



# Near Carbon-Neutral Power Generation by DME in $s\text{CO}_2$ Oxy-Combustion Cycles

The International Supercritical  $\text{CO}_2$  Energy Technologies Symposium  
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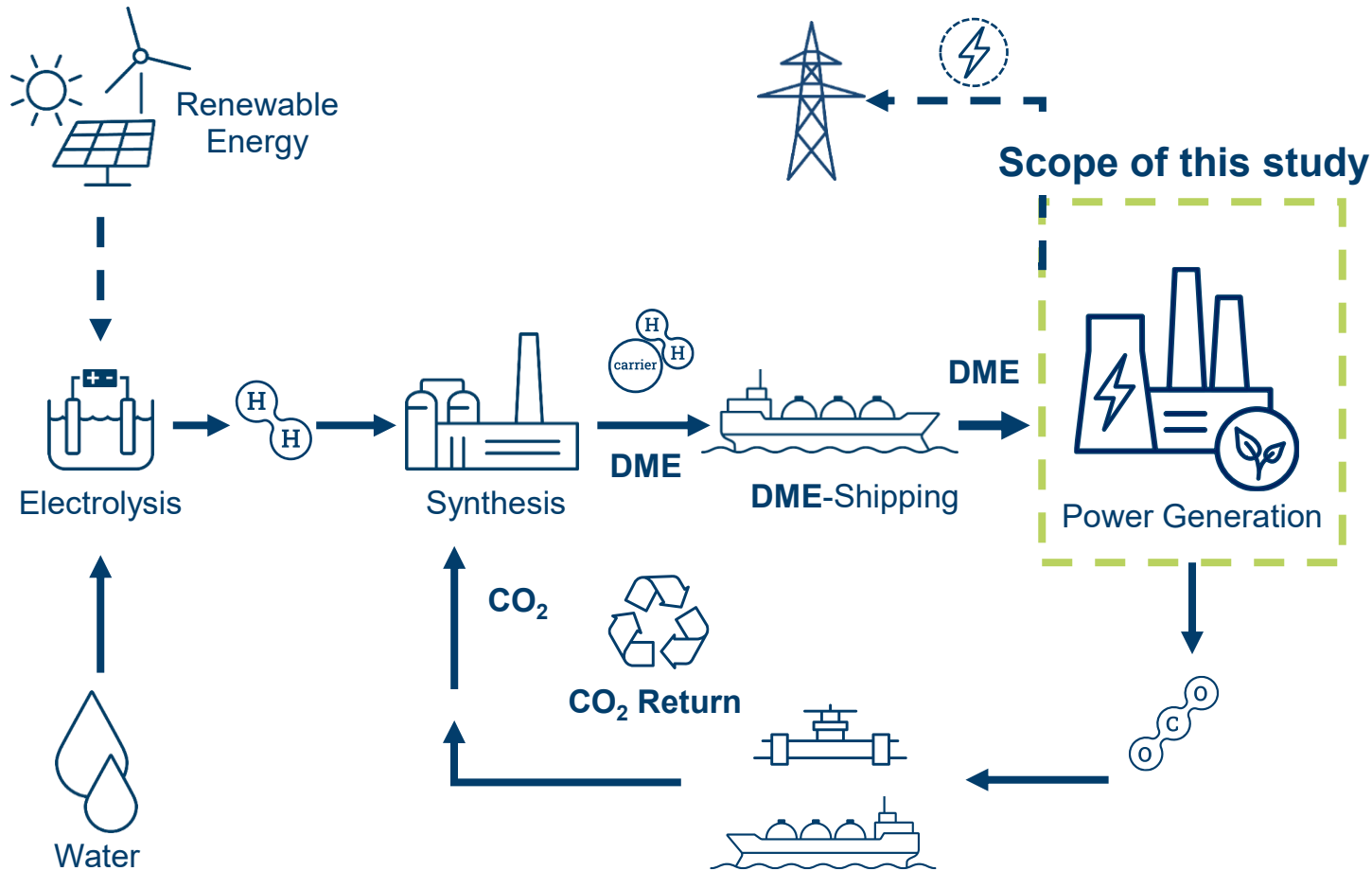
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# Outline

- **Motivation**
- **Investigated DME-fueled Power Cycles**
- **Results**
- **Conclusion & outlook**

# TOWARD CARBON NEUTRAL POWER GENERATION

## Electricity On-Demand with DME and the DME/CO<sub>2</sub> storage cycle<sup>[1]</sup>



### General

- Dimethyl Ether (DME) - H<sub>2</sub> vector
  - High energy density
  - Transport and storage
- DME in thermal power generation
  - Electricity on demand
- Capturing the CO<sub>2</sub>
  - Recycling of CO<sub>2</sub> to produce DME
  - Circular Carbon loop

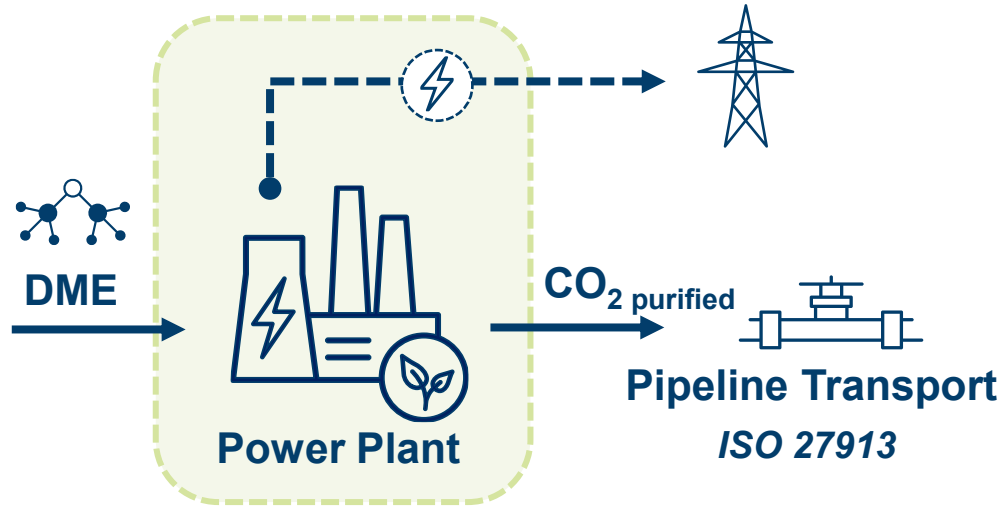
[1] P. Schühle, et al. P. Wasserscheid, O. Salem, Energy & Environmental Science, 2023, 16, 3002

[2] Mitsui O.S.K. Lines, Ltd ; World's First LCO<sub>2</sub> / Methanol Carrier; <https://www.mol.co.jp/en/pr/2025/25058.html>

# TOWARD CARBON NEUTRAL POWER GENERATION

## Key requirements for Near-Carbon-Neutral power

### Scope of this study



- High CO<sub>2</sub> capture rates
- Conditioned CO<sub>2</sub>
- High efficiency

### Investigated Power Cycles

sCO<sub>2</sub>

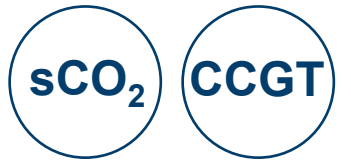
Semi-closed sCO<sub>2</sub> oxy-combustion cycles

- DME-fueled Allam
- Liquefied Recycle Allam cycle - LiRAC

CCGT

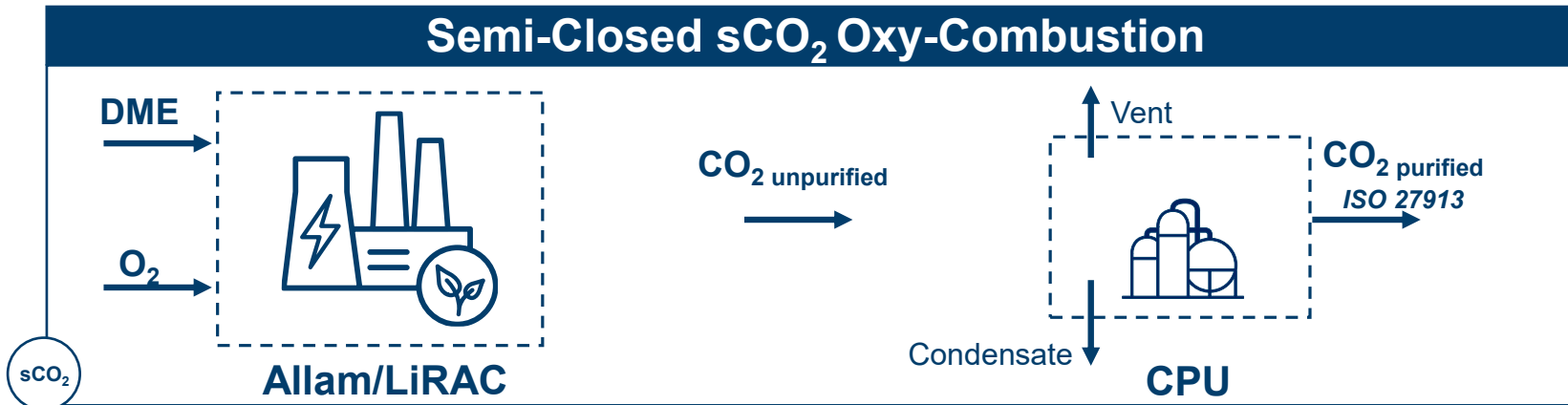
Combined Cycle Gas Turbine with solvent-based Post Combustion Capture (CCGT-PCC)

# INVESTIGATED DME-FUELED POWER CYCLES



Consistent system boundaries and assumptions for fair comparison

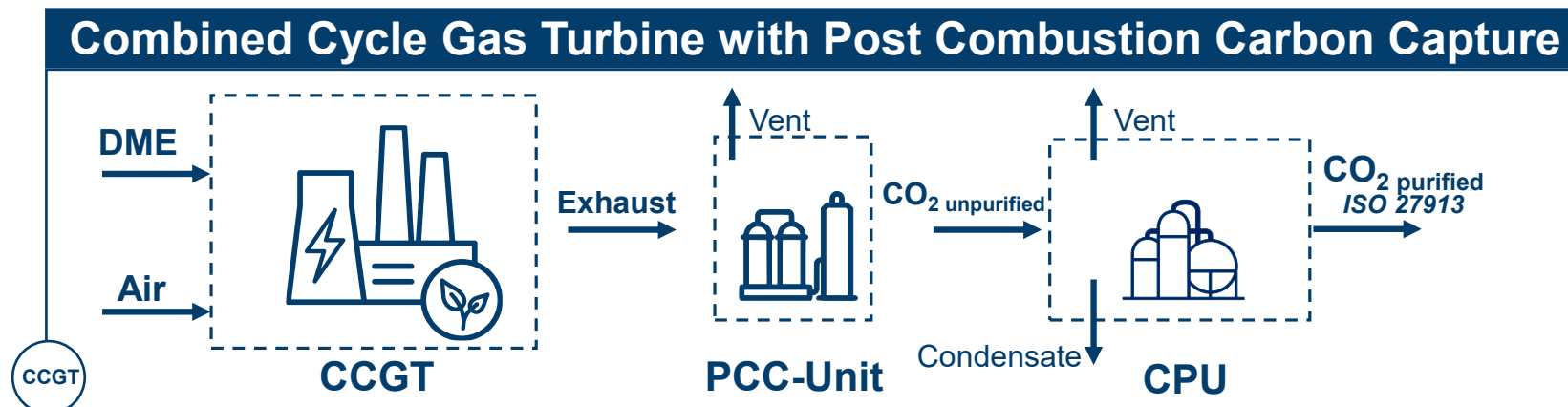
## Semi-Closed sCO<sub>2</sub> Oxy-Combustion



## Assumptions

- Fuel DME<sup>[3]</sup>
- Heat input 1536 MWth
- Maximizing CO<sub>2</sub> capture rates
- CO<sub>2</sub> pipeline specs<sup>[4]</sup>

## Combined Cycle Gas Turbine with Post Combustion Carbon Capture



**CPU:** Compression and Purification Unit  
**PCC:** Solvent-based Post Combustion Carbon Capture  
**O<sub>2</sub>:** Oxygen provided by an air separation unit

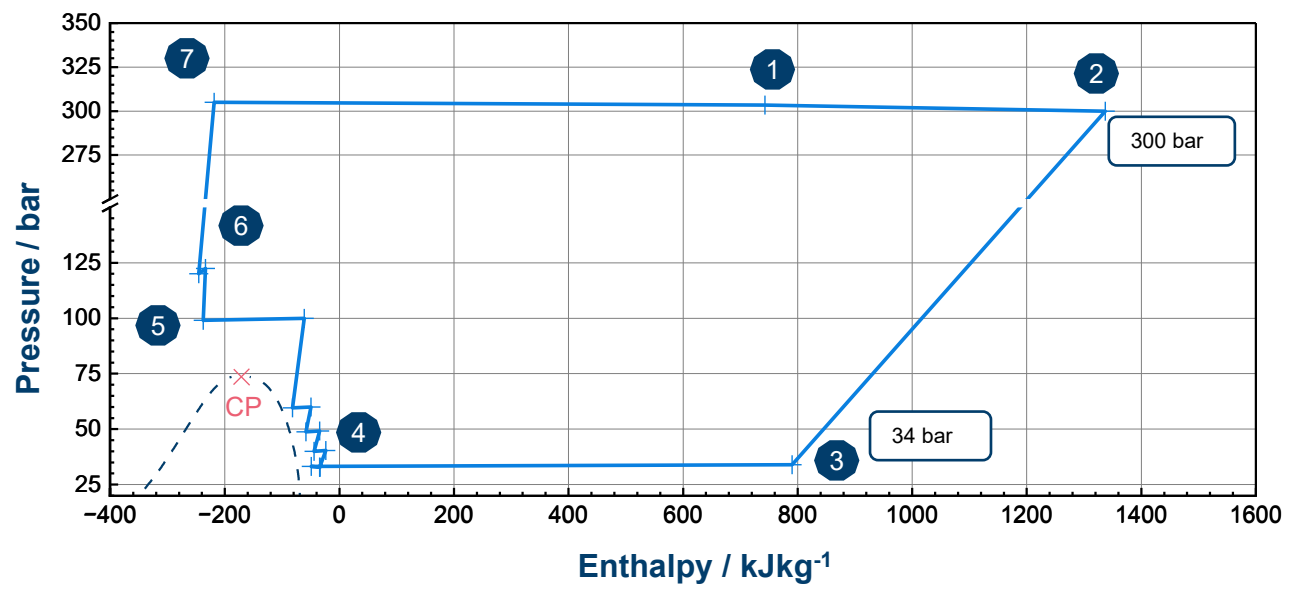
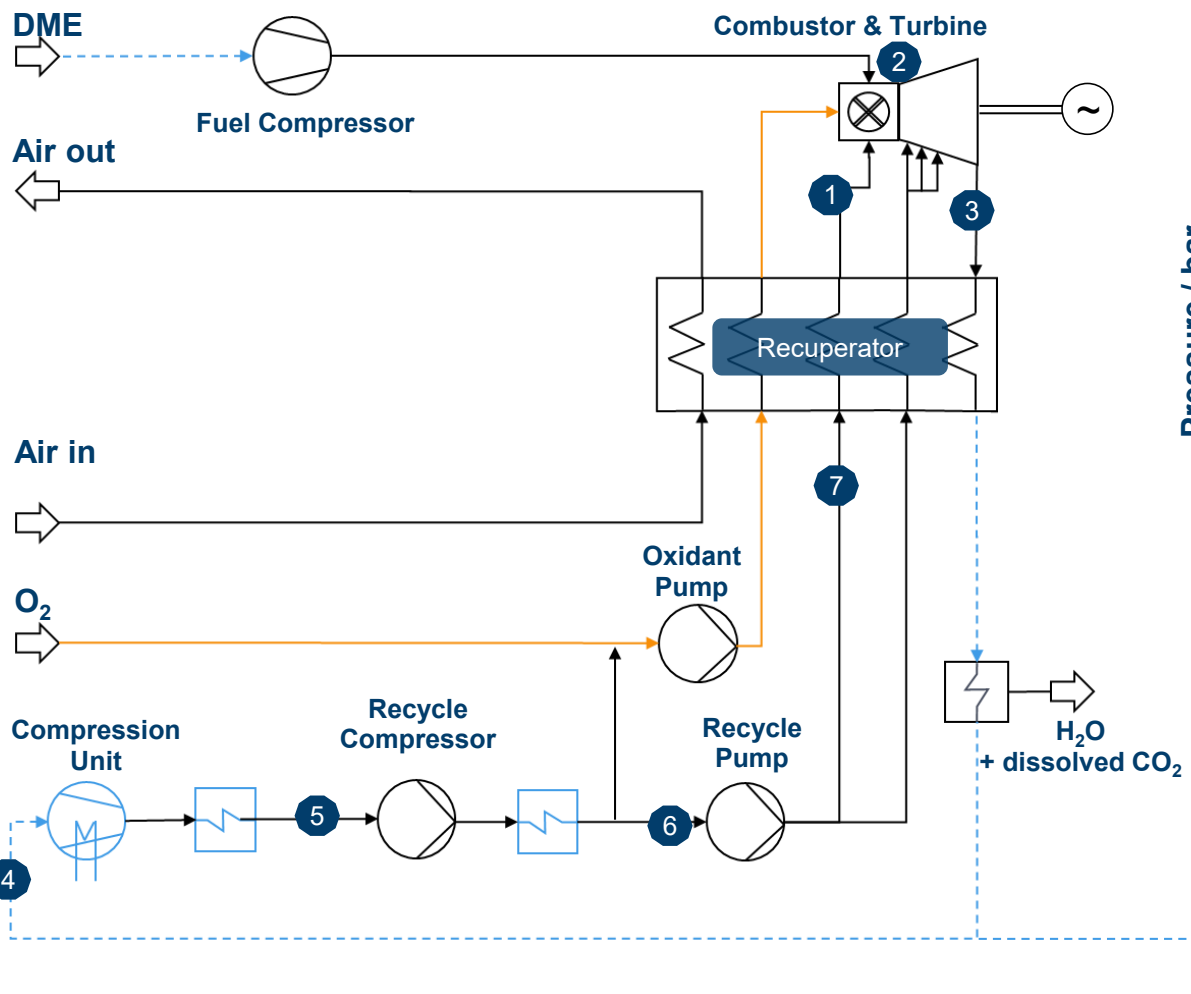
[3] DIN/TS 51698 Fuels Requirements Dimethyl ether (DME)

[4] ISO 27913. Carbon dioxide capture, transportation and geological storage - Pipeline transportation systems; 2024.

# SEMI-CLOSED sCO<sub>2</sub> OXY-COMBUSTION CYCLE



## DME-fueled Allam Cycle<sup>[5][6]</sup>



[5] IEAGHG. Oxy-Combustion Turbine Power Plants, 2015/05, August, 2015.

[6] Scaccabarozzi R, Gatti M, Martelli E. Thermodynamic analysis and numerical optimization of the NET Power oxy-combustion cycle. Applied Energy 2016;178:505–26.

<https://doi.org/10.1016/j.apenergy.2016.06.060>

[7] Abi Haidar G, Morsch P, Peschel A. Low-carbon power generation using DME: A thermodynamic assessment of two DME-fueled sCO<sub>2</sub> oxy-combustion power cycles. Energy Conversion and Management 2026;357:121439.

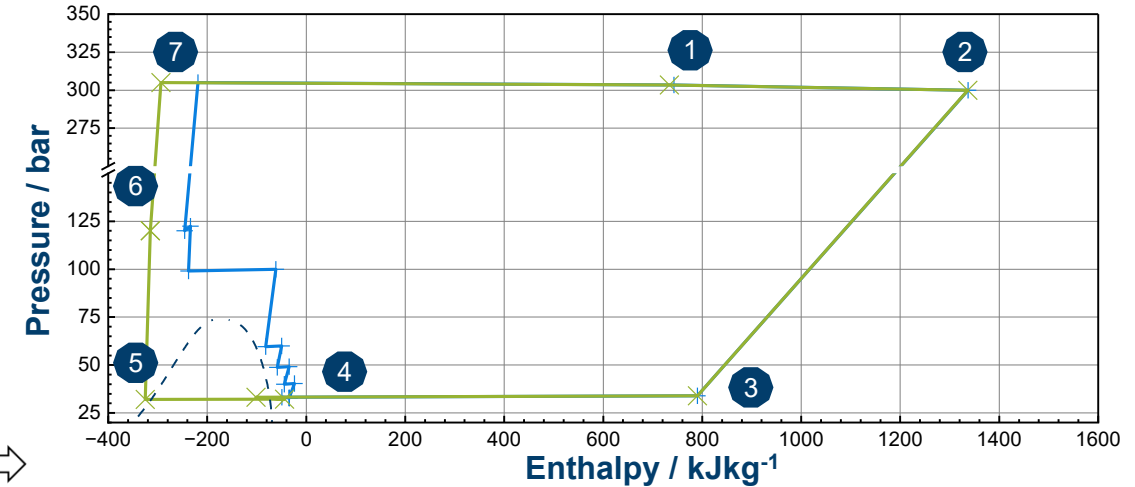
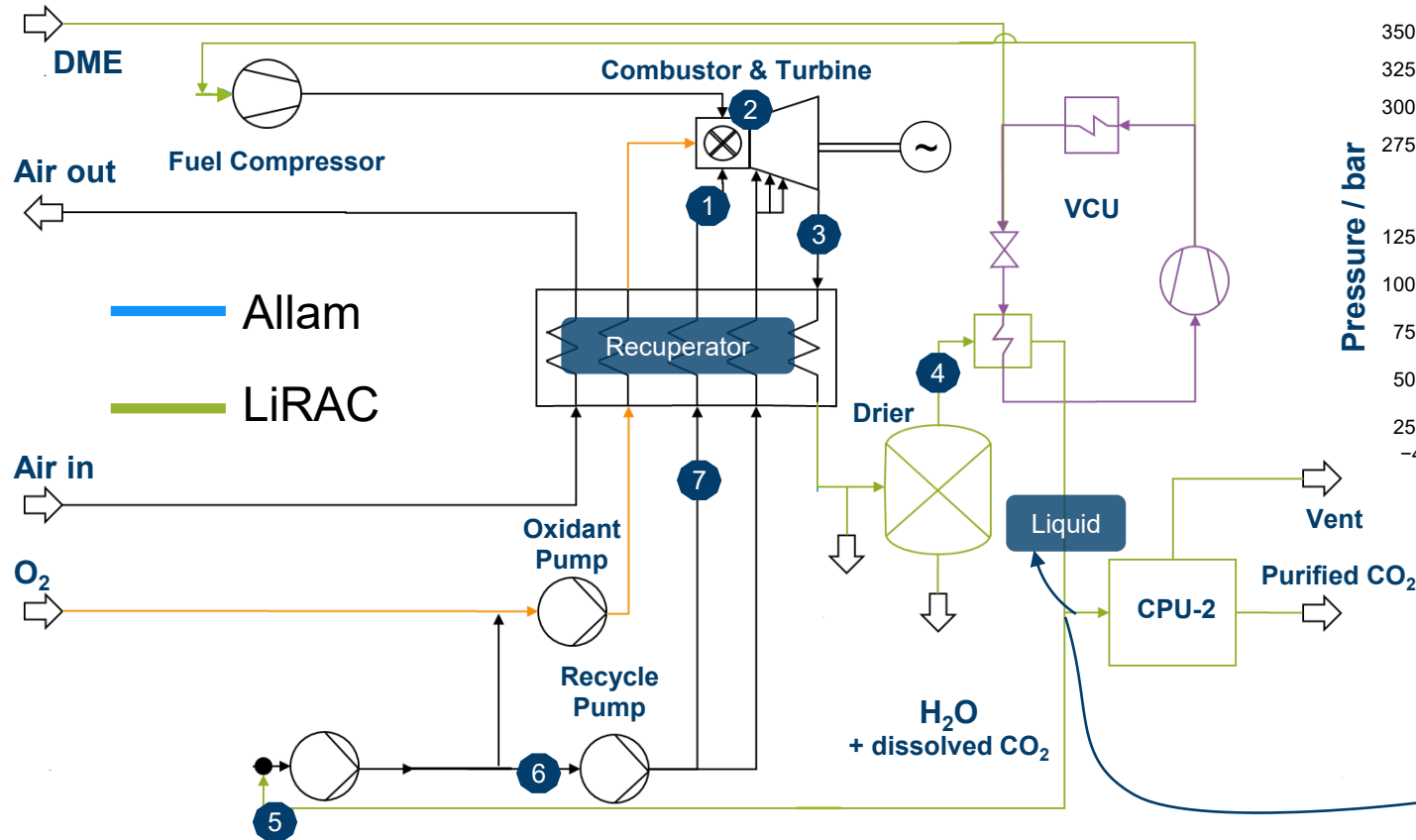
<https://doi.org/10.1016/j.enconman.2026.121439>



# SEMI-CLOSED sCO<sub>2</sub> OXY-COMBUSTION CYCLE

sCO<sub>2</sub>

## Liquefaction – DME-driven Vapor Compression Unit (VCU)<sup>[7]</sup>

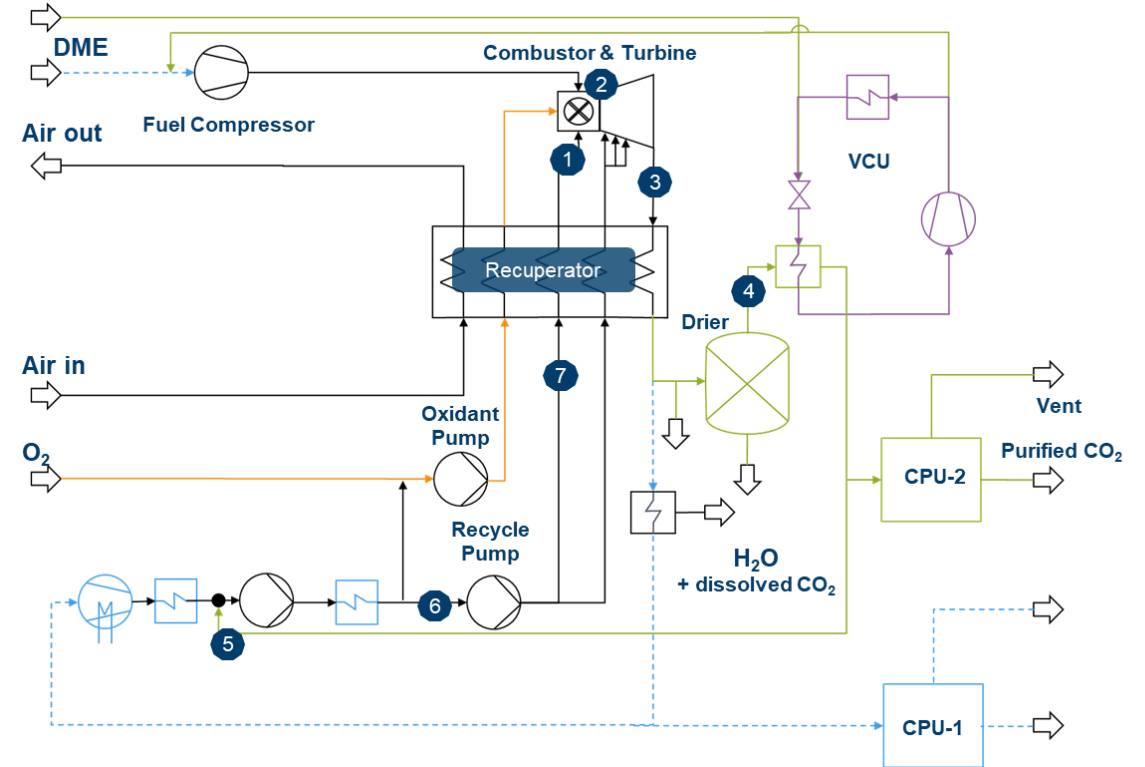
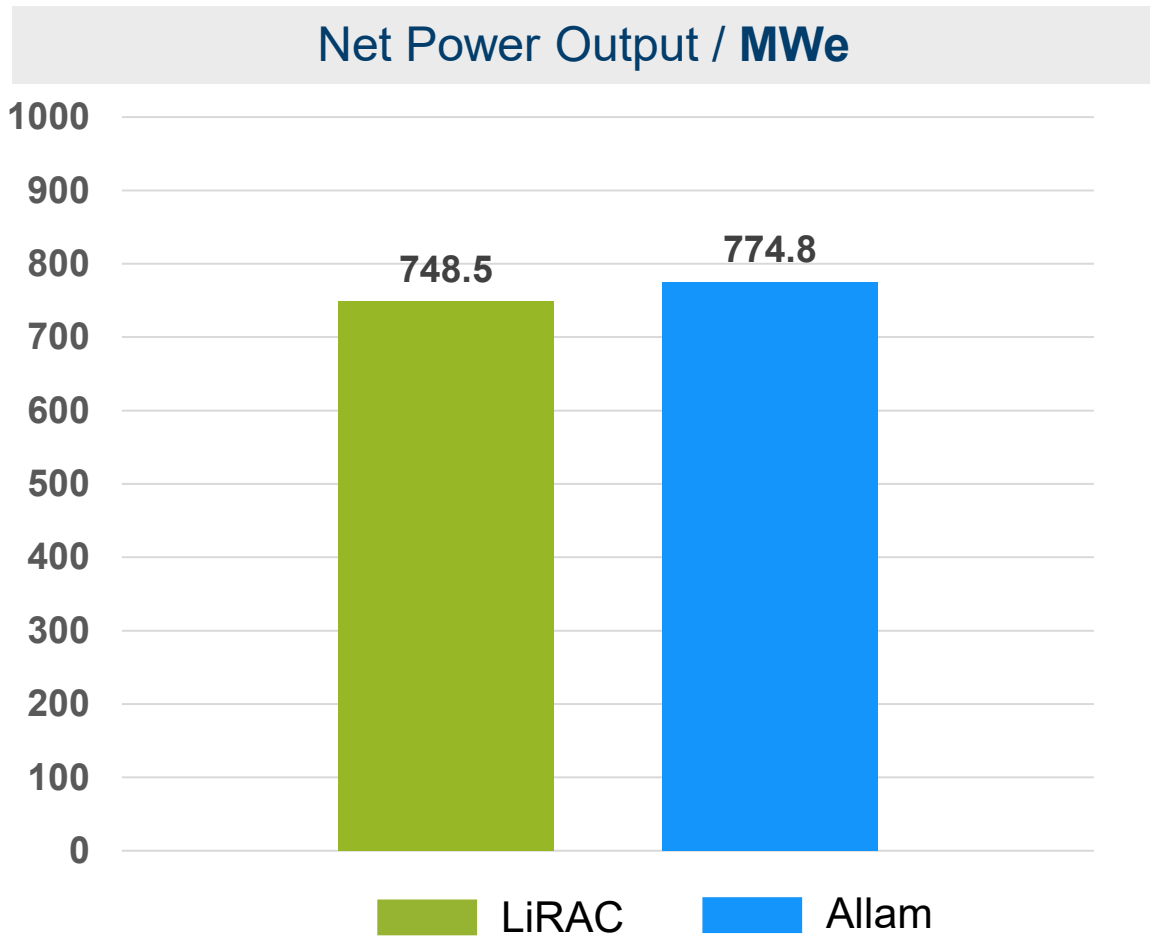


- Liquid Recycle and Liquid CPU-Feed
- Temporary storage of the liquid recycle
  - Reducing operational interdependency

[7] Abi Haidar G, Morsch P, Peschel A. Low-carbon power generation using DME: A thermodynamic assessment of two DME-fueled sCO<sub>2</sub> oxy-combustion power cycles. Energy Conversion and Management 2026;357:121439. <https://doi.org/10.1016/j.enconman.2026.121439>  
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# ENERGY BREAKDOWN

## Net power output

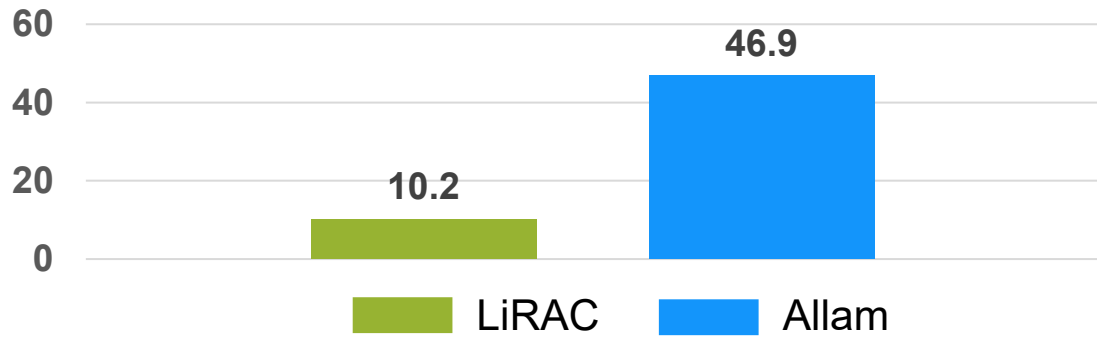


➤ LiRAC achieves lower net power output

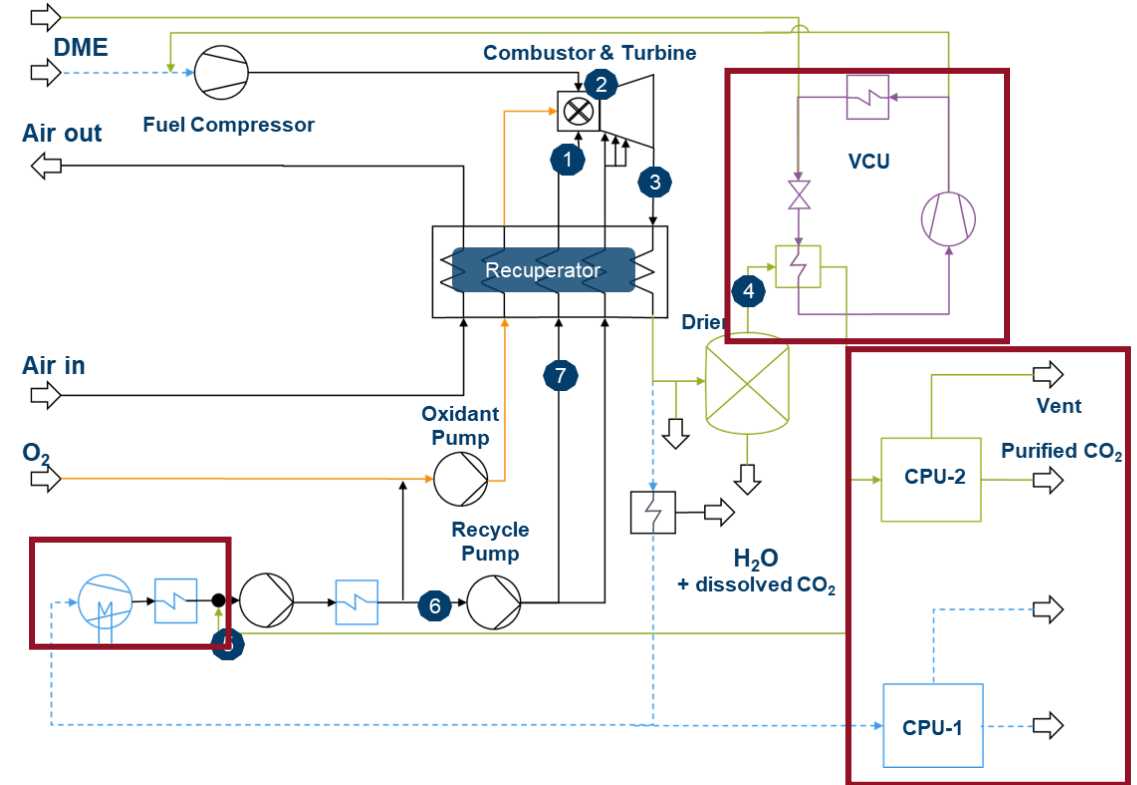
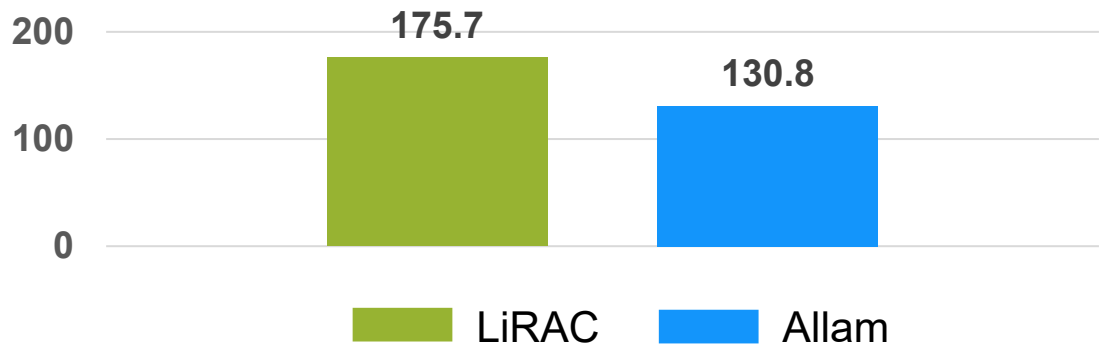
# ENERGY BREAKDOWN

## CO<sub>2</sub> conditioning and VCU compressors

Power Demand – CO<sub>2</sub> Conditioning (CPU) / MWe

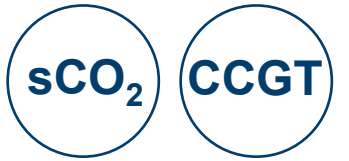


Power Demand – Compressors / MWe

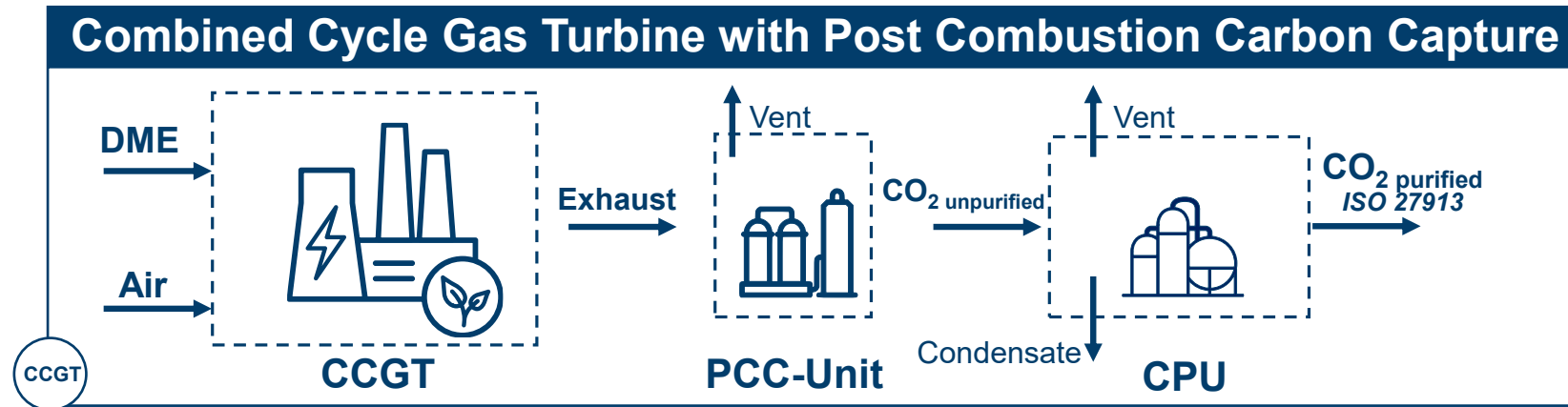


- 78 % less power for downstream CO<sub>2</sub> conditioning
- 34 % more power for VCU compressors

# INVESTIGATED POWER CYCLES

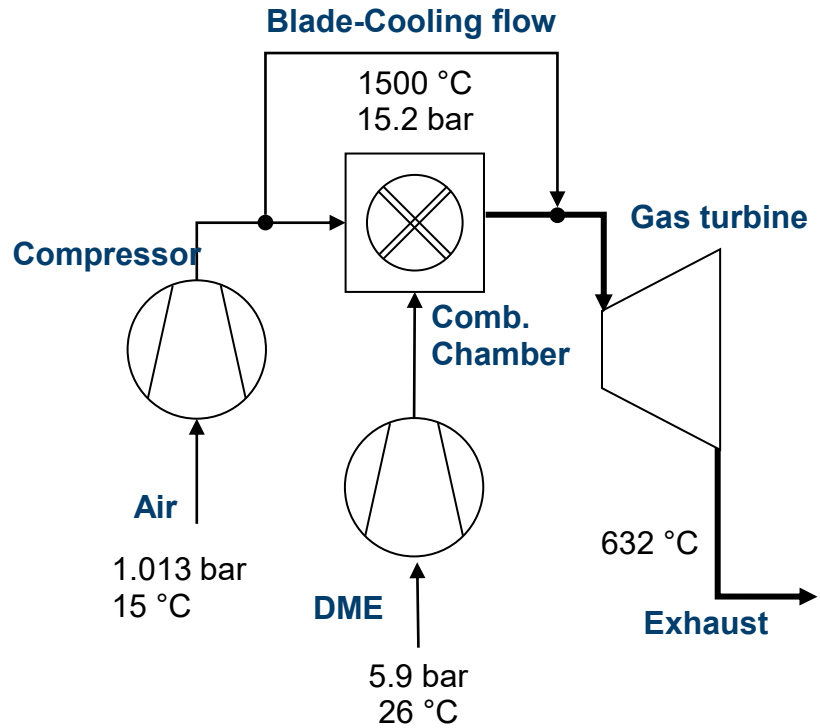


## Combined Cycle Gas Turbine with Post Combustion Carbon Capture (CCGT-PCC)



# REFERENCE POWER CYCLE

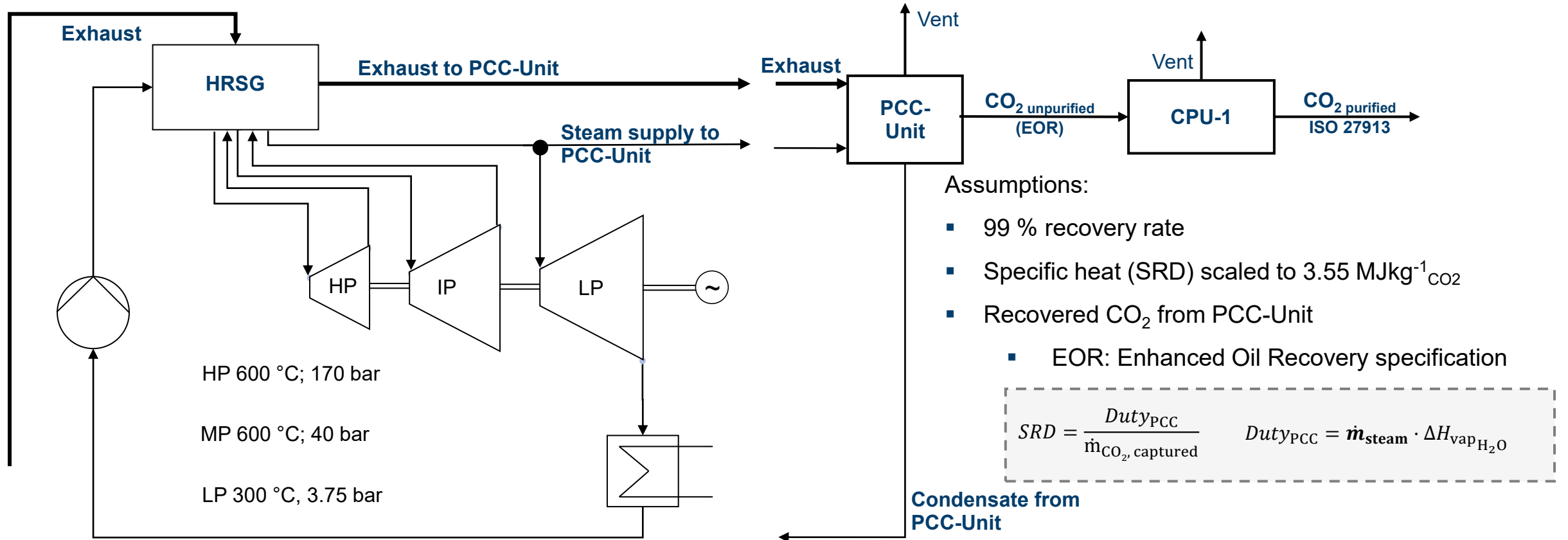
## Combined Cycle Gas Turbine (CCGT)<sup>[8,9,10]</sup>



[8] Maria Jonsson, Olav Bolland, Dominikus Bucker, Miker Rost. Gas turbine cooling model for evaluation of novel cycles. In: Proceedings of ECOS 2005  
 [9] IEAGHG. CO2 Capture at Gas Fired Power Plants, 2012/8, July, 2012.  
 [10] IEAGHG. Retrofit of CO2 Capture to Natural Gas Combined Cycle Plants. Report Number 2005 / 1 2005.

# REFERENCE POWER CYCLE

## CCGT-PCC<sup>[11][12]</sup> – Modeling of the post combustion carbon capture unit



SRD: Specific Reboiler Duty

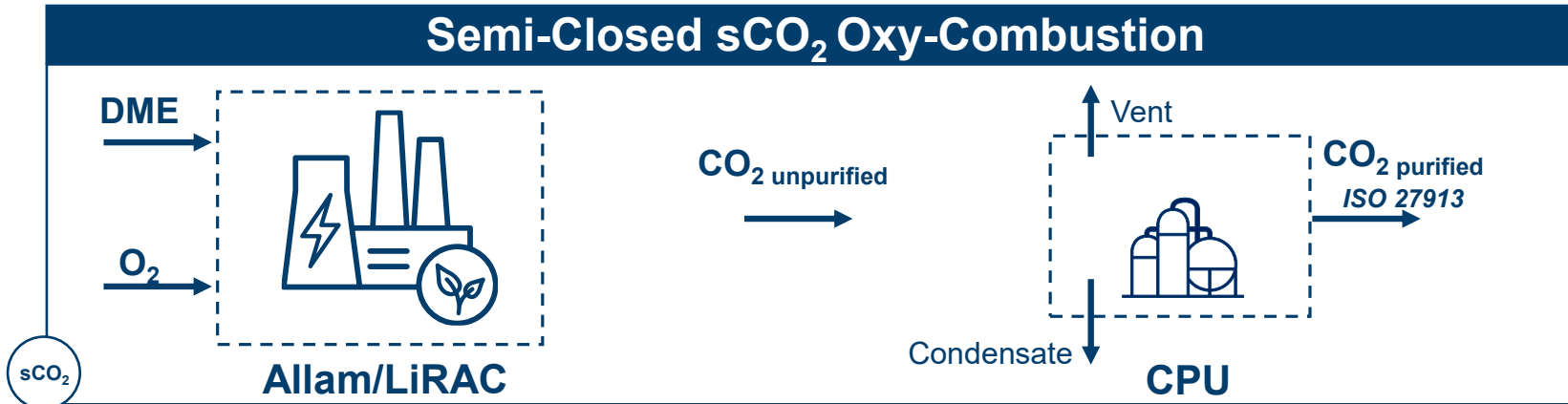
[11] M. Turner, T. Schmitt, M. Oakes, J. Konrade, M. Bleckinger, M. Sturdivan. Cost and Performance Baseline for Fossil Energy Plants. Volume 3: Low Rank Coal and Natural Gas to Electricity. Pittsburgh; 2023.

[12] IEAGHG. Update techno-economic benchmarks for fossil fuel-fired power plants with CO<sub>2</sub> capture, 2020/07, July 2020.

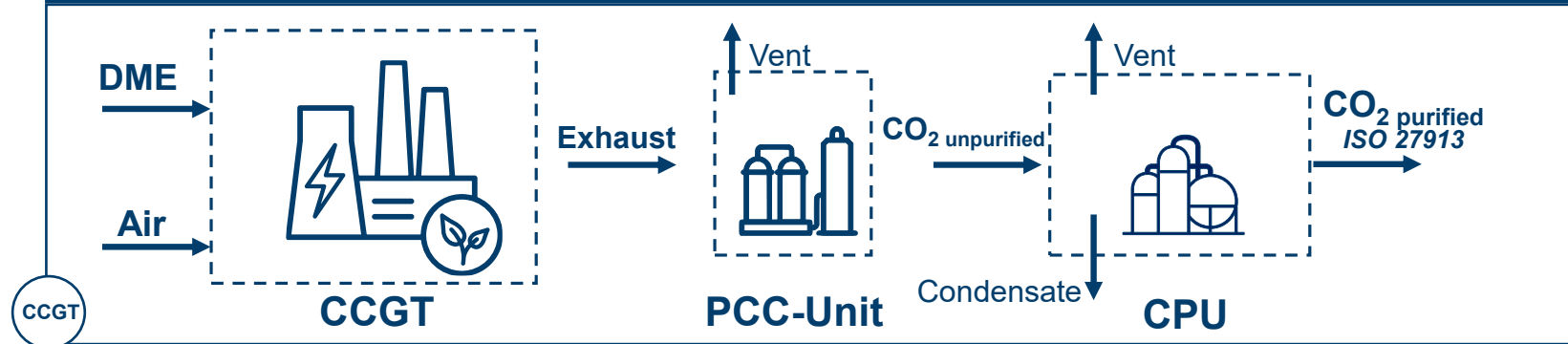
# INVESTIGATED POWER CYCLES

## Recap

### Semi-Closed sCO<sub>2</sub> Oxy-Combustion



### Combined Cycle Gas Turbine with Post Combustion Carbon Capture



### Investigated Cycles

- DME-fueled Allam
- LiRAC
- DME-fueled CCGT-PCC

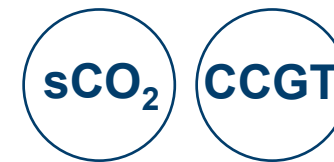
### Assumptions

- Same fuel DME, 1536 MWth
- Same CO<sub>2</sub> specs
- Maximizing CO<sub>2</sub> capture rates

### Key Metrics

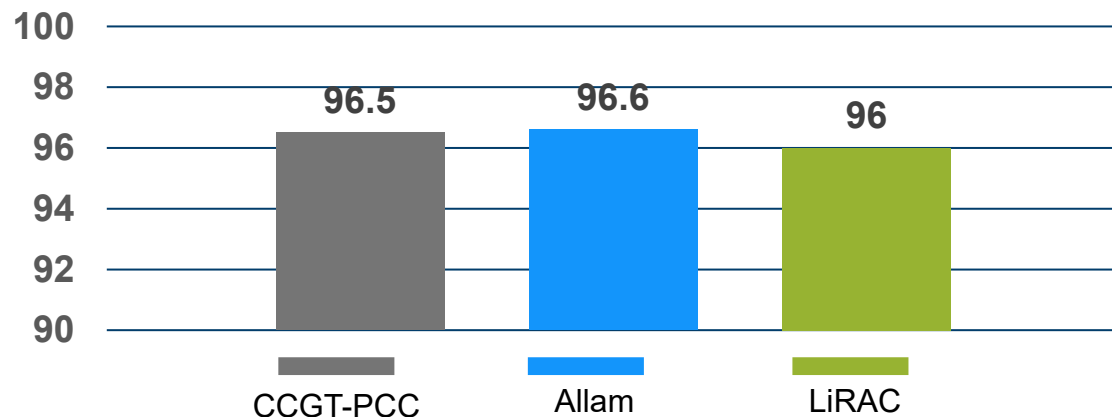
- CO<sub>2</sub> capture rates
- Net efficiency

# COMPARATIVE ANALYSIS

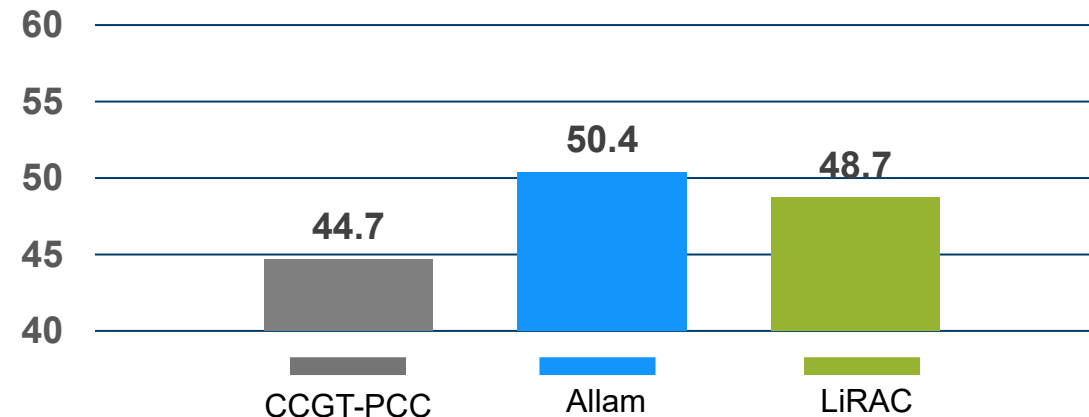


## Carbon Capture – Highest capture rate by DME-fueled Allam cycle

Effective CO<sub>2</sub> Capture Rate / %



Net Efficiency / %



- Very high capture rates across all cycles
- Highest efficiency for DME-Allam cycle
- LiRAC competitive efficiency with fundamental reconfiguration
- sCO<sub>2</sub> cycles more efficient than CCGT-PCC

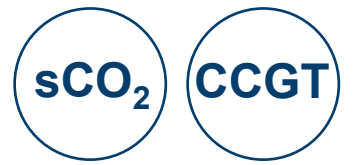
$$\text{Effective capture rate: } R_{CC} = \frac{\dot{m}_{\text{CO}_2, \text{purified}}}{(\dot{m}_{\text{CO}_2, \text{input, air}})_{\text{CCGT}} + \dot{m}_{\text{CO}_2, \text{fuel, stoich}}}$$

$$\dot{m}_{\text{CO}_2, \text{fuel, stoich}} = \dot{m}_{\text{CO}_2, \text{generated}} + \dot{m}_{\text{CO}_2, \text{input, fuel}}$$

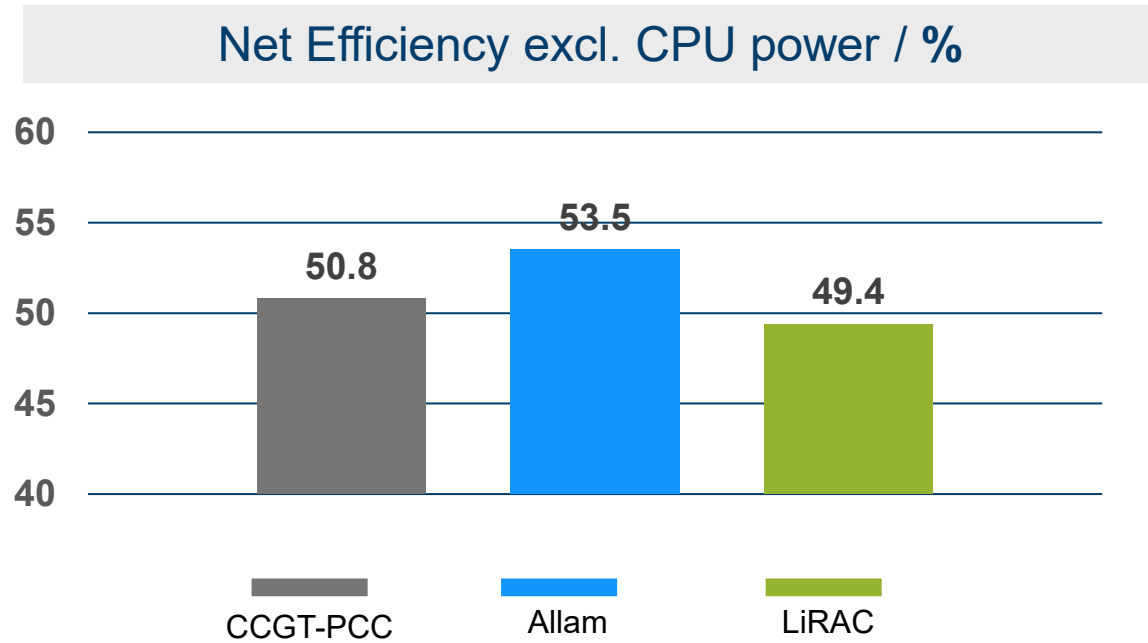
$$\eta_{\text{net}} = \frac{P_{\text{net}}}{\dot{m}_{\text{fuel}} * \text{LHV}} \quad P_{\text{net}} \text{ inc. CPU and ASU* power demand}$$

\*: ASU's power demand is represented by specific energy consumption of 1390 kJkg<sup>-1</sup>O<sub>2</sub>

# COMPARATIVE ANALYSIS



Efficiency – sCO<sub>2</sub> based power cycles outperform the state of the art



- DME-Allam better than CCGT even without CO<sub>2</sub> conditioning (CPU)

- Assuming the CO<sub>2</sub> doesn't need further purification
  - \*Unpurified CO<sub>2</sub>
- Exclude the power of the CPU from efficiency calculation

\*Different system boundaries due to difference in unpurified CO<sub>2</sub>

$$\eta_{\text{net}} = \frac{P_{\text{net}} - P_{\text{CPU}}}{\dot{m}_{\text{DME}} * LHV_{\text{DME}}}$$

$P_{\text{net}}$  inc. CPU and ASU\* power demand

\*: ASU's power Demand is represented by specific energy consumption of 1390 kJkg<sup>-1</sup>O<sub>2</sub>

# Conclusion & Outlook



- Integration of **DME** into power generation to enable **electricity On-Demand** and a **circular carbon loop**.



- Two **sCO<sub>2</sub> power cycles** were evaluated and **benchmarked** against a reference cycle (**CCGT-PCC**) under **aligned system boundaries**.
- **LiRAC** was introduced, with a liquefied working medium and an alternative pressurization strategy.



- DME-fueled **sCO<sub>2</sub> oxy-combustion power cycles** demonstrated **efficient near-carbon-neutral** power generation.
- LiRAC maintains **competitive efficiency** while offering **potential operational advantages**.



- Investigating part-load performance of the **LiRAC**.

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# THANK YOU FOR YOUR ATTENTION!



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