BASF, OASE Blue)
- Chilled ammonia process (Baker Hughes, CAP)
- Hot potasium carbonate (UOP, Benfield)
- Chilled methanol (Linde / AL, RECTISOL)
- Mixed MEG / PEG (Dow, SELEXOL)
- Carbonic anhydrase enzyme / potasium carbonate, CO2 Solutions / SAIPEM)

Svante – Temperature Swing Adsorption (TSA) CO2 capture using solid amine or Metal-Organic Framework (MOF) adsorbents.

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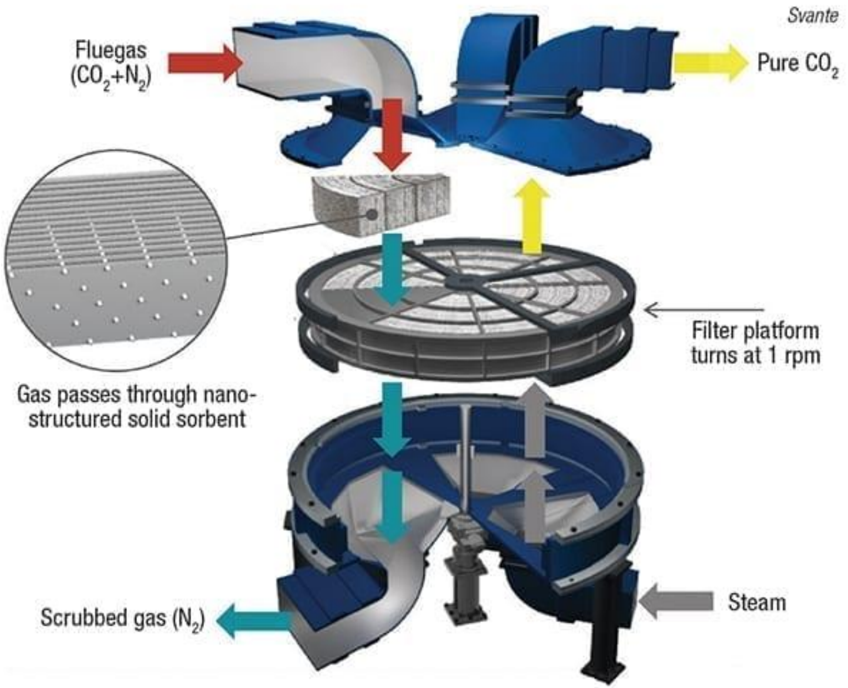

https://www.bccpa.ca/news-events/latest-news/2019/global-impact-svante-is-disrupting-the-world-s-co2-marketplace/
https://www.chemengonline.com/new-project-aims-scale-rapid-carbon-capture-process/

Vacuum Swing Adsorption (VSA) proven for CO_2 capture at Air Products SMR, Port Arthur for high-pressure, high-concentration, pre-combustion CO_2 capture. Power is the main input for regeneration, not heat.

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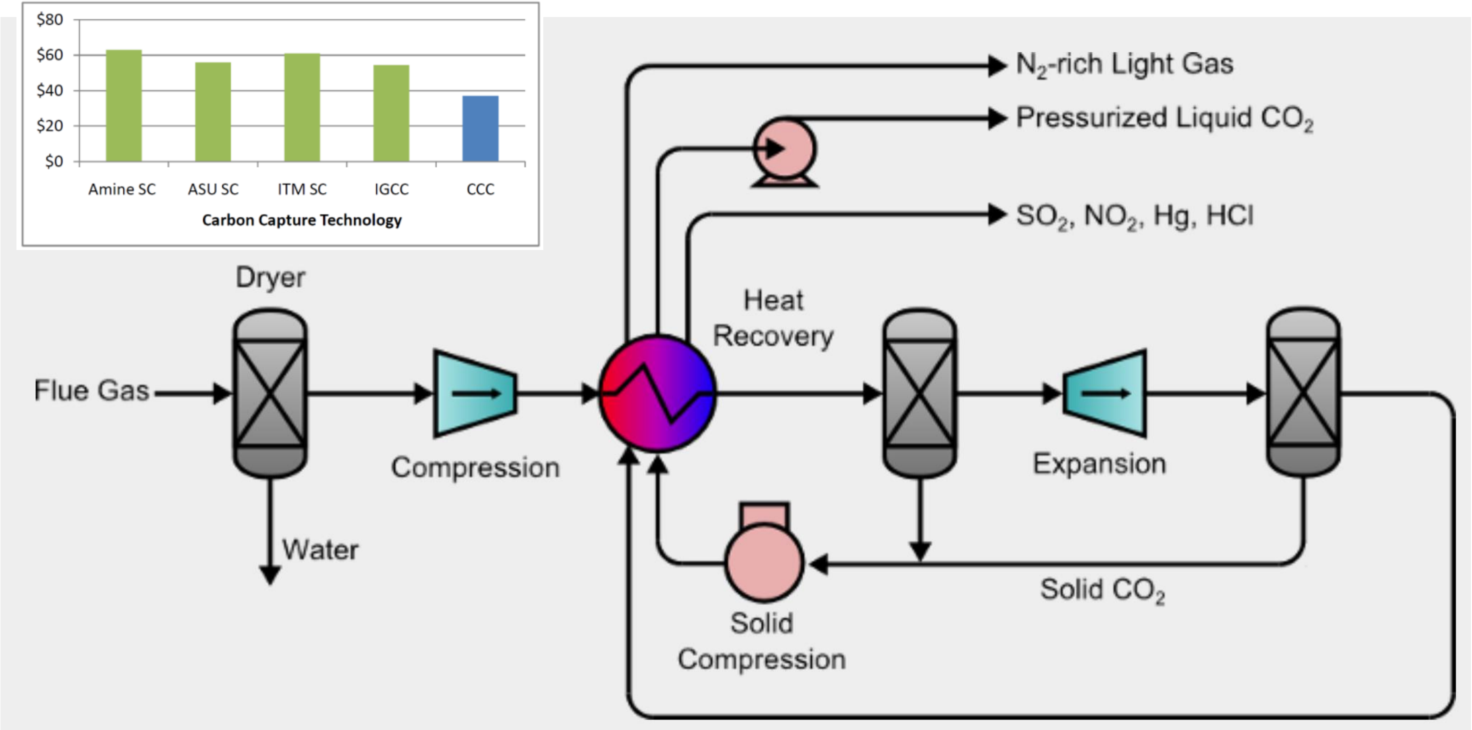
Image courtesy of APCI Inc

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 Co2 capture could potentially utilise waste heat to minimise the parasitic load of CO_2 capture.

CO_2 capture technology selection – points for consideration.

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- Availability of heat vs power
- Scale of operation
- TRL requirement for investment
- Available space
- CO_2 concentration in the gas stream
- Pressure of the gas stream
- Need for SO_2 reduction to protect the solvent?
- Solvent emissions to air and water
- Required CO_2 purity
- CO_2 to be produced as liquid or gas?

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2) Simplification of CO_2 capture using IGCC with oxygen-fed coal gasification

Pre-combustion CO_2 capture from oxygen-fed gasification does not need to treat nitrogen from combustion air and can operate at high pressure.

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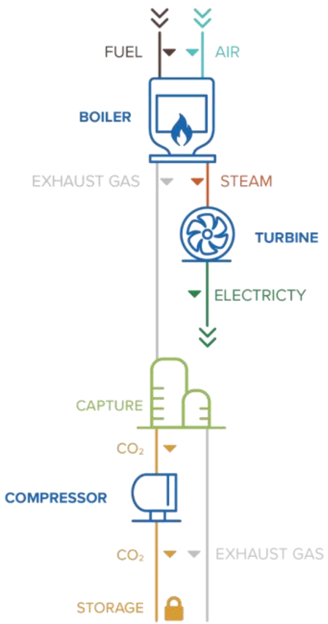
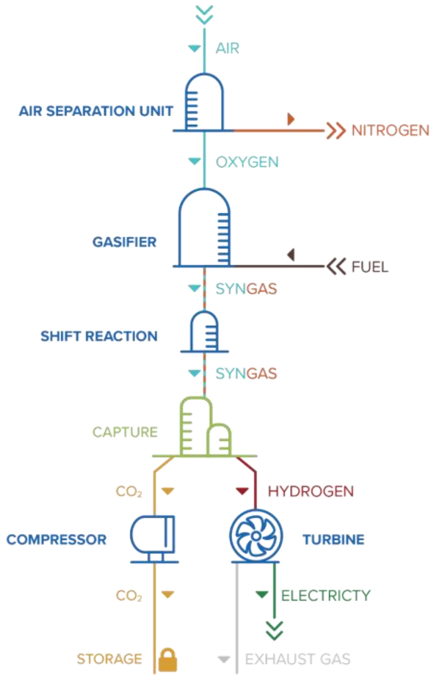
POST-COMBUSTION CO_2 CAPTURE



PRE-COMBUSTION CO_2 CAPTURE



Syngas can be used for thermal power generation in the Integrated Gasification Combined Cycle (IGCC). Oxygen feed simplifes CO_2 capture by avoiding nitrogen ballast gas flow.

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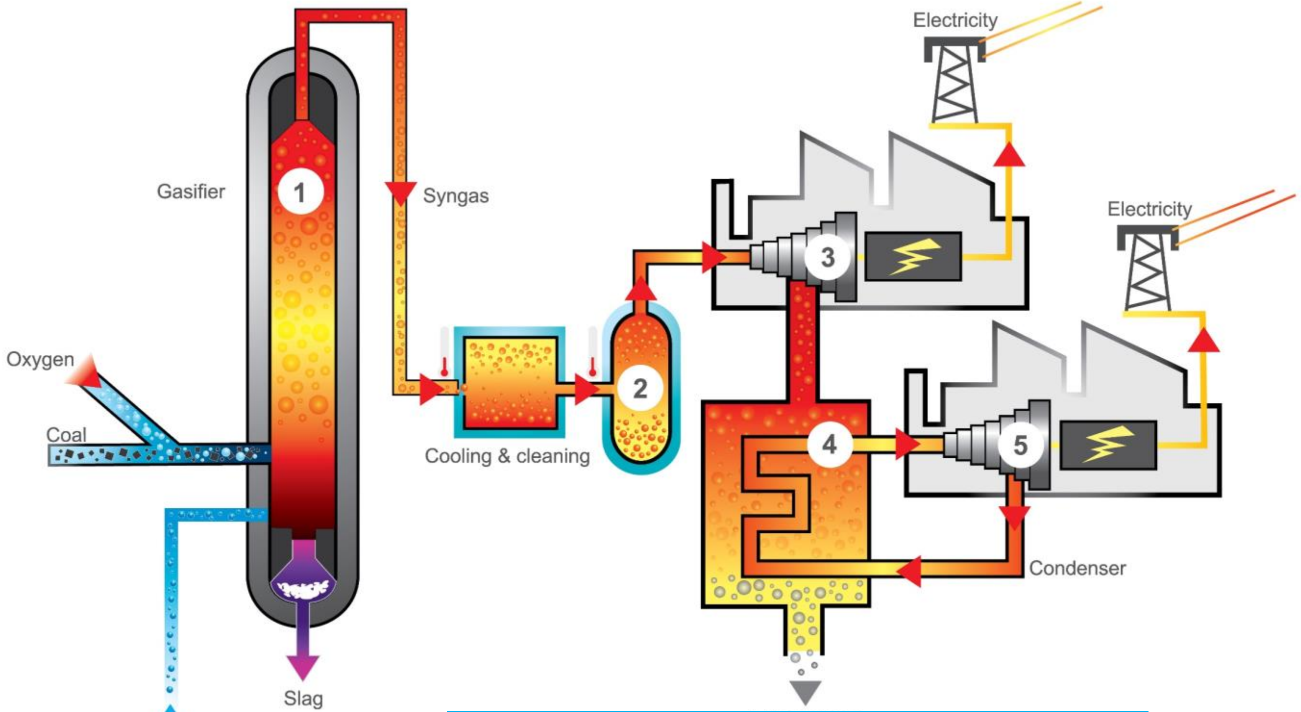

1) Oxygen-fed coal gasifier
2) Syngas clean up
3) Syngas-fired gas turbine
4) Heat recovery loop
5) Steam turbine

Flue gas to Carbon Capture unit

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

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3) The Allam-Fetvedt cycle: Oxy-fuel process with integrated CO_2 capture to achieve clean power from coal

Allam-Fetvedt cycle demonstration facility, La Porte USA.

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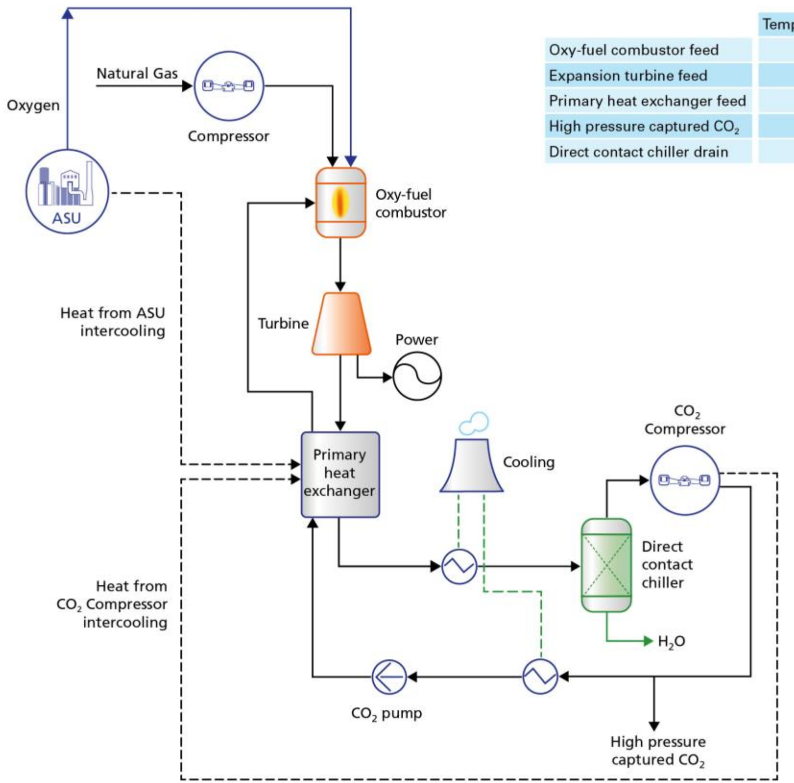
https://www.eenews.net/articles/co2-free-natural-gas-ccs-project-powers-grid-for-first-time/

The Allam cycle for natural gas: oxy-fuel thermal power generation with integrated CO_2 capture



	Temperature °C	Pressure bar	Stream composition, referenced to combustor feed			
			CO_2 wt%	Natural gas wt%	Oxygen wt%	H_2O 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_2	60	80	100	0	0	0
Direct contact chiller drain	20	30	0	0	0	100

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1) Air separation plant for oxygen production
2) Oxygen compression
3) Natural gas, or syngas fuel compression
4) Oxy-fuel burner
5) Supercritical CO2 turbine operating with some moisture
6) Heat exchange of CO2-rich working fluid leaving turbine against turbine inlet gases
7) Moisture removal from CO2 working fluid through cooling and condensation
8) CO2 recompression for working fluid recycle
9) CO2 bleed for CCS

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

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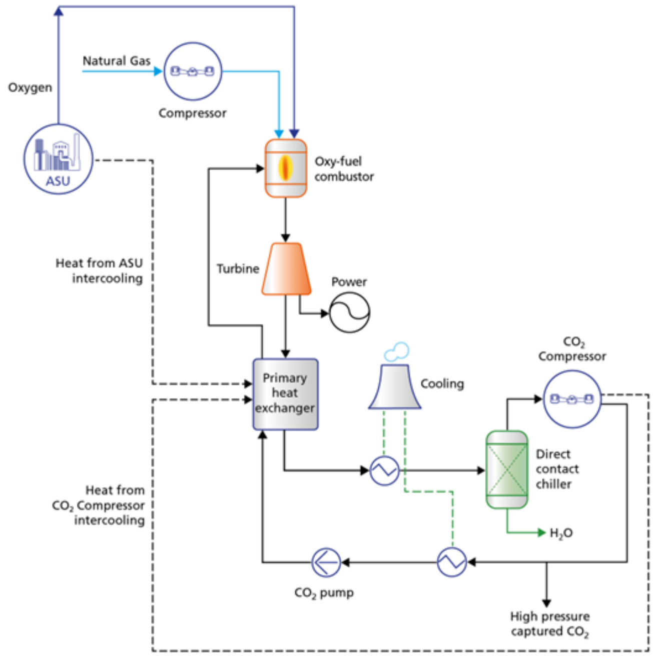
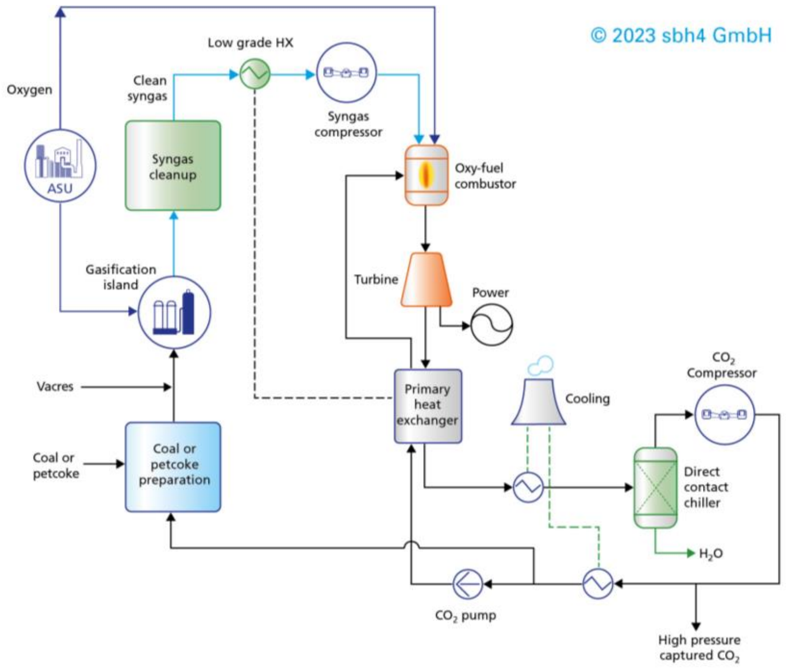


Classic Allam cycle for natural gas



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.

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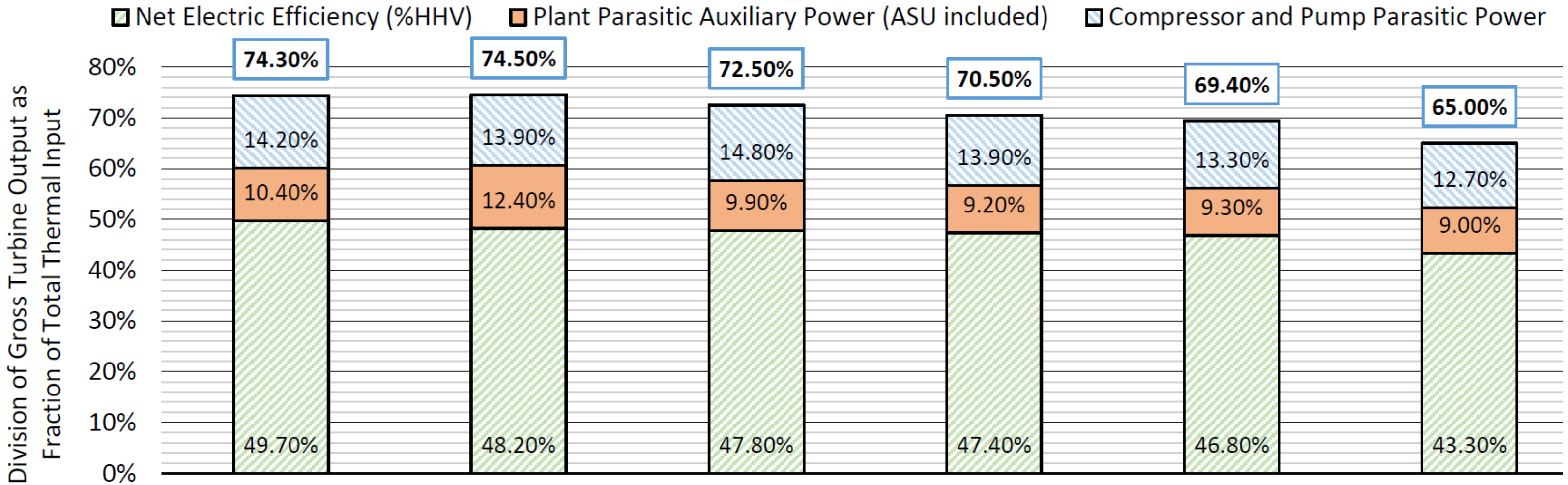

Coal Type	Bituminous	Lignite	Bituminous	Lignite	Bituminous	Lignite
Gasifier Type and Operation	Entrained flow, dry-feed	Moving bed	Entrained flow, dry-feed	Entrained flow, dry-feed	Entrained flow, slurry	Fluidized bed
	Slagging	Slagging	Slagging	Slagging	Slagging	Non-slagging
Heat Recovery Scheme	Syngas cooler	Full water quench	Full water quench	Full water quench	Syngas cooler	Syngas cooler

https://www.researchgate.net/publication/308499888_Integration_and_Optimization_of_Coal_Gasification_Systems_With_a_Near-Zero_Emissions_Supercritical_Carbon_Dioxide_Power_Cycle

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4) CO_2 Source / sink matching and concluding remarks

Permanent CO_2 storage is integral to CCS and clean power from coal. South East Asia has huge CO_2 storage potential in locations close to major CO_2 emissions sources.

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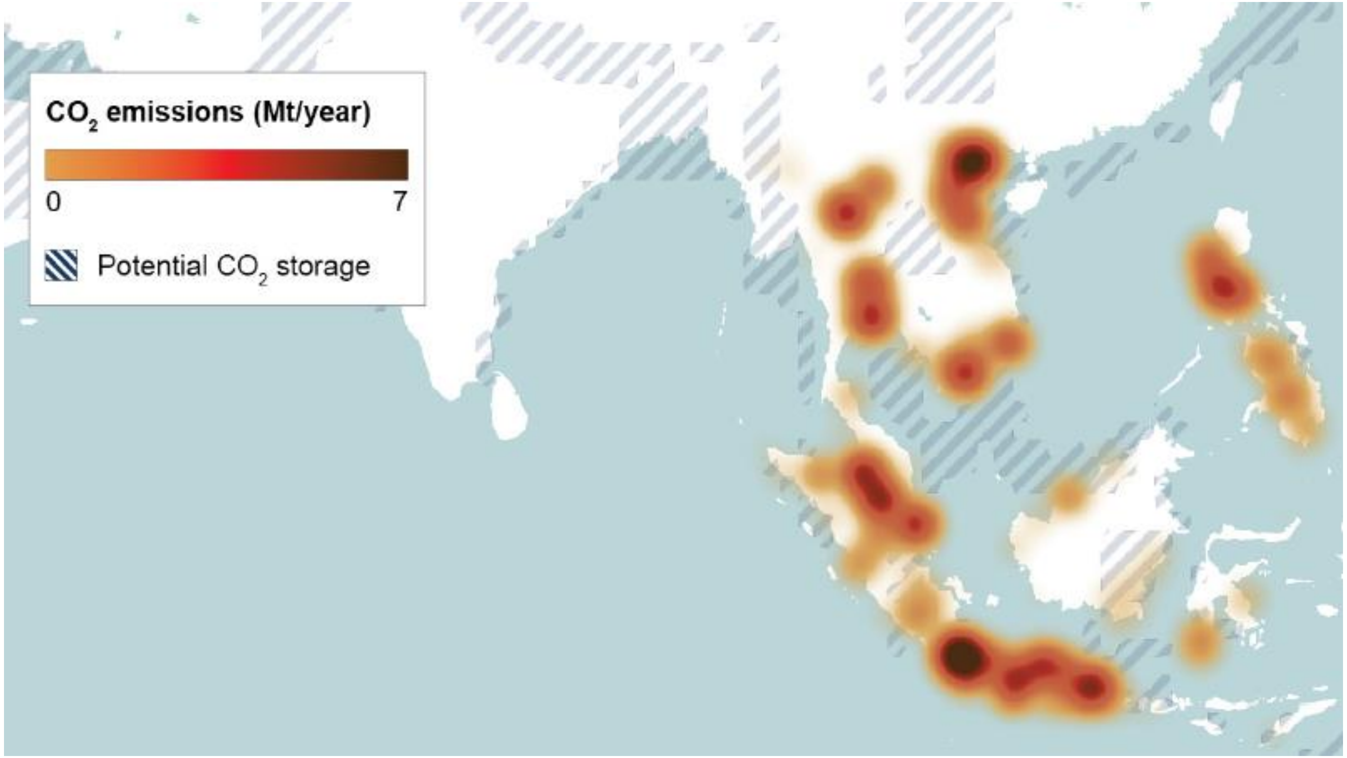

Source: Carbon capture, utilisation and storage, The opportunity in Southeast Asia, IEA 2021

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_2 capture is the simplest retrofit option to existing power plants
3) Amine wash is the dominant CO_2 capture technology, but many other carbon capture technologies are emerging and will challenge its dominance
4) IGCC with CO_2 capture can be more cost-effective than post-combustion CO_2 capture for new-build thermal power generation due to CO_2 capture at higher pressure and higher concentration
5) Oxygen-fed gasification for IGCC can further reduce the cost of CO_2 capture by further increasing CO_2 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_2 transmission and utilisation or sequestration (eg with underground injection) is a critical enabler for all of the above

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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 **gas**world editorial advisory boards, Stephen advises the direction for these leading hydrogen and CO_2 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.