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EMISSION REDUCTION WITH PARTIAL OXIDATION OF NATURAL GAS IN COMBINED CYCLE

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Presentation outline

- Overview of work
- Power plant configuration
- Chemical reactions in
  - partial oxidation reactor
  - shift reactor and
  - combustion chambers
- Results

  Effect of air fuel ratio, steam fuel ratio and compressor pressure ratio on
  - unconverted methane

  Effect of air fuel ratio and steam fuel ratio on
  - CO_2 in exhaust
  - hydrogen generation
  - temperature of partial oxidation reactor
  - exergy efficiency of combined cycle
- Conclusions

- The analysis discusses the selection of some important parameters necessary to obtain a maximum level of conversion of hydrogen from natural gas in the partial oxidation reactor.
- The parameters which influence the hydrogen production are air-to-methane ratio, steam-to-methane ratio and reactor pressure.
- The results showed that a net efficiency of 43 percent, with a 95.5 percent of fuel conversion can be obtained by combined cycle with dual pressure heat recovery steam generator based on present technological status.

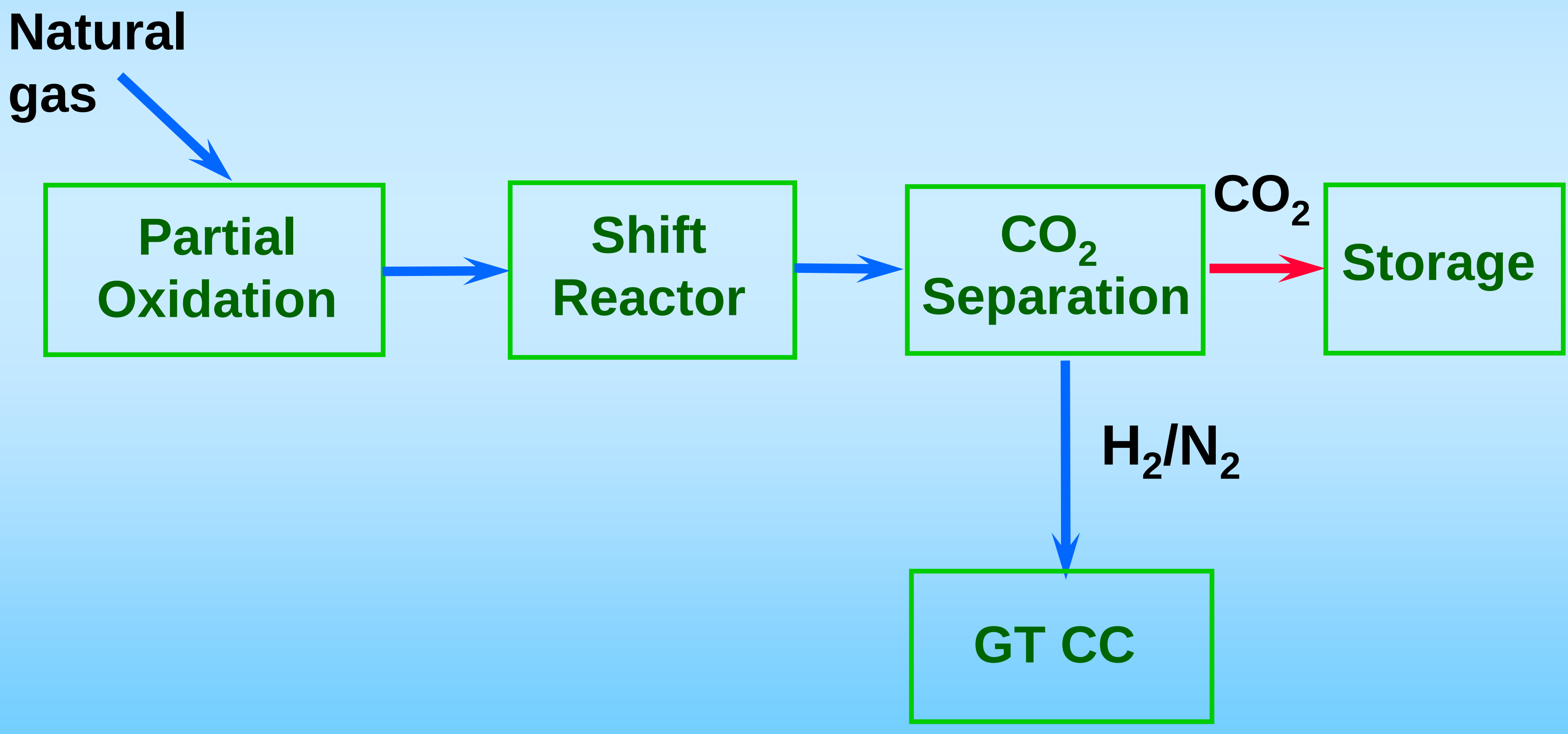
- The aim of the present work is to apply the thermodynamic analysis for fuel decarbonisation concept to natural gas, for efficient removal of CO_2 from combined cycles.
- An effort has been made towards the minimization of carbon dioxide emission.
- The performance of the integrated plant configuration is analysed with respect to the combined cycle parameters based on the optimized parameters in partial oxidation reactor.

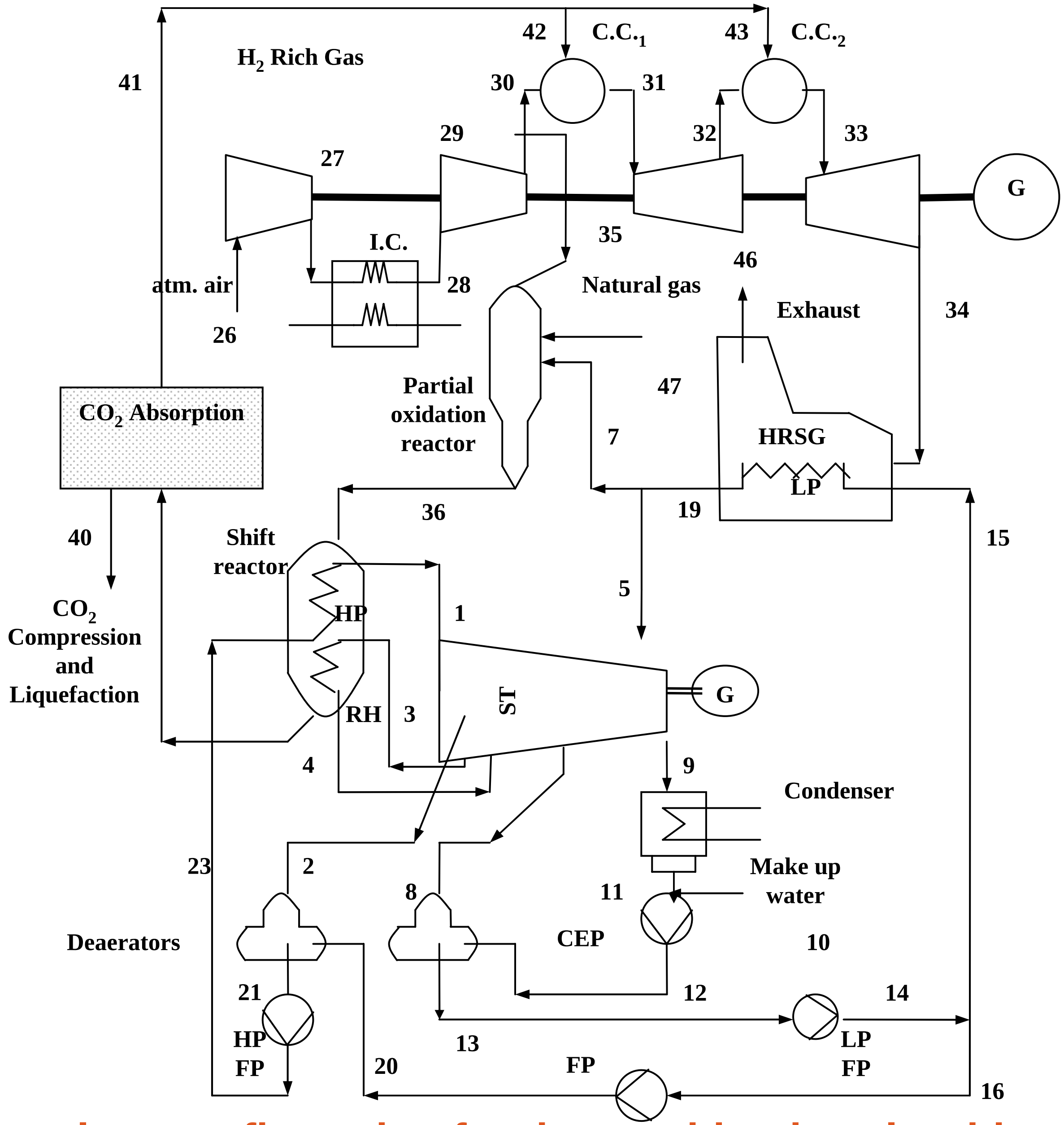
CO_2 Capture Technologies

- Pre-Combustion
- Post-Combustion
- Oxy-Fuel Combustion

- Separation of CO_2 from the fossil fuel.
- Removal of CO_2 from combustion flue gases.
- Combustion with pure O_2 and Recycled Flue Gas to reduce CO_2 emissions

Gas Pre-Combustion Capture Concept





Power plant configuration for the combined cycle with natural gas decarburisation and carbon dioxide chemical absorption

PARTIAL OXIDATION REACTOR

The combustion reaction in the partial oxidation reactor is

$a_1\ CH_4 + a_2\ H_2O + a_3\ (O_2 + 3.76\ N_2)$

$= b_1\ CH_4 + b_2\ CO + b_3\ CO_2 + b_4\ H_2 + b_5\ H_2O$

$+ b_6\ N_2$

- Methane reforming: $CH_4 + H_2O = CO + 3H_2$
- Water shift reaction: $CO + H_2O = CO_2 + H_2$

Equilibrium constants

$$K_{p,1} = \frac{P_{co} P_{H_2}^3}{P_{CH_4} P_{H_2O} P_0^2}$$

$$= \frac{b_2(4a_1 - 2a_3 - 4b_1 - b_2)^3 P^2}{b_1(a_2 + 2a_3 - 2a_1 + 2b_1 + b_2)(3a_1 + a_2 + 3.76a_3 - 2b_1)^2}$$

$$K_{p,2} = \frac{P_{co2} P_{H_2}}{P_{CO} P_{H_2O}}$$

$$= \frac{(a_1 - b_1 - b_2)(4a_1 - 2a_3 - 4b_1 - b_2)}{b_2(a_2 + 2a_3 - 2a_1 + 2b_1 + b_2)}$$

$$P = P_{reactor} / P_0$$

SHIFT REACTOR

The following is reaction is the exothermic chemical reaction in the shift reactor.

$$b_1\,CH_4 + b_2\,CO + b_3\,CO_2 + b_4\,H_2 + b_5\,H_2O + b_6\,N_2 = c_1\,CH_4 + c_2\,CO_2 + c_3\,H_2 + c_4\,H_2O + c_5\,N_2$$

COMBUSTION CHAMBER

The following is the combustion reaction equation in the gas turbine combustion chamber.

$a[c_1\ CH_4 + c_3\ H_2 + c_4\ H_2O + c_5\ N_2 + x_1\ (O_2 + 3.76\ N_2)] = a[d_1\ CO_2 + d_2\ H_2O + d_3\ O_2 + d_4\ N_2]$

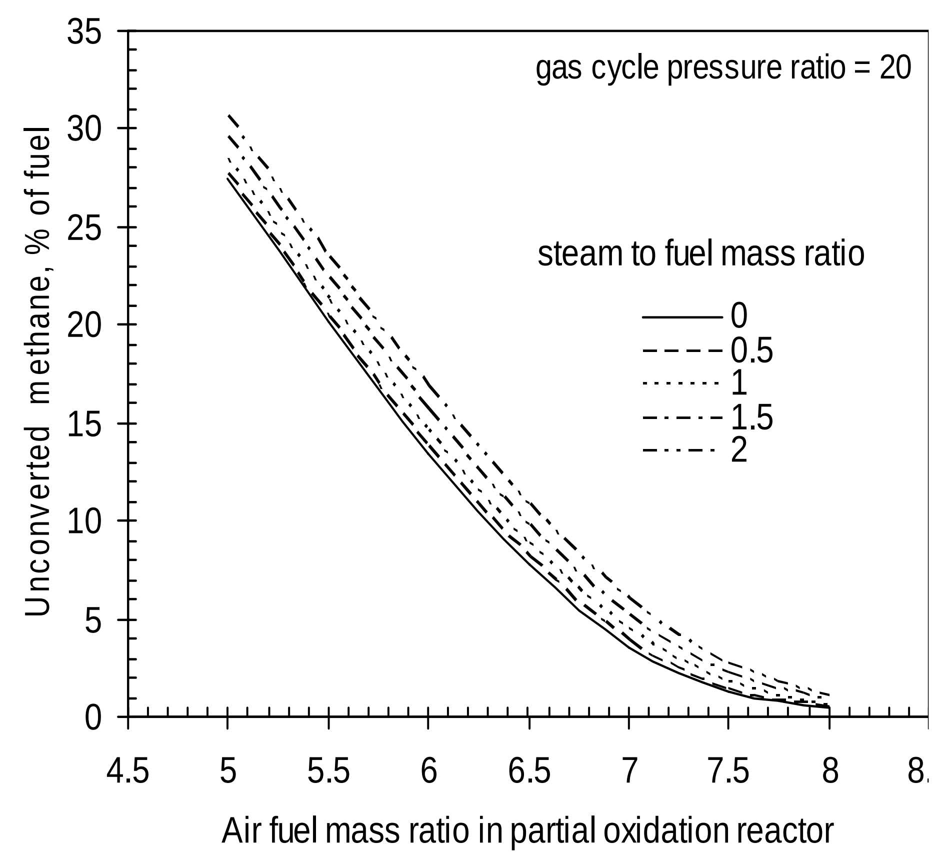
The combustion equation is the gas reheater is

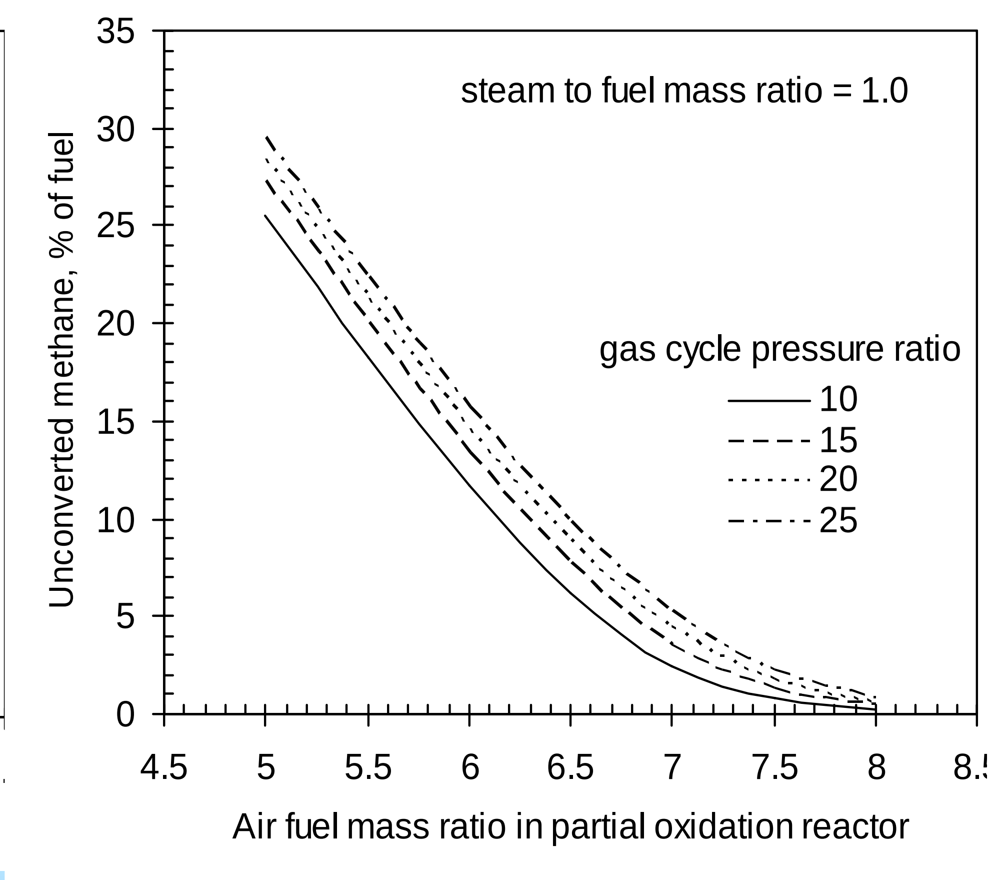
$a(d_1\ CO_2 + d_2\ H_2O + d_3\ O_2 + d_4\ N_2) + (1\text{-}a)(c_1\ CH_4 + c_3\ H_2 + c_4\ H_2O + c_5\ N_2) = e_1\ CO_2 + e_2\ H_2O + e_3\ O_2 + e_4\ N_2$

Exergy efficiency of combined cycle,

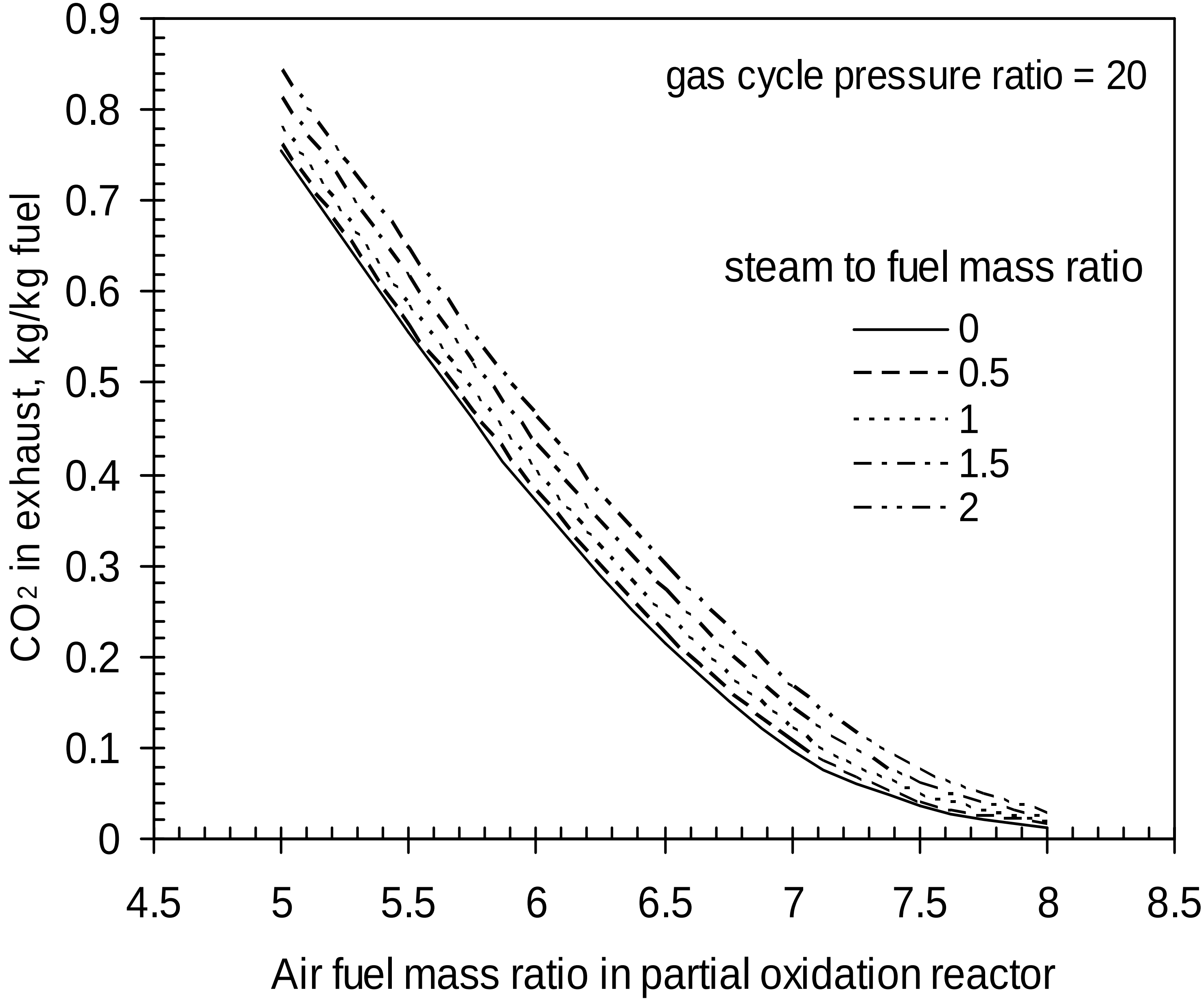
$$\eta_{2,cc} = \left(\frac{w_{net\ cc}}{\overline{\varepsilon^{0}}_{CH_4}} \right) \times 100$$

RESULTS

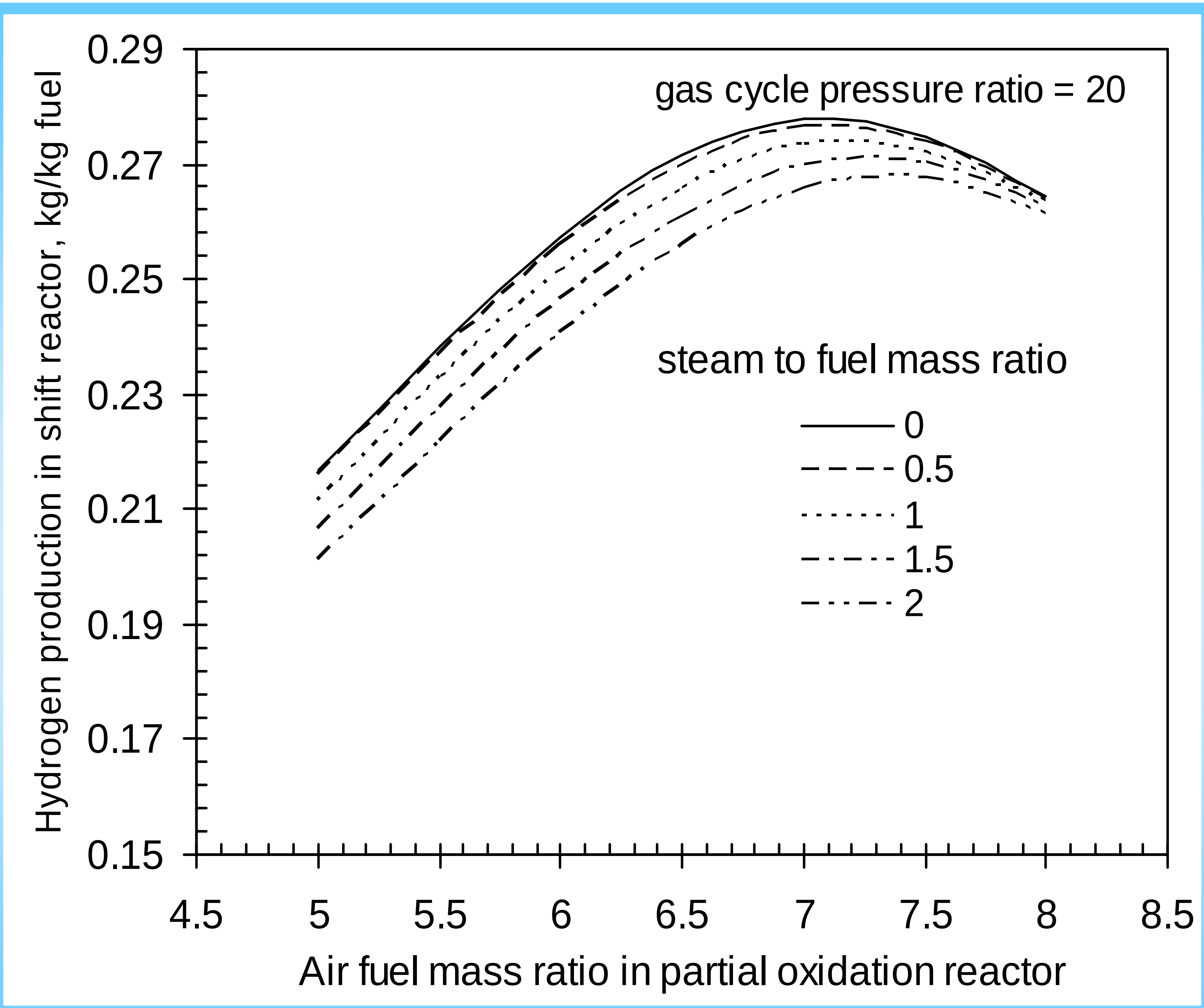




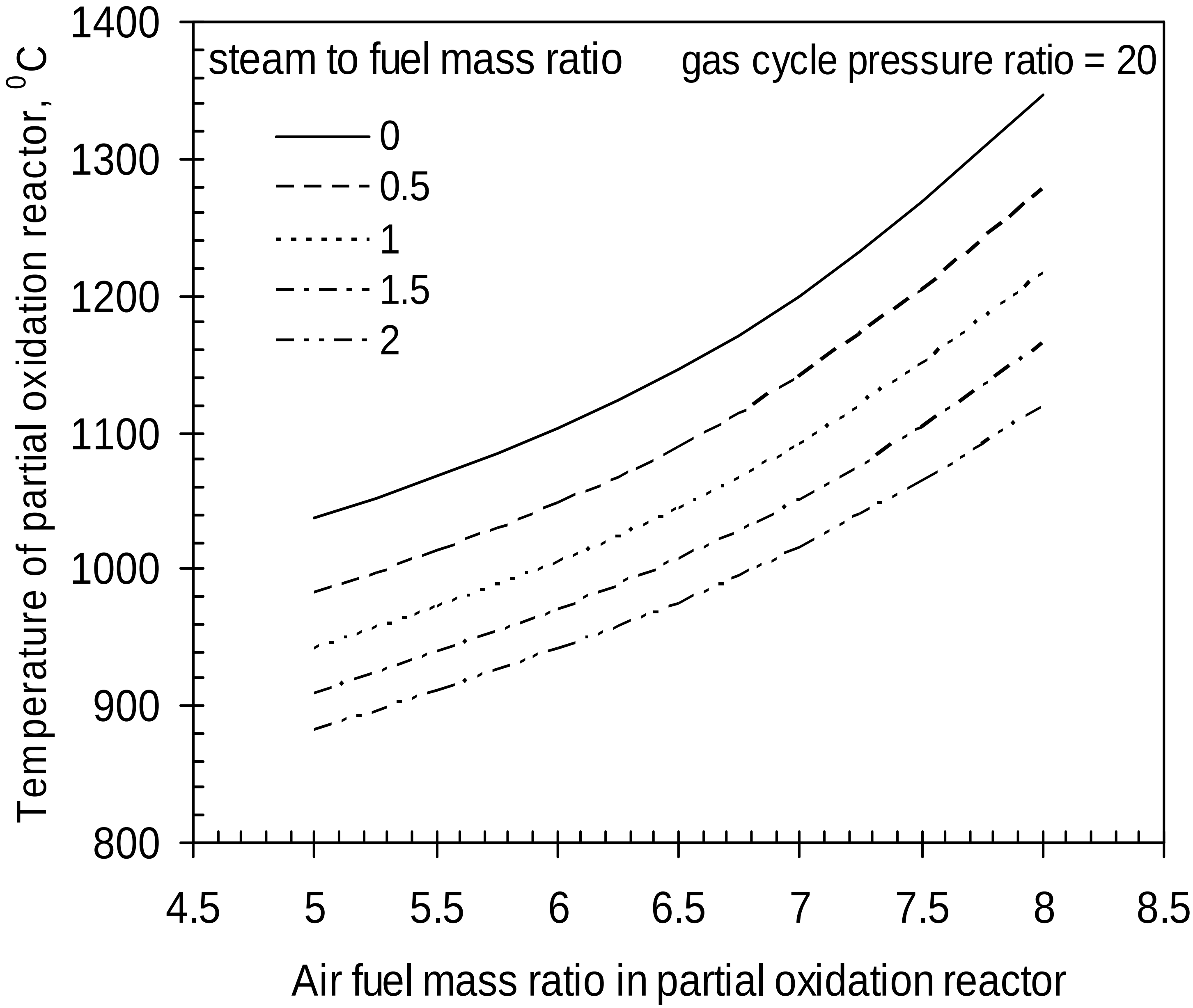
Effect of the air fuel ratio , steam fuel ratio and gas cycle pressure ratio on the conversion of fuel



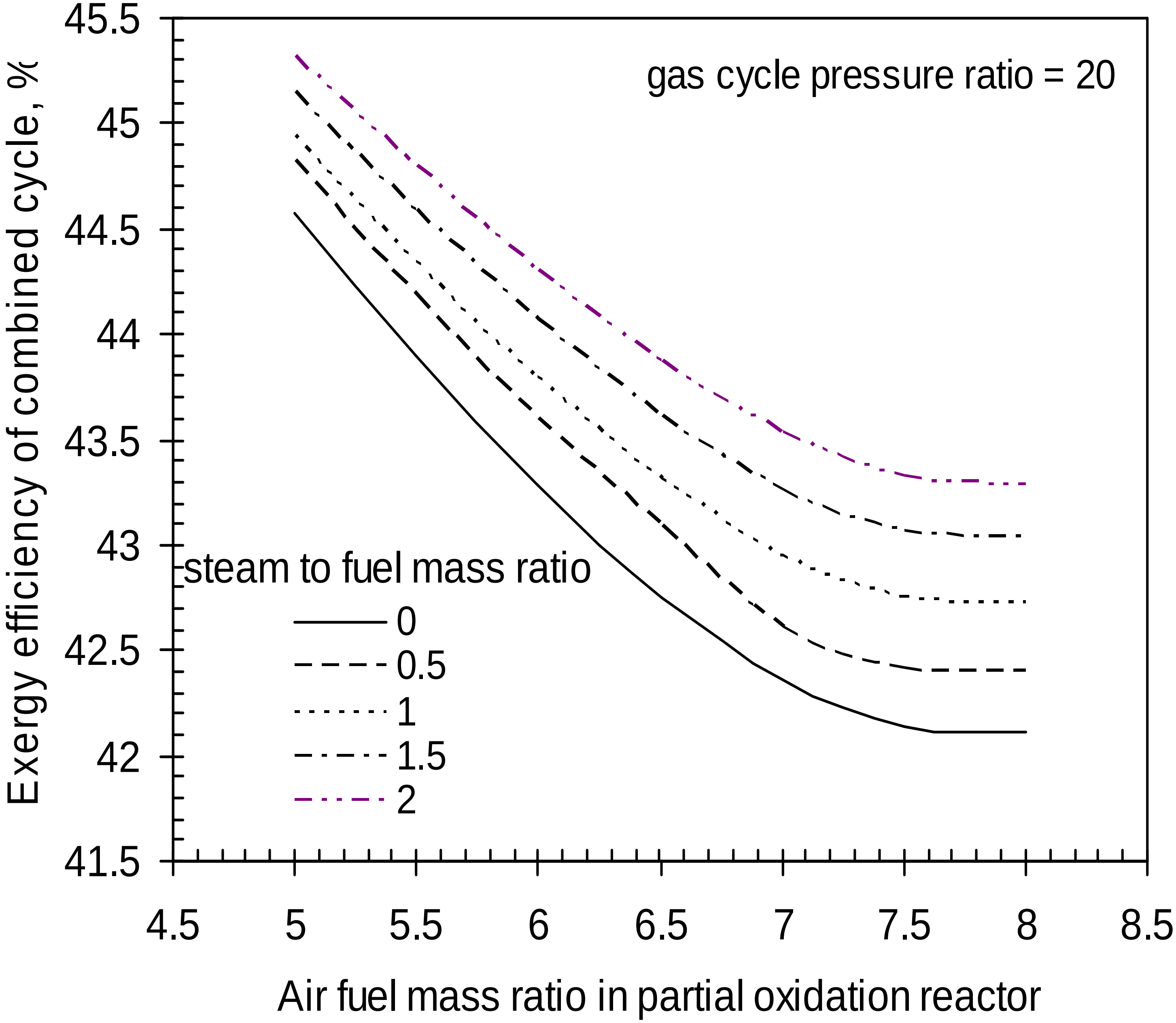
Effect of the air and steam mass ratios on the carbon dioxide emission from the plant



Effect of the air and steam ratios on hydrogen generation in shift reactor



Effect of the air and steam mass ratio on reactor's temperature at the cycle pressure ratio of 20



Effect of the air fuel ratio on the exergy efficiency of the combined cycle with the steam fuel ratio

CONCLUSIONS

- Unconverted methane into hydrogen, emission of carbon dioxide and exergy efficiency of the combined cycle decreases with increase in the air fuel ratio and increases with increase in the steam fuel ratio.

- The fuel conversion is more effective at low pressures compared to high pressures.

- The carbon dioxide cannot be removed in the emissions without a loss of mechanical power.
- The chemical thermodynamic analysis helps to find the optimum air and steam mass ratio for maximum hydrogen production in the shift reactor.
- The temperature of the partial oxidation reactor can be controlled with the steam injection.

THANK YOU