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Tapping into new technologies to minimise carbon emissions from fossil fuelled power generation

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Tapping into new technologies to minimise carbon emissions from fossil fuelled power generation

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1. Mitigating fossil fuel power generation carbon emissions with innovative post combustion CCS technology

2. Simplification of CCS with CO_2 capture on the IGCC oxy-fuel process with coal, Vac Res or petcoke gasification

3. The Allam cycle, an oxy-fuel based advanced thermal process with CCS to achieve clean power from coal or natural gas

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1) Mitigating fossil fuel power generation carbon emissions with innovative post combustion CCS technology

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

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Amine-wash is the most used CO_2 capture technology across pre- and post-combustion applications

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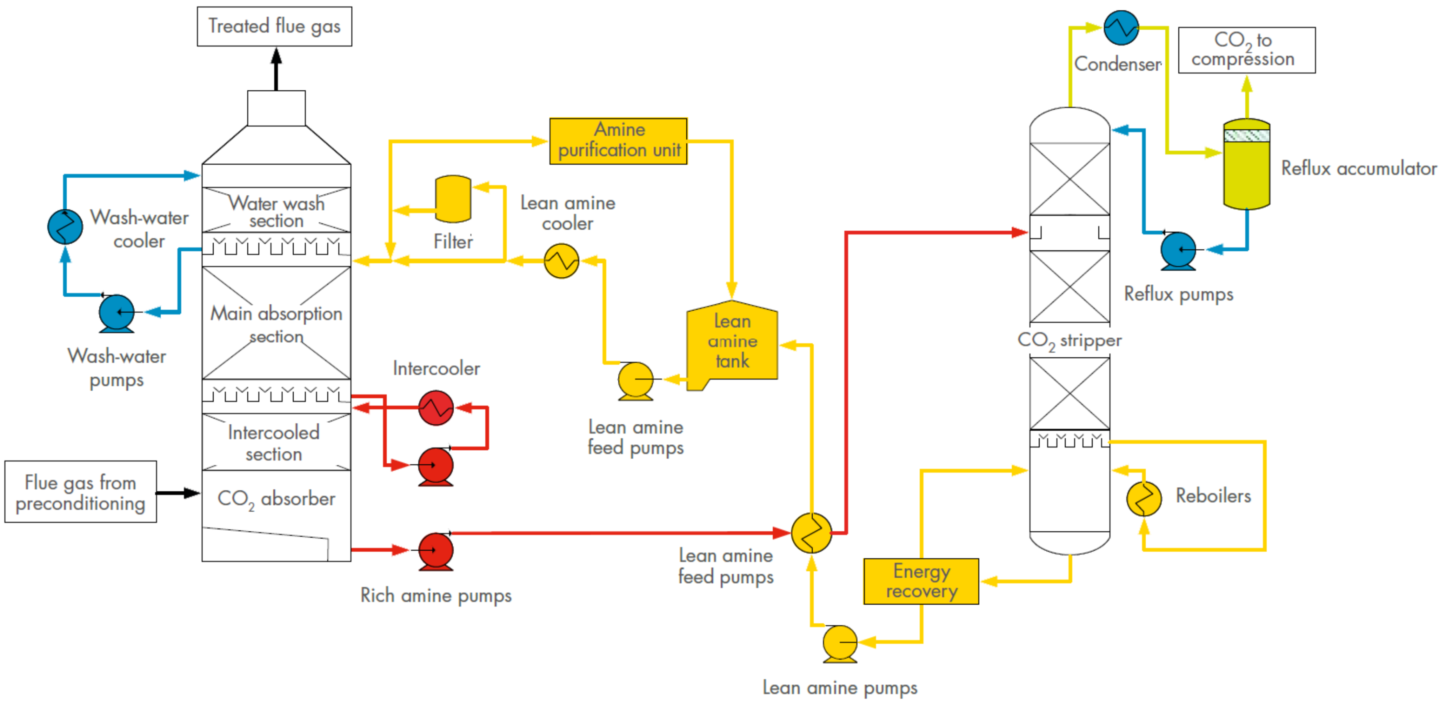

CCUS technologies – Absorption based

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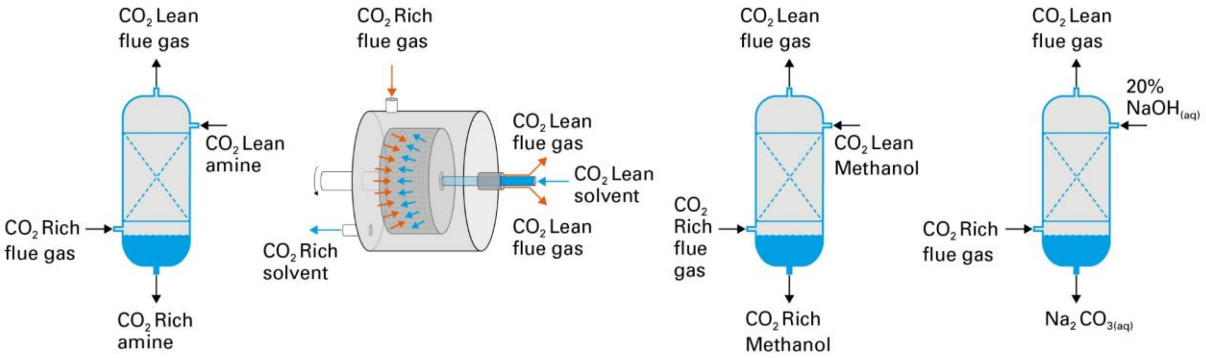

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	Amine-wash with tower contactor	Amine-wash rotating disk contactor	Methanol wash	Mineralisation
Separation principle	Absorption	Absorption	Absorption	Absorption
Specific energy demand	3 GJ/t_{CO2}	Predominantly electrical power, with heat	1.4 GJ/t_{CO2}	8.3 GJ_e/t_{CO2}
Typical temperature	40-60°C	40-60°C	-40°C	<35°C
Typical pressure	Ambient	Ambient	25-70 bar_g	Ambient
Typical CO_2 removal	90%	90% (target)	Up to 100%	90%
Typical CO_2 purity	>99%	95% (target)	>98.5%	CO_2 mineralisation to Na_2CO_3
Typical plant size (Tonnes per year CO_2 removal)	40,000 – 400,000	1,000 – 500,000	>100,000,000	1,000 – 75,000
Technology maturity level	Commercial from many suppliers	Laboratory, eg ROTA-CAP from GTI & CCSL	Commercial, eg Linde Rectisol	Demonstration, eg SkyMine

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Summary of absorption based CO_2 capture and enrichment technologies.

- Methanol wash is generally used for very large processes, eg syngas production from coal gasification.
- The rotating disc contactor uses more power and less heat than the amine wash system. It used the same solvent, only the contacting process changes. The main benefit is process intensificiaton and reduction of plant size (and capex).
- The energy requirements for mineralisation shown in the graphic are for the SkyMine process and the majority of that is for NaCl electrolysis.

Adsorption is an alternative to absorption. VSA (like PSA or VPSA) proven for carbon capture at Air Products SMR, Port Arthur for SMR pre-combustion process gas emissions

Image courtesy of APCI Inc

CCUS technologies – Adsorption based & others

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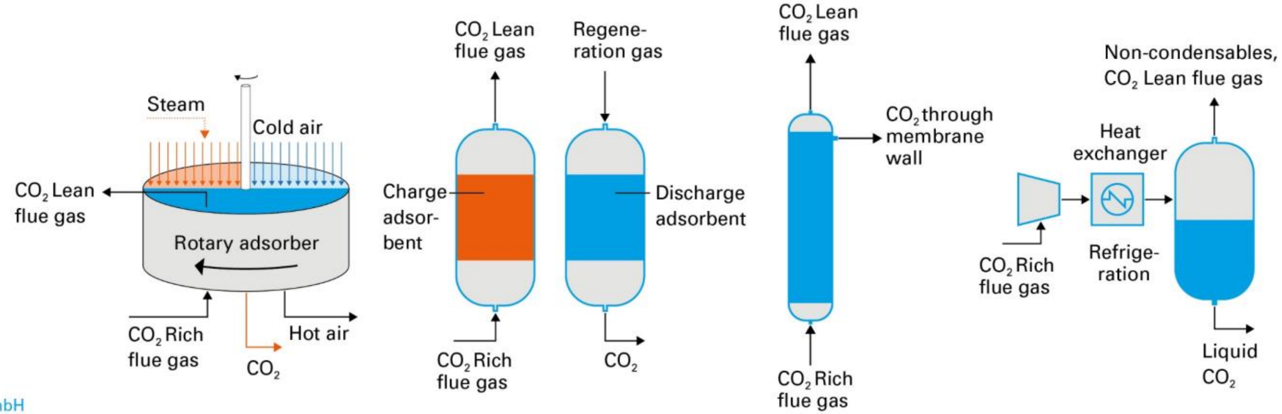

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	TSA – temperature swing adsorption and desorption	VSA – vacuum (pressure) swing adsorption and desorption	Selective membrane separation	Cryogenic CO_2 liquefaction
Separation principle	Adsorption	Adsorption	Membrane	Physical (phase separation)
Specific energy demand	1.5 GJ/t_{CO2}	1.7 GJ/t_{CO2}	1.20 GJ_e/t_{CO2}	n.a.
Typical temperature	40-60°C	<40°C	30-50°C	-50°C
Typical pressure	Ambient	1 bar_a / 0.03 bar_a	~3 bar_a / 0.196 bar_a	20-50 bar_g
Typical CO_2 removal	90% (target)	<90%	<80%	>99% (with CO_2 feed >50%)
Typical CO_2 purity	95% (target)	<95%	95%	>99% (with CO_2 feed >50%)
Typically combined with	Standalone	Cryogenic Liquefaction	Amine wash, Cryogenic Lique-faction	VSA, Membrane (eg Cryocap)
Typical plant size (Tonnes per year CO_2 removal)	200 – 2,000,000	1,000 – 500,000	1000 – 1,000,000	> 100,000
Technology maturity level	Pilot / Commercial, eg Husky Energy SK, Lafarge Holcim Cement, BC	Demonstration / Commercial, eg Air Products Port Arthur SMRs, USA	Demonstration / Commercial	Demonstration / Commercial, eg Air Liquide Cryocap at Port-Jérôme SMR, France

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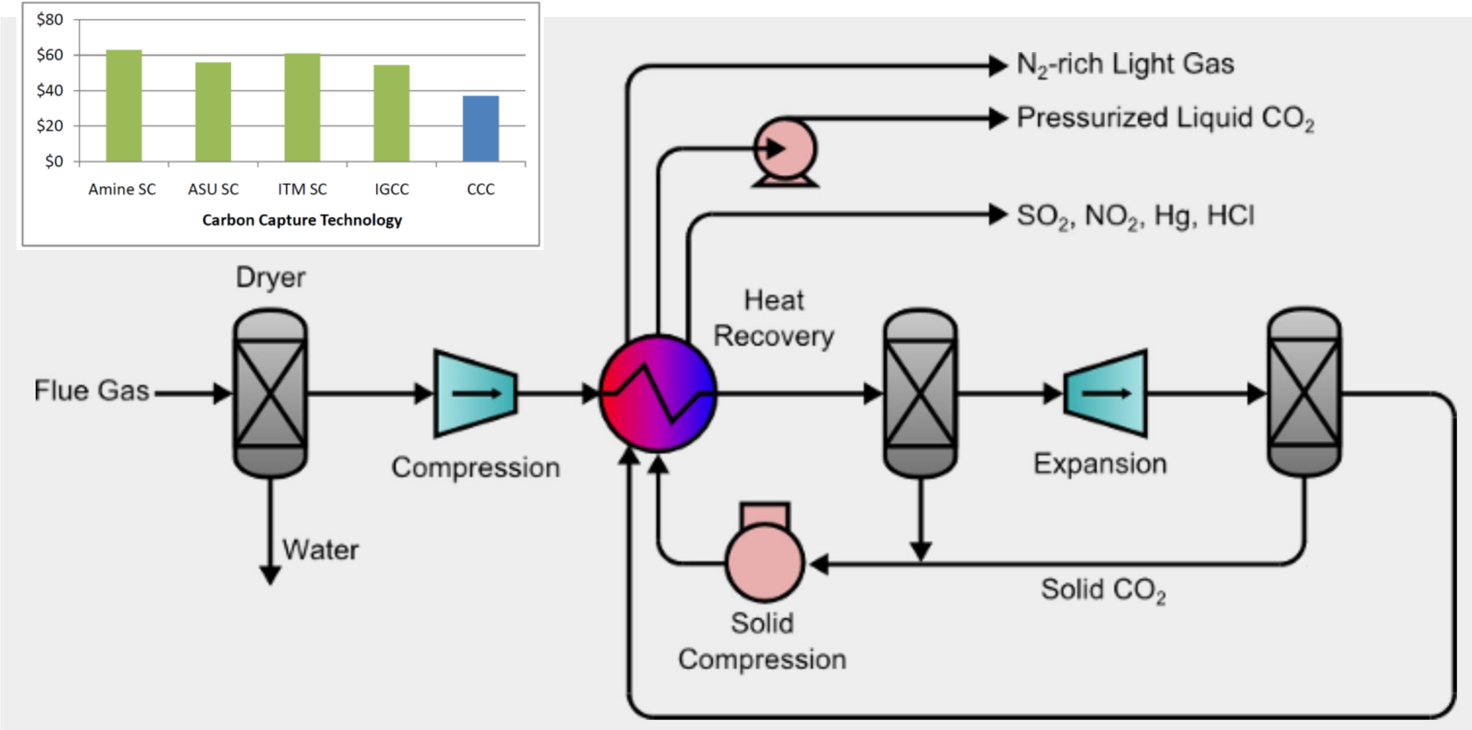
Summary of non-absorption based CO_2 capture and enrichment technologies.

- TSA is being piloted by Svante for refinery and cement emissions.
- PSA has been implemented by Air Products for refinery SMR applications.
- Membranes have a lower TRL than TSA or PSA but have the potential to be energy efficient.
- Cryogenic separation has been / is being piloted by SES / Chart Industries on refinery and cement applications.

Chart Industries (SES innovations) Cryogenic Carbon Capture (CCC)



SES Innovations claims a 30 to 40% reduction in overall cost (capex and opex) versus amine wash.

The CCC process uses power and the amine wash uses heat, which could be waste heat or from a natural gas burner.

As with most CO_2 capture systems, mid- and large-scale units have favourable capex and opex per tonne of CO_2 captured

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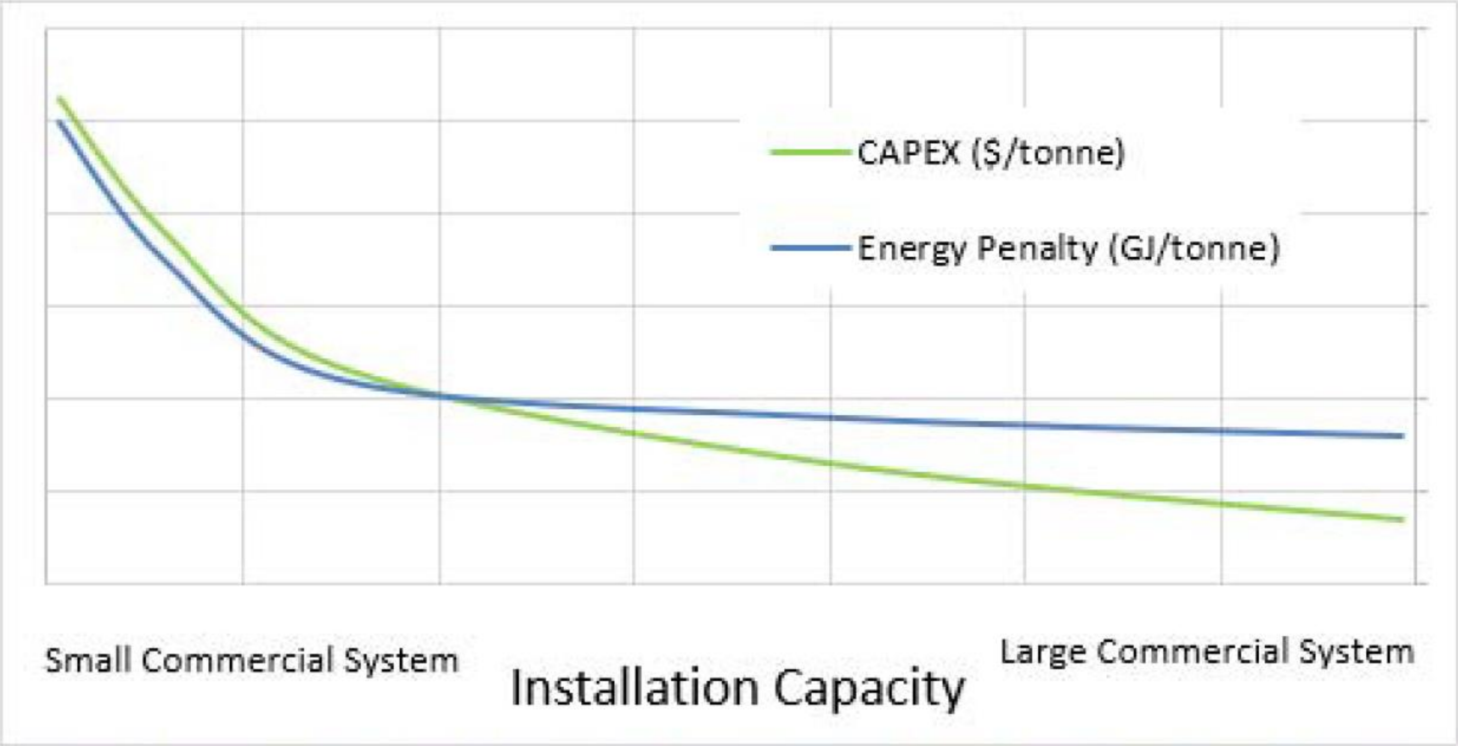

Provided by Chart Industries, SES

As with most CO_2 capture systems, higher CO_2 concentrations in the flue gas yield favourable capex and opex per tonne of CO_2 captured

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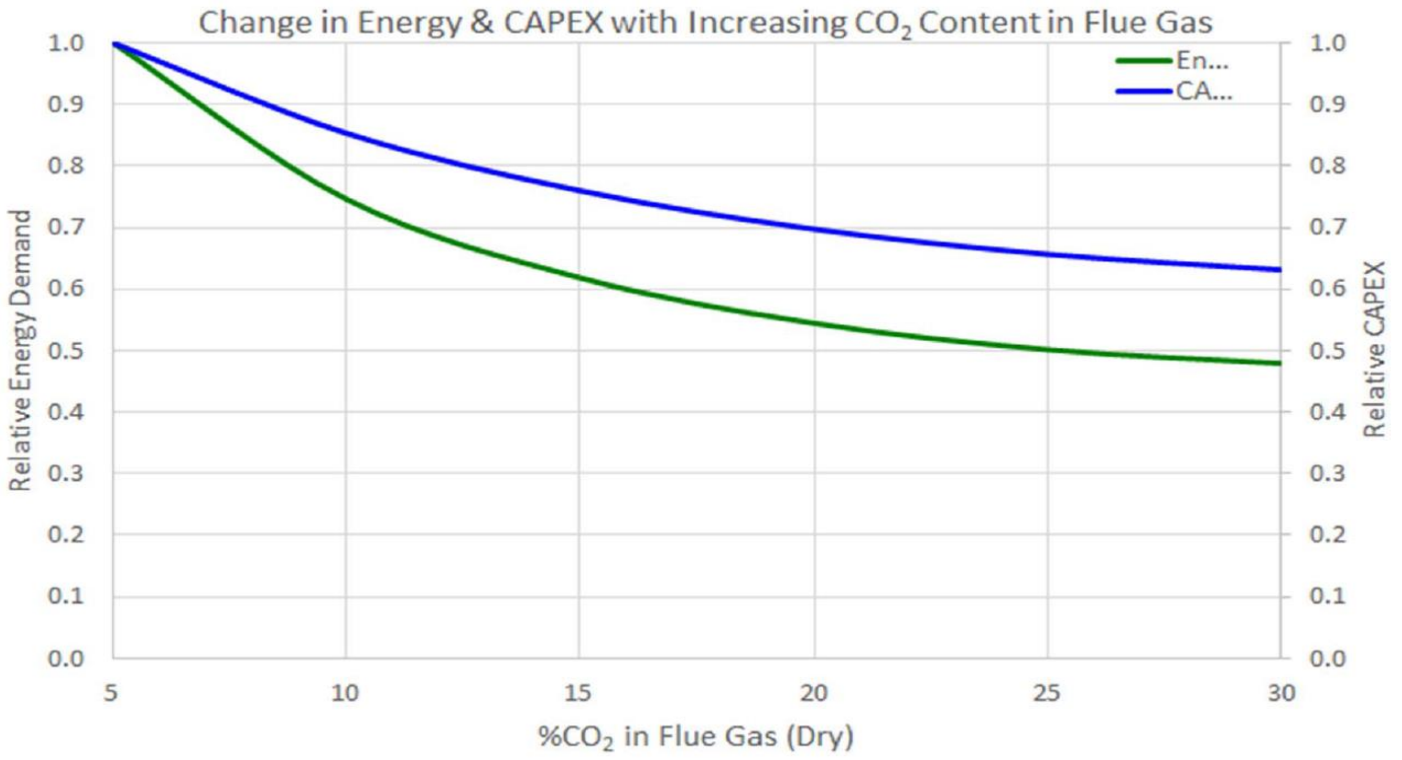

Provided by Chart Industries, SES

Chart Industries (SES innovations) Cryogenic Carbon Capture (CCC)

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SES Innovations CCC process pilots completed

Chart's Sustainable Energy Solutions Cryogenic Carbon Capture Pilot Plant, Copyright Chart Industries Inc

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2) Simplification of CCS with CO_2 capture on the IGCC oxy-fuel process with coal, Vac Res or petcoke gasification

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Pre-combustion CO_2 capture from oxygen-fed gasification does not need to treat nitrogen from combustion air

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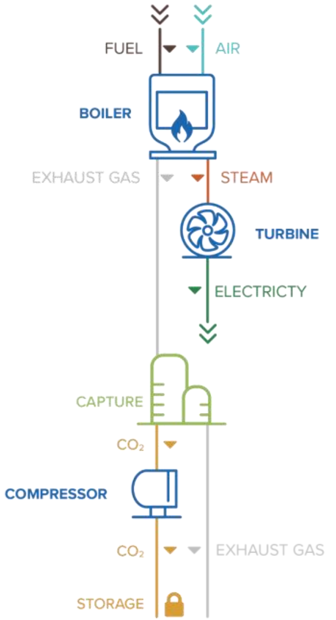
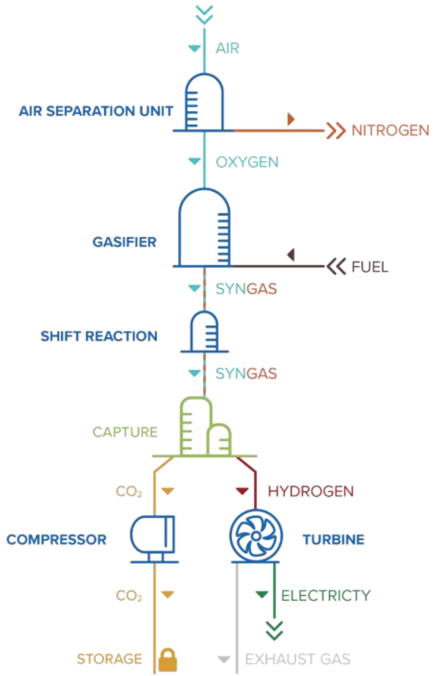
POST-COMBUSTION CO_2 CAPTURE



PRE-COMBUSTION CO_2 CAPTURE



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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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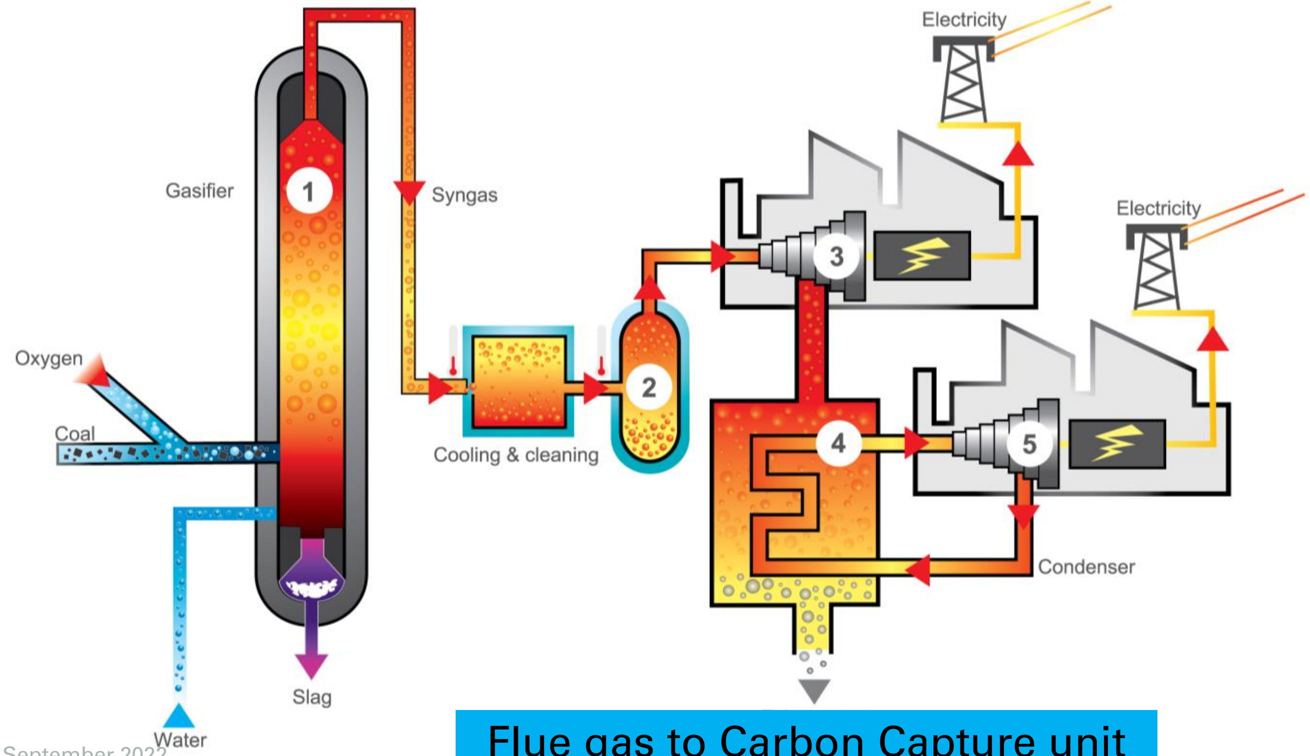

Flue gas to Carbon Capture unit

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

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

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16 September 2022

Aramco Refinery, Jazan KSA – Vac Res gasification for syngas, hydrogen, steam and 2.4 GW IGCC

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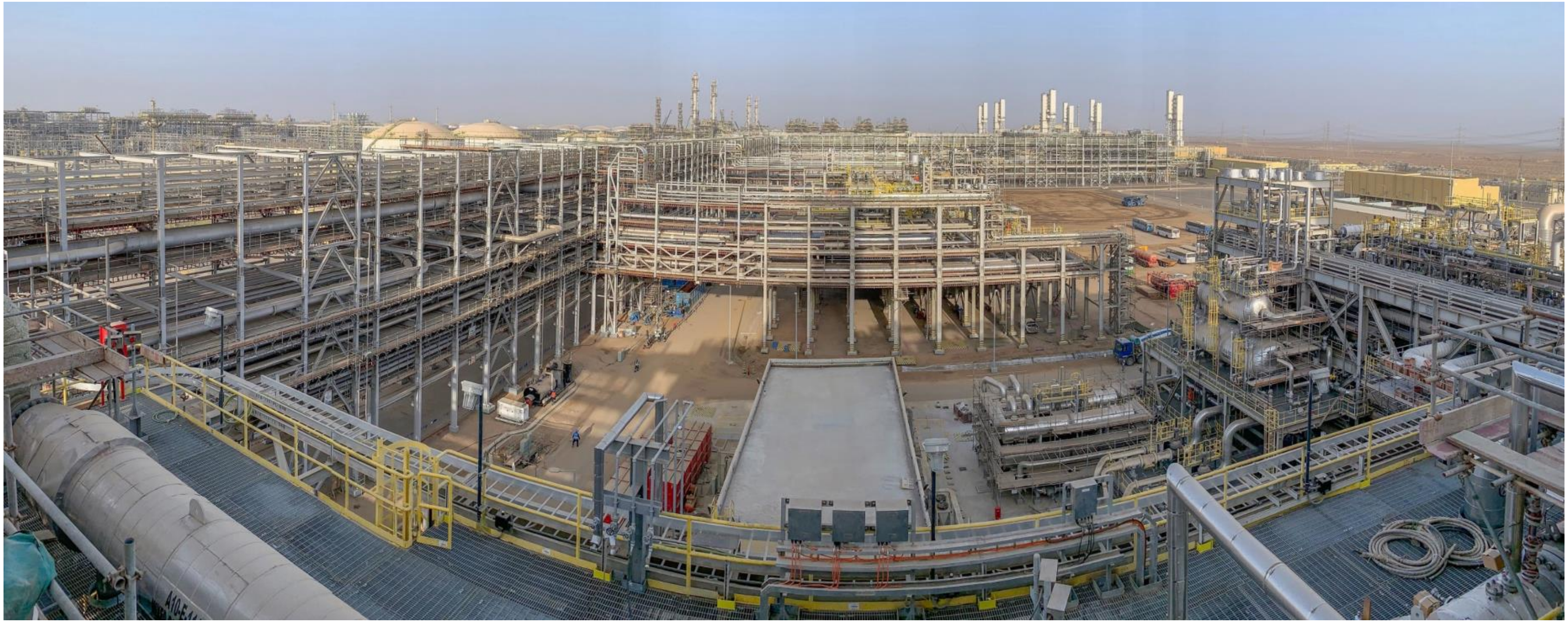

Reliance Industries Limited (RIL): 10x petcoke + coal gasifiers produce 20,000 Sm^3 of syngas per day. Captured CO_2 to be used for chemical production.

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Gasification

10 gasifiers
2 mscm/d syngas/gasifier
0.85 mmt/yr petcoke
1.0 mmt/yr petcoke + coal

ASU

5 trains
O_2 to gasifier
5250 t/d O_2/ASU

OGBL

Processing

AGR
SRU/TGT
SWS
CO shift

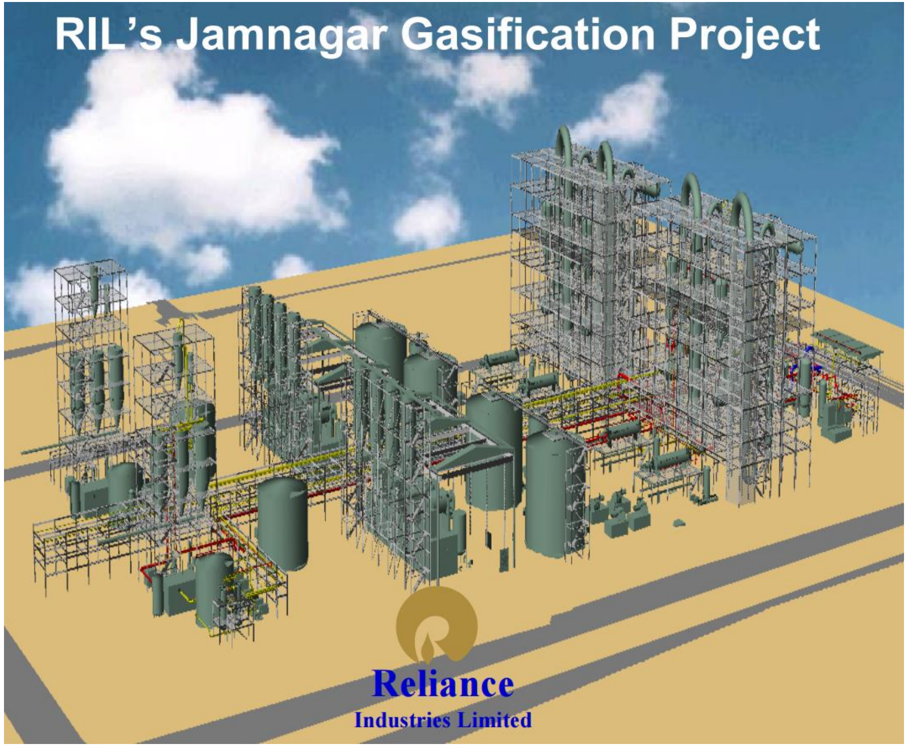
Product

PSA for H2
SNG
CO recovery

ASU = Air seperation unit

OGBL = Outside gasification battery limit

OSBL = Outside battery limit



Gasifiers are flexi-fuel and can operate with coal / petcoke mix to ensure feedstock availability

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3) The Allam cycle, an oxy-fuel based advanced thermal process with CCS to achieve clean power from coal and gas

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The Allam cycle – indicative mass flows and basic process flow diagram for gas feed

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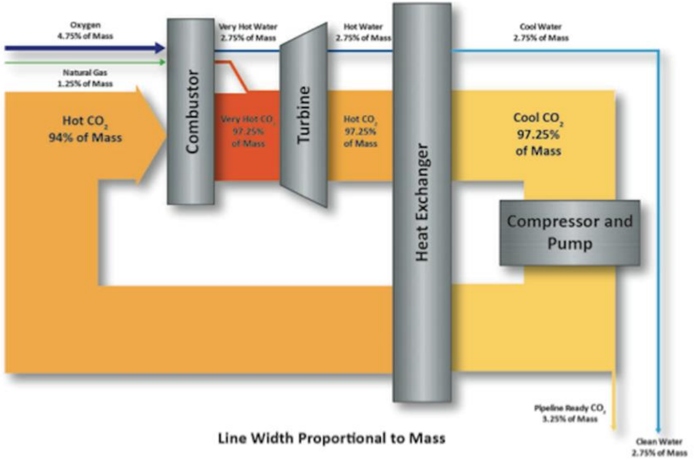

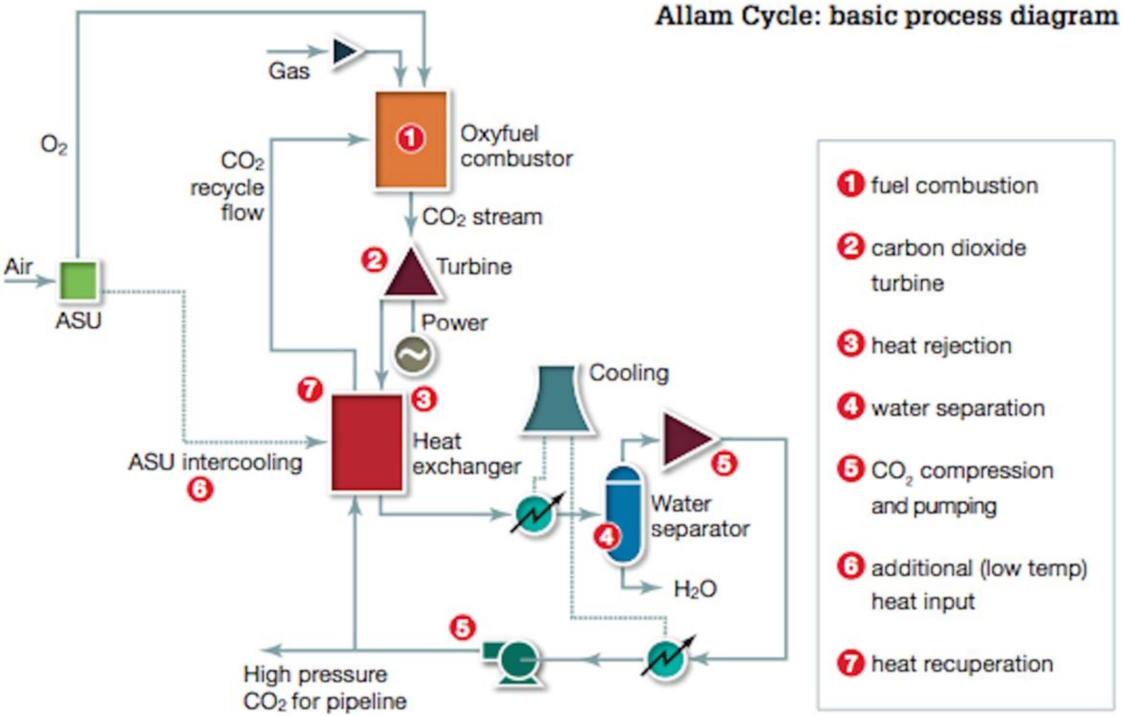

https://www.modernpowersystems.com/features/featurebreaking-ground-for-a-groundbreaker-the-first-allam-cycle-power-plant-4893271//featurebreaking-ground-for-a-groundbreaker-the-first-allam-cycle-power-plant-4893271-477349.html

Allam cycle demonstration facility, Net Power LLC, 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 – core process for natural gas and adaption for coal

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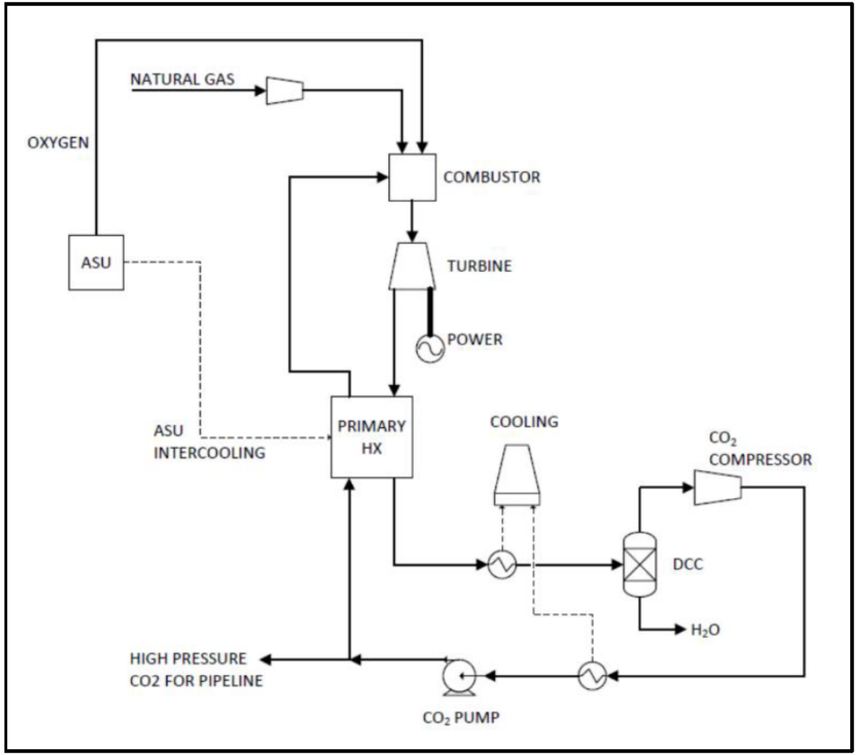

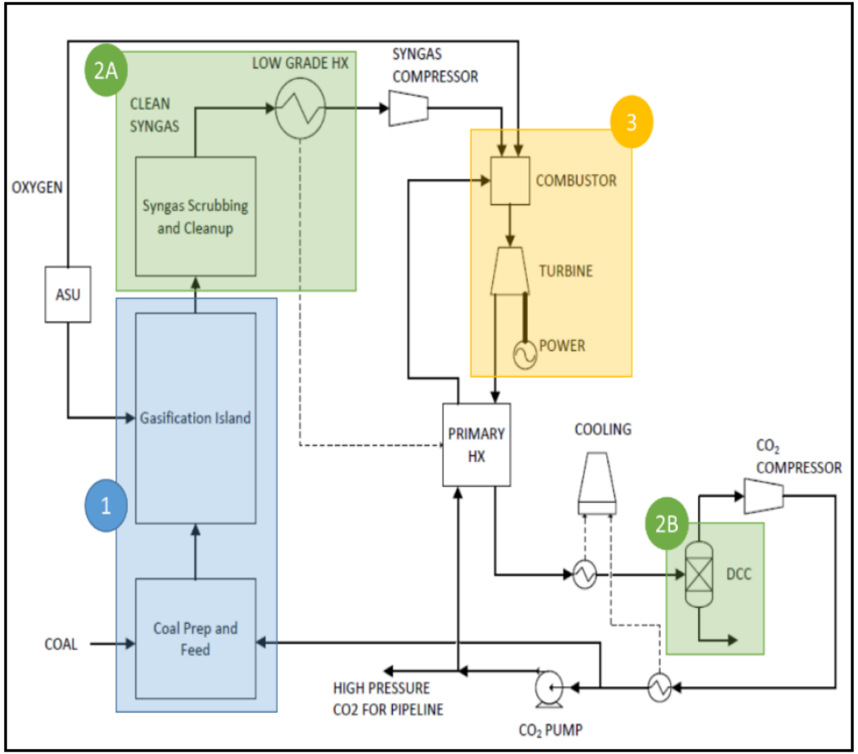

https://www.modernpowersystems.com/features/featurebreaking-ground-for-a-groundbreaker-the-first-allam-cycle-power-plant-4893271//featurebreaking-ground-for-a-groundbreaker-the-first-allam-cycle-power-plant-4893271-477349.html

Modelled efficiencies of the Allam cycle for various coal types and gasification regimes

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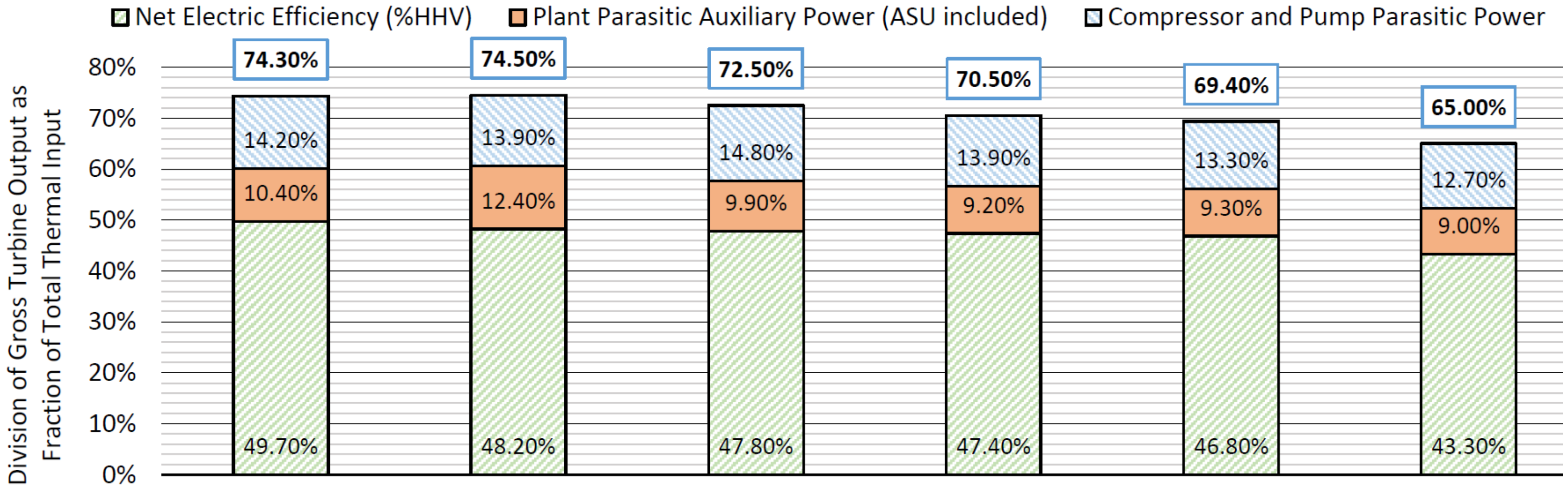

Coal Type	Bituminous	Lignite	Bituminous	Lignite	Bituminous	Lignite
Gasifier Type and Operation	Entrained flow, dry-feed	Moving bed	Entrained flow, dry-feed	Entrained flow, dry-feed	Entrained flow, slurry	Fluidized bed
	Slagging	Slagging	Slagging	Slagging	Slagging	Non-slagging
Heat Recovery Scheme	Syngas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

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Concluding remarks

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Clean thermal power from fossil fuels - concluding remarks

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1) CCS can help to decarbonise thermal power generation from fossil fuels: natural gas, petcoke, Vac Res and 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 technolgies 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
5) Oxygen-fed gasification for IGCC can further reduce the cost of CO_2 capture by increasing CO_2 concentration in the flue gas
6) Advanced thermal cycles, also with oxy-fuel combustion, such as the Allam Cycle are likely to be cost-effective clean technologies for thermal powergeneration from both natural gas and 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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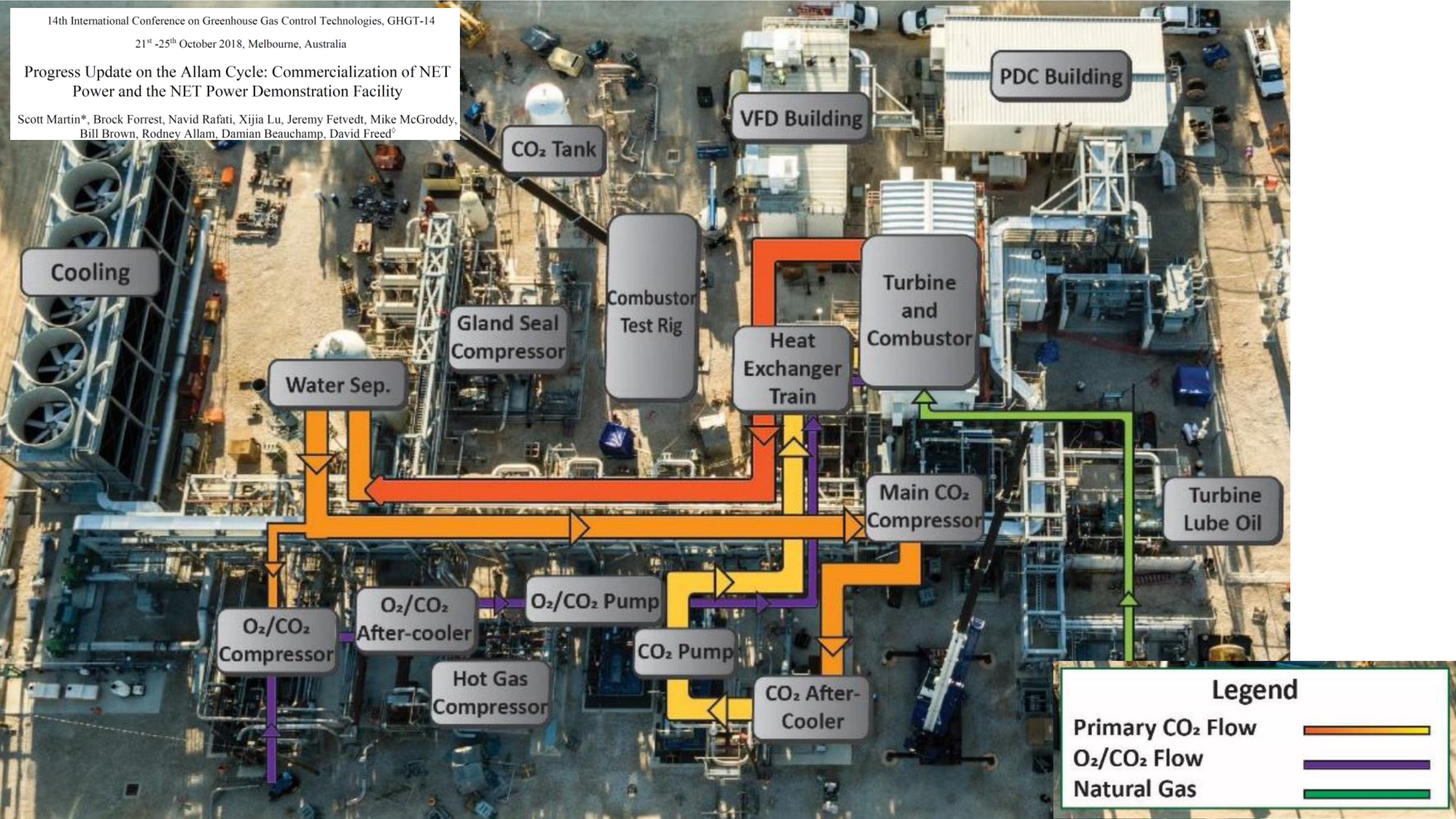
14th International Conference on Greenhouse Gas Control Technologies, GHGT-14

21st -25th October 2018, Melbourne, Australia

Progress Update on the Allam Cycle: Commercialization of NET Power and the NET Power Demonstration Facility

Scott Martin*, Brock Forrest, Navid Rafati, Xijia Lu, Jeremy Fetvedt, Mike McGroddy, Bill Brown, Rodney Allam, Damian Beauchamp, David Freed[0]



RIL – proposal to capture and utilise CO_2 from coal and petcoke gasification

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Repurpose Gasification Assets - CO_2 as an Asset

Reliance Industries Limited

1. Hydrogen production from gasification provides highly concentrated CO_2 stream which provides unique opportunity to capture ~15 MMTPA of CO_2 at 30% of typical cost of carbon capture.
2. CO_2 can be monetized with application in following products / end-uses -
   - ✓ Urea production - using green ammonia (nitrogen from ASU + green hydrogen)
   - ✓ E-products, and fuels - using green hydrogen, facilitating circular carbon economy
   - ✓ Synthetic Aviation Fuel
   - ✓ Construction mineralization, Dry Ice
   - ✓ Algal oil, super proteins made through synthetic biology pathways
3. Biomass based gasification, coupled with CO_2 capture can potentially lead to significant cut in emissions

CO_2 as a product can be captured at much lower cost to sell as feedstock for chemicals production

Coal gasification for "coal to liquids" via syngas. Lu'an, Shanxi province, China.

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Image copyright Air Products and Chemicals Inc

4x Giga-scale oxygen plants, each 2,500 tonnes per day O_2 for coal gasification – Lu'an CTL, China

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Image courtesy of APCI Inc

Introduction to Stephen B. Harrison

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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. He has also served as the international hydrogen and CCS expert for multiple ADB projects in Pakistan, Palau and Viet Nam.

Stephen's 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.

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

As a member of the H2 View and **gas**world editorial advisory boards, Stephen advises the direction for the leading hydrogen and CO_2 focused international publications. He is also on the Technical Committee for the Green Hydrogen Summit in Oman in December 2022, CEM 2023 in Barcelona and on the Advisory Board of the International Power Summit in Munich in September 2022.