# A Novel Gas Pressurized Stripping (GPS) Technology for $CO_2$ Separation

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# Features of GPS Technology

- **GPS technology is a process, applicable to:**
  - *$CO_2$ capture from post-combustion flue gases*
  - *$CO_2$ separation from EOR recycled gas*
  - *$CO_2$ separation from natural gases (natural gas sweetening)*
  - *$CO_2$ separation from syngas*
  - *$CO_2$ separation for chemical processes ($H_2$, ethylene oxide, etc.)*
- **Applicable to existing $CO_2$ separation facilities**
  - *Minimal retrofitting (only stripper needs to be modified*
  - *Significant compression work saving, 50-90%*
  - *Could eliminate compressor entirely*
- **Applicable to different solvents**
  - *Tailor operating conditions (T and P) to different solvents*
  - *Best for non-aqueous solvents (no stripping gas)*

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# Advantages of the GPS Technology

- **Technology is mature**
  - *Use off-the-shelf absorption/stripping equipment*
  - *Suitable for large scale applications such as power plants*
- **Produces high pressure $CO_2$**
  - *Best for high pressure feed gas with $CO_2$ partial pressure at bars*
  - *Perfect for processes requiring high pressure $CO_2$*
  - *Can match upstream or downstream process conditions (pressure match between absorber and stripper or with other process units)*
- **High thermal efficiency**
  - *High stripping pressure enables efficient recovery of $CO_2$ pressure*
  - *High pressure of $CO_2$ product reduces compression work*
  - *Low stripping heat*
  - *Enhance solvent working capacity reduces sensible heat*

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# Current Status of the GPS Technology

- **$CO_2$ Capture from Post-Combustion Flue Gases**
  - **Bench-Scale test is finished at NCCC（funded by DOE）**
  - ***Planning pilot scale test and looking for partners (DOE FOA)***
- ***$CO_2$ separation from syngas***
  - ***Pilot scale test is finished at a urea plant (funded by private sector)***
  - ***A commercial plant is in progress for the same urea plant (funded by private sector)***
- ***$CO_2$ separation from EOR recycled gas***
  - ***Conducted computer simulations for many cases***
  - ***Looking for partners***
- ***$CO_2$ separation from natural gases (natural gas sweetening)***
  - ***Conducted computer simulations for many cases***
  - ***Looking for partners***

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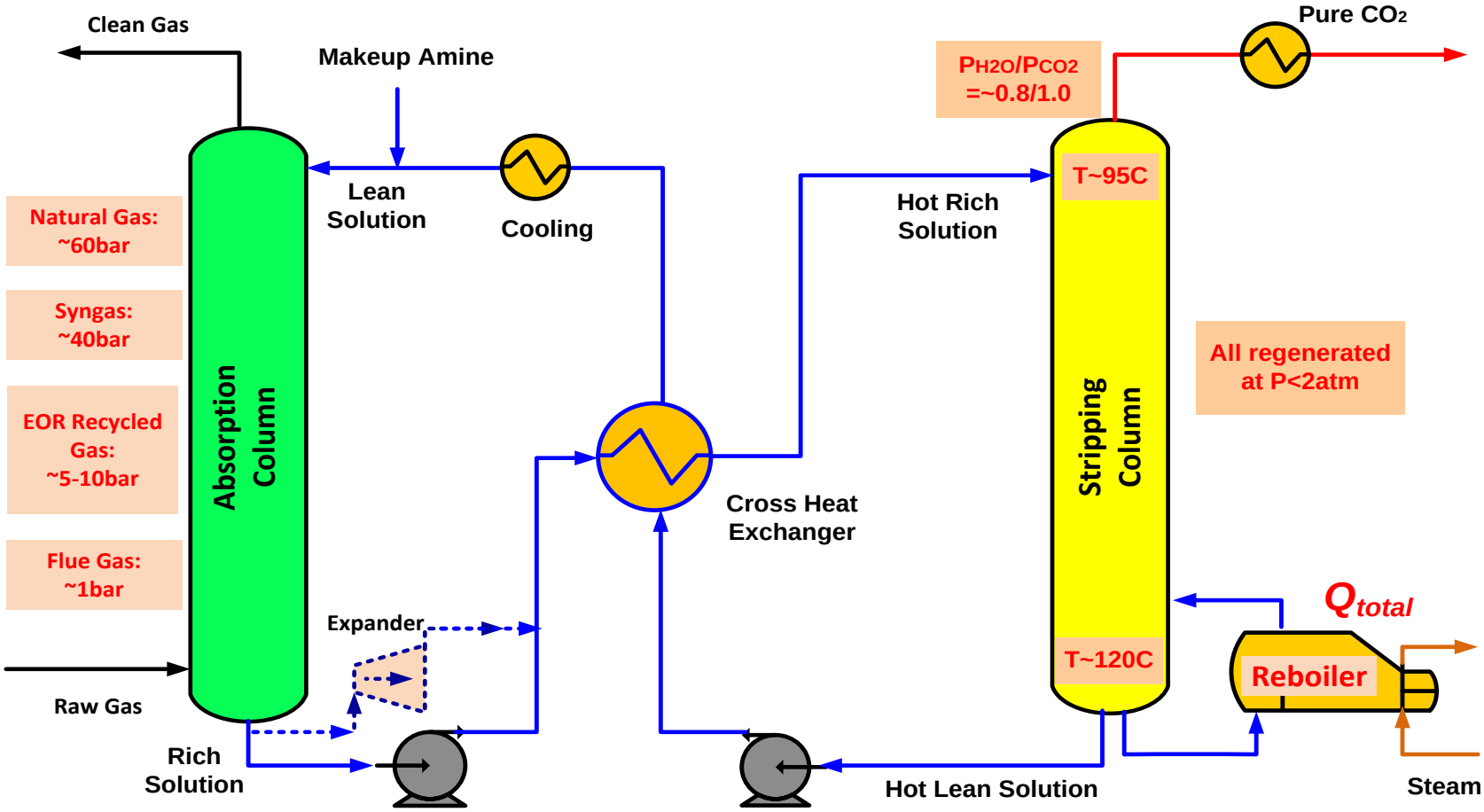
# Conventional Amine-Based Absorption/Stripping Process

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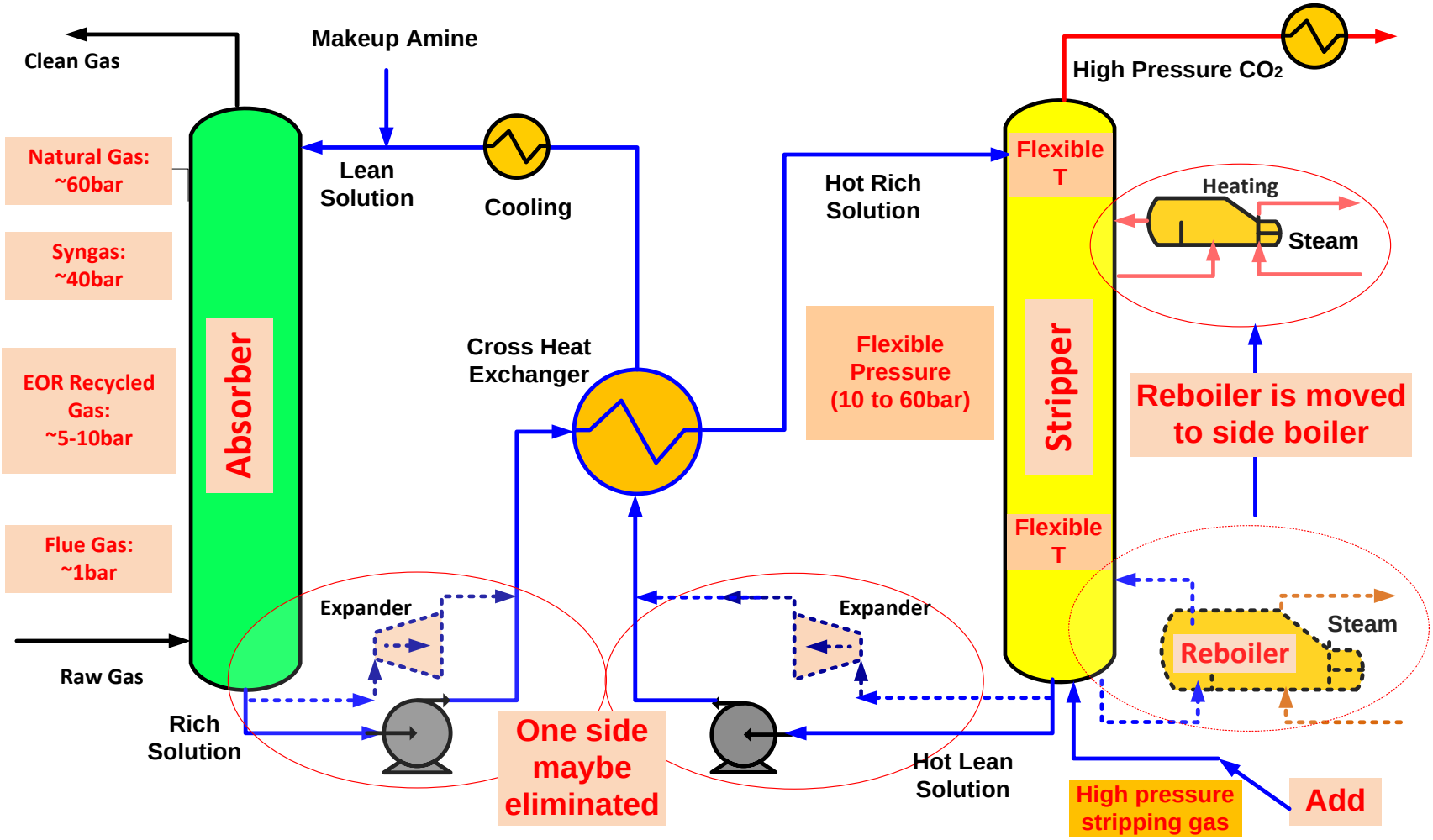
# The Novel GPS Based Absorption/Stripping Processes

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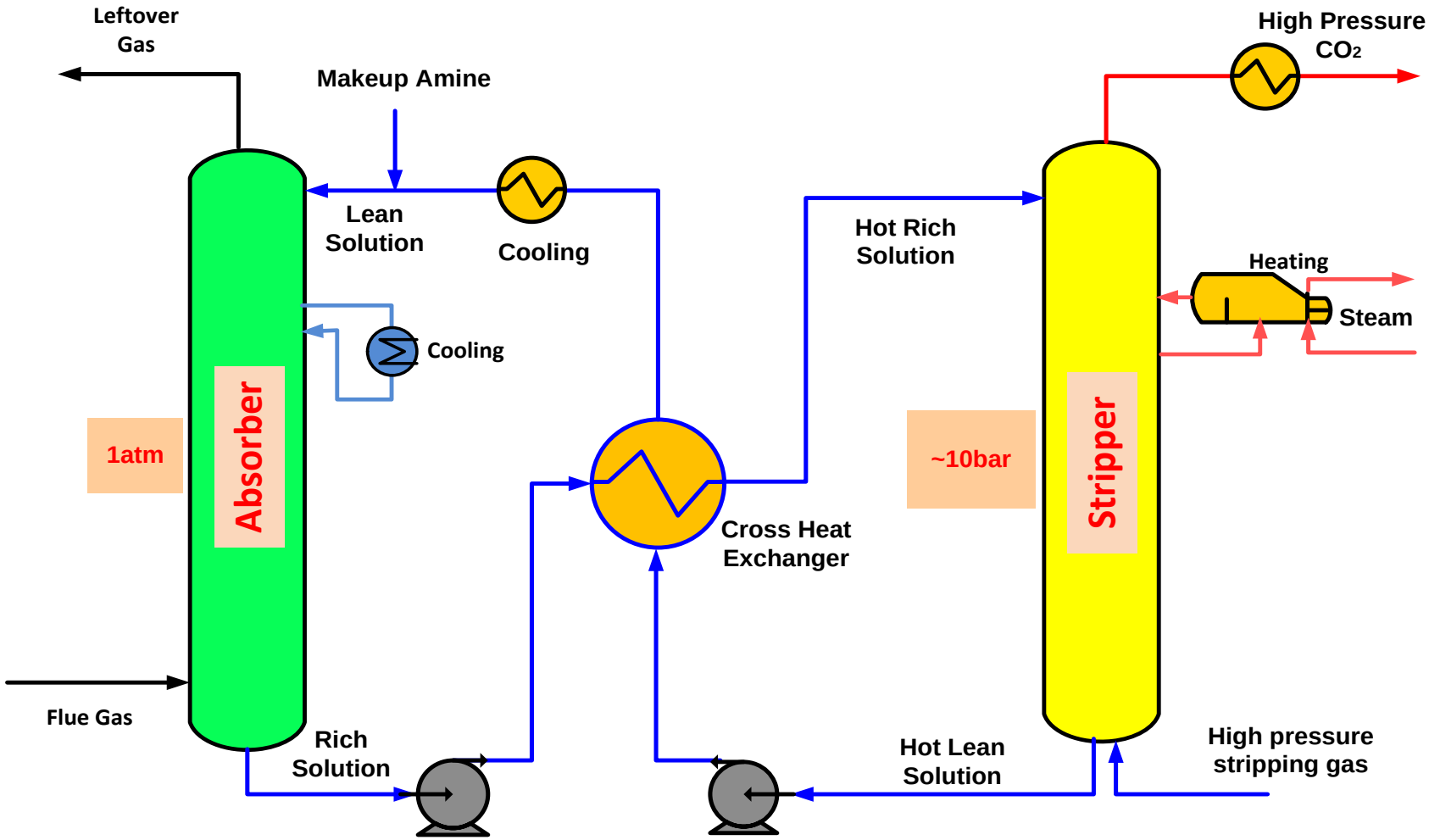
# GPS Technology For Post-Combustion $CO_2$ Capture

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# Energy Performance of the Optimized GPS Process

| Process | Baseline MEA | GPS Process |
|---|---|---|
| Operating Pressure (atm) | 1.8 | ~6 |
| Reaction Heat (kJ/kg$CO_2$) | 1870 | 1355 |
| Sensible Heat (kJ/kg$CO_2$) | 990 | 295** |
| Stripping Heat (kJ/kg$CO_2$) | 690 | 231 |
| Total Heat (kJ/kg$CO_2$) | 3550 | 1881 |
| Electricity Equivalent (kWh/kg$CO_2$) | 0.29 | 0.12 |
| Other load (kWh/kg$CO_2$) | 0.04 | 0.04 |
| Compression Work (kWh/kg$CO_2$) | 0.09 | 0.06 |
| Electricity Equivalent (kWh/kg$CO_2$) | 0.42 | 0.22 |
| Energy Penalty to SPC Plant (%) | 30 | 18 |

***LMTD=5.12 $^{O}$C*

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# Techno-economic Analysis

| Type of $CO_2$ Capture Technology | Case 11 | Case 12 MEA | Nexant Inc. MEA | GPS Process |
|---|---|---|---|---|
| Power Production, MW | | | | |
| Gross Power | 580 | 663 | 704 | 762 |
| Net Power | 550 | 546 | 575 | 647 |
| Capital Cost, $MM | | | | |
| Power Plant | 866.4 | 1109.9 | 1114.9 | 1125.5 |
| PCC Plant | 0.0 | 410.8 | 390.6 | 430.8 |
| $CO_2$ Compression and Drying | 0.0 | 46.4 | 122.4 | 60.5 |
| Start Up Costs (2% TPC before Contingency) | 15.5 | 26.4 | 27.4 | 27.2 |
| Total Capital Cost, $MM | 881.9 | 1,593.5 | 1,655.4 | 1,644.0 |
| Operating Cost excl Fuel, $MM/yr | | | | |
| Fixed Operating Cost | 13.8 | 20.5 | 21.0 | 22.6 |
| Variable Operating Cost | | | | |
| Non PCC related Opt Cost | 20.0 | 33.6 | 35.5 | 34.6 |
| NaOH | | 0.9 | 0.9 | 0.9 |
| $H_2SO_4$ | | 0.3 | 0.3 | 0.3 |
| Amine M/U | | 1.0 | 1.1 | 2.0 |
| Active Carbon | | 0.6 | 0.5 | 0.5 |
| Corrosion Inhibitor/Solvent MU | | 0.0 | 0.0 | 0.0 |
| Total Operating Cost excl Fuel, $MM/yr | 33.8 | 56.9 | 59.3 | 61.1 |
| Fuel Cost, $MM/yr | 64.5 | 92.0 | 92.0 | 92.0 |
| LCOE (excl $CO_2$ TS&M), mills/kWh | 63.9 | 112.0 | 109.6 | 97.4 |
| % of Case 11 LCOE - Compare to 2007 | 100% | 175% | 171% | 152% |

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# $CO_2$ Capture Cost for a 500 MWe PC Power Plant

LCOE for GPS: 97.4 mills/kwh

LCOE for Case 11(2007): 63.9 mills/kwh

$CO_2$ removed: 13050 kmol/h=632.9 tons (US short)

Net power of GPS based: 647MW

$CO_2$ capture cost = ($COE_{ccs}$ - $COE_{nonccs}$ )/($CO_2$ captured/kWh)

=(97.4-63.9)/(632.9/647)

=$34.24/ton = $37.7/tonne

If $CO_2$ capture is done at the current electricity market price then $CO_2$ capture cost could be further reduced to:

$CO_2$ Capture Cost = $29/tonne

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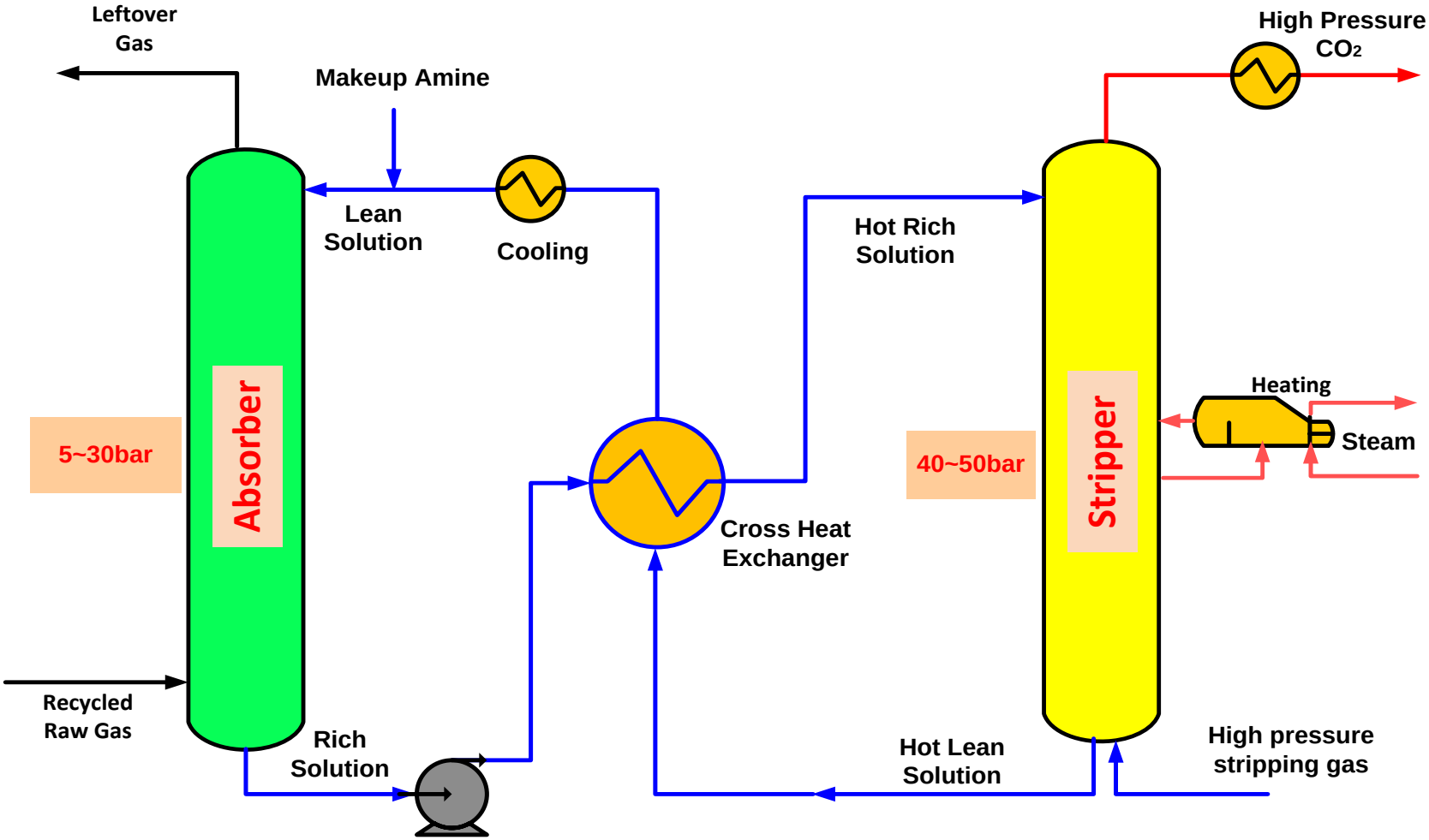
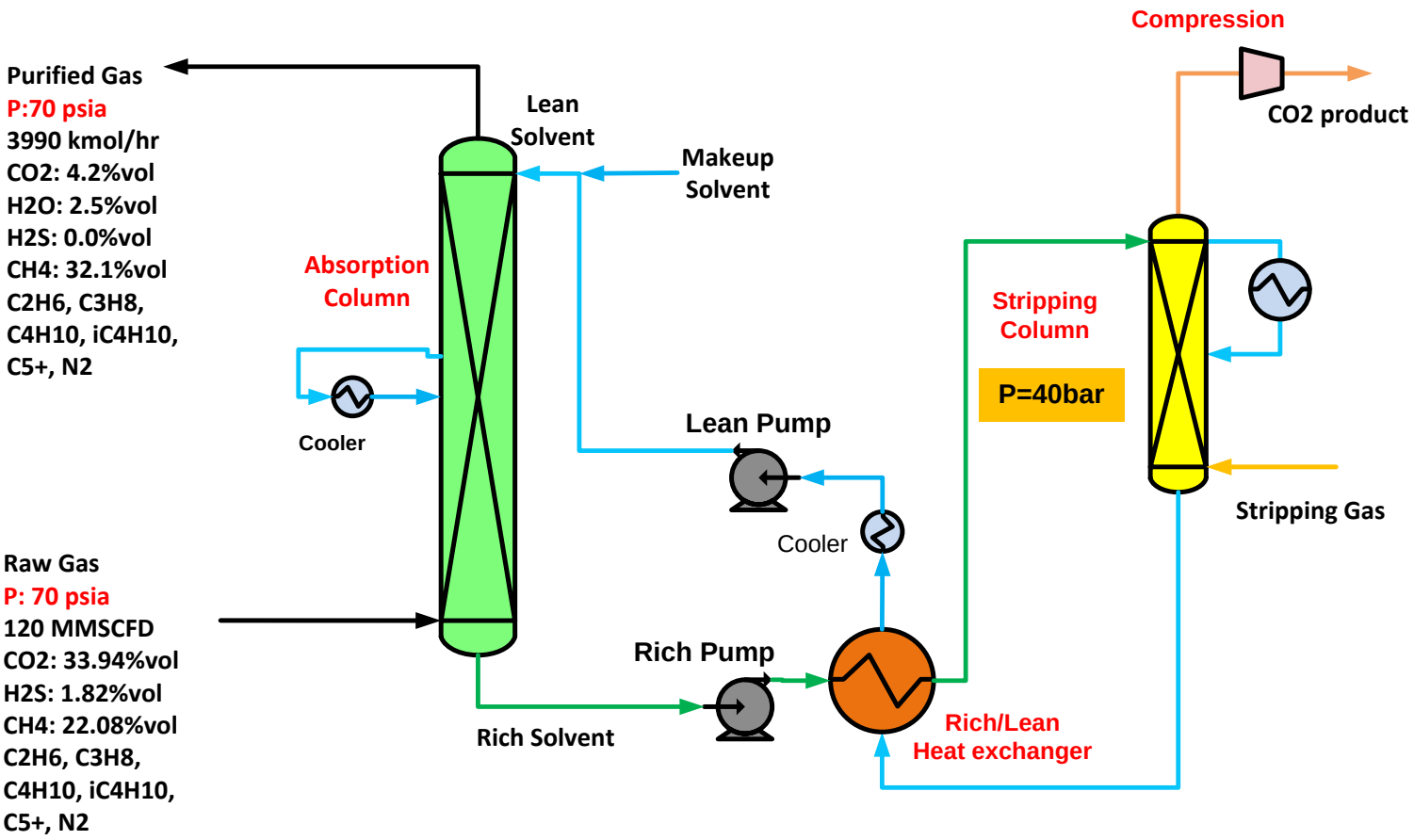
# GPS Process for EOR Recycled Gas $CO_2$ Separation



# 5 bar EOR Recycle Gas Treatment Example

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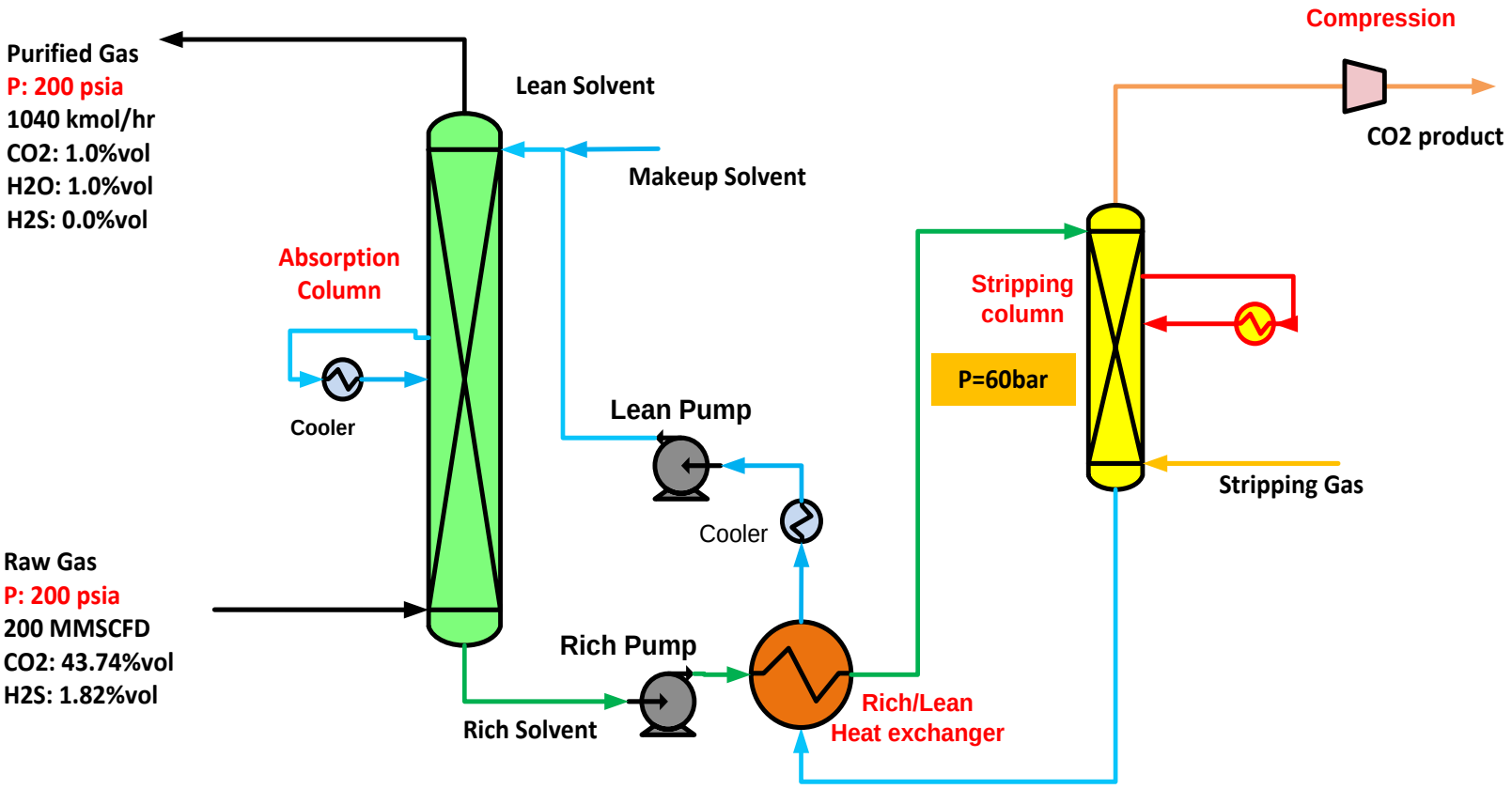
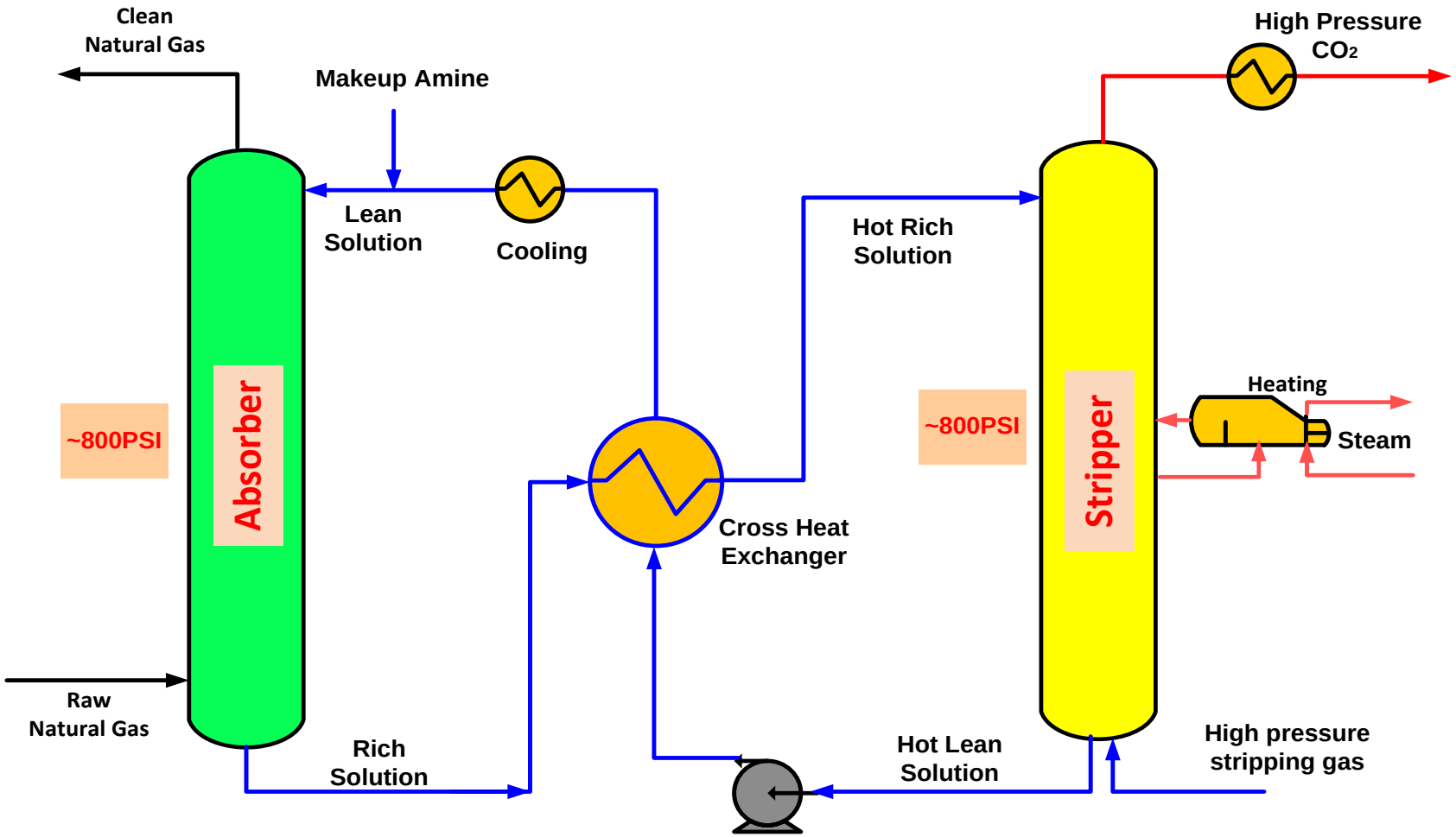
# 15 bar EOR Recycle Gas Treatment Example



# GPS Process for Syngas/Natural Gas Sweetening

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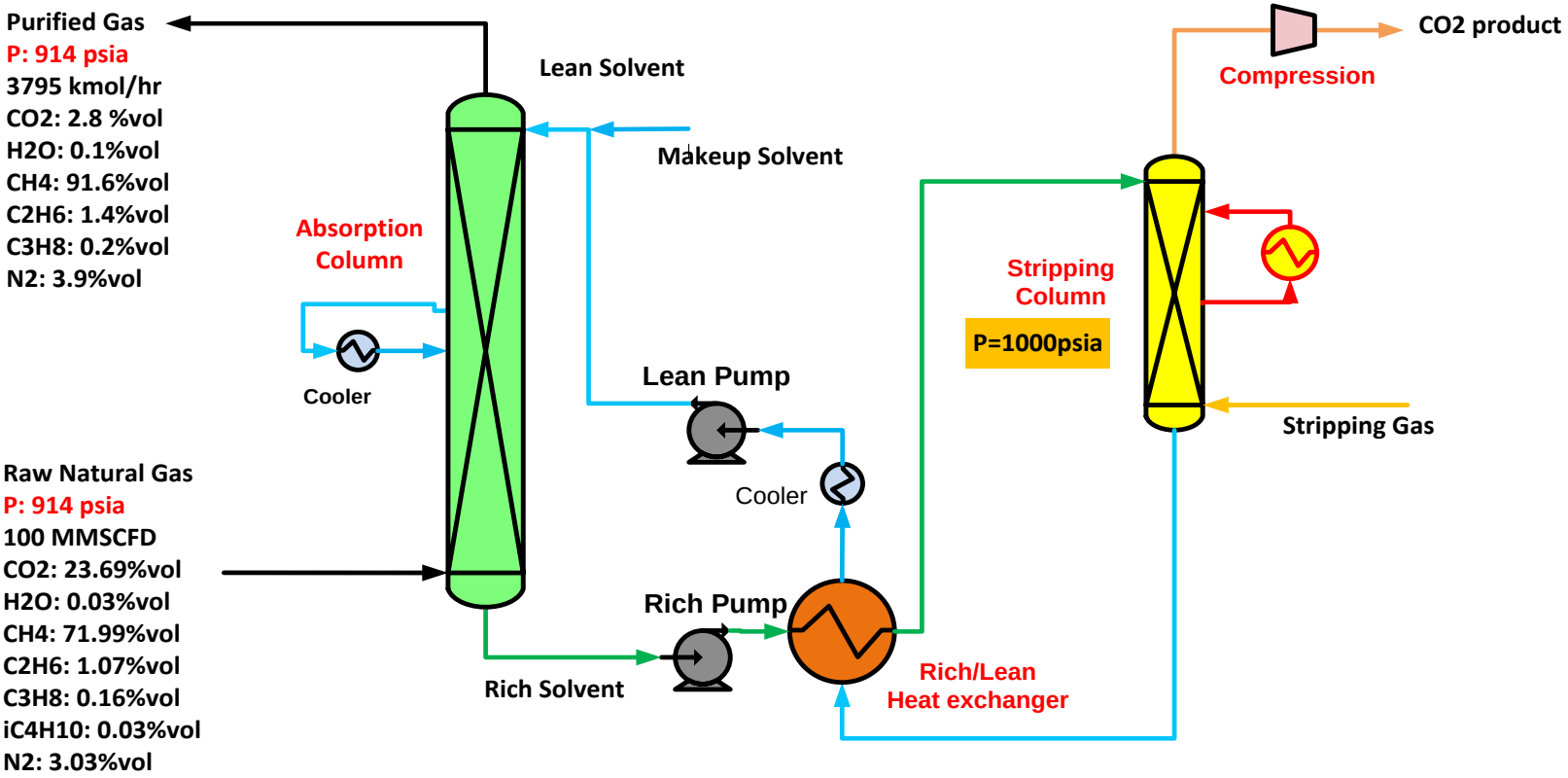
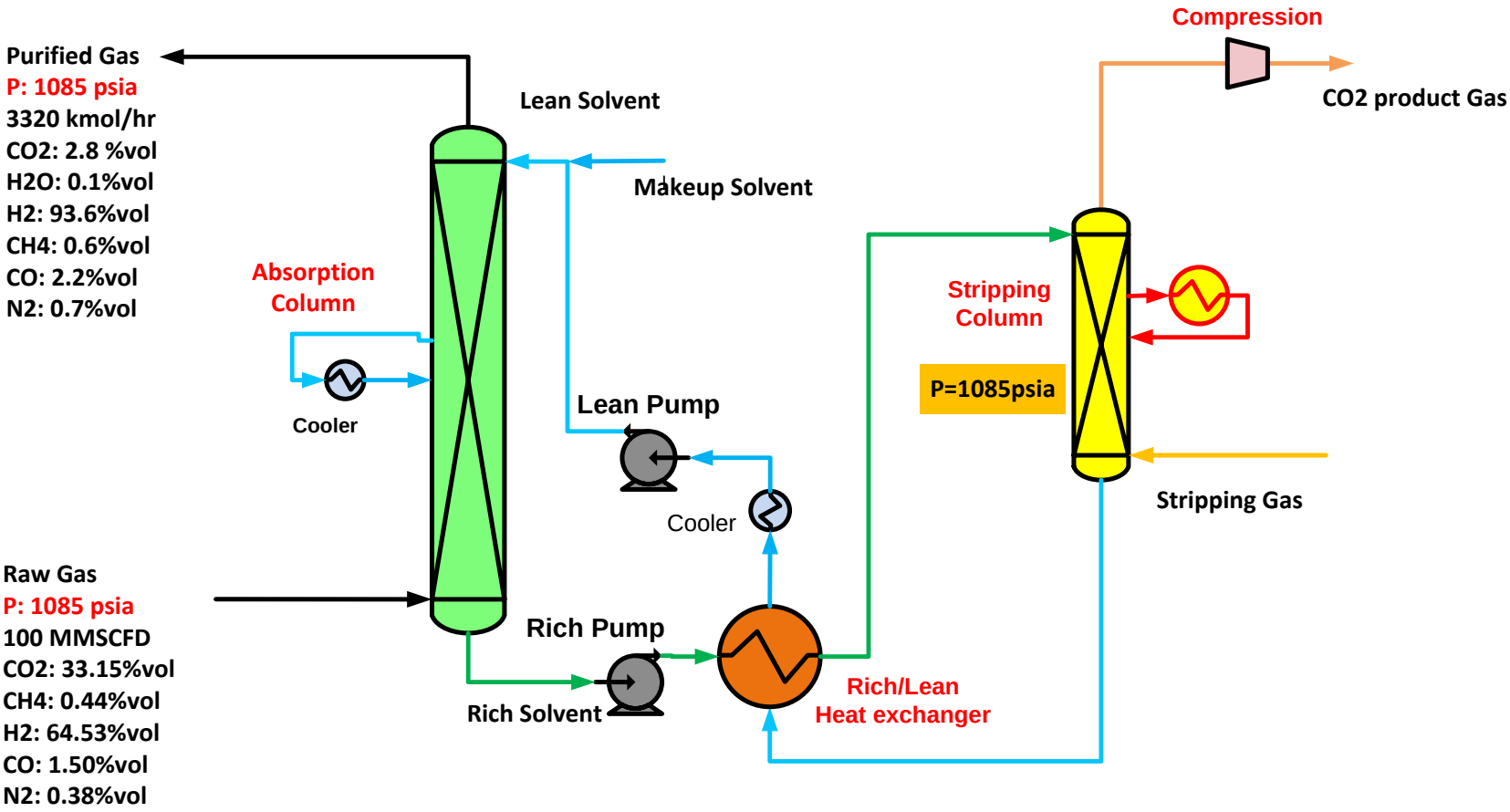
# GPS for Natural Gas Purification Example



# GPS for Syngas Purification Example 1

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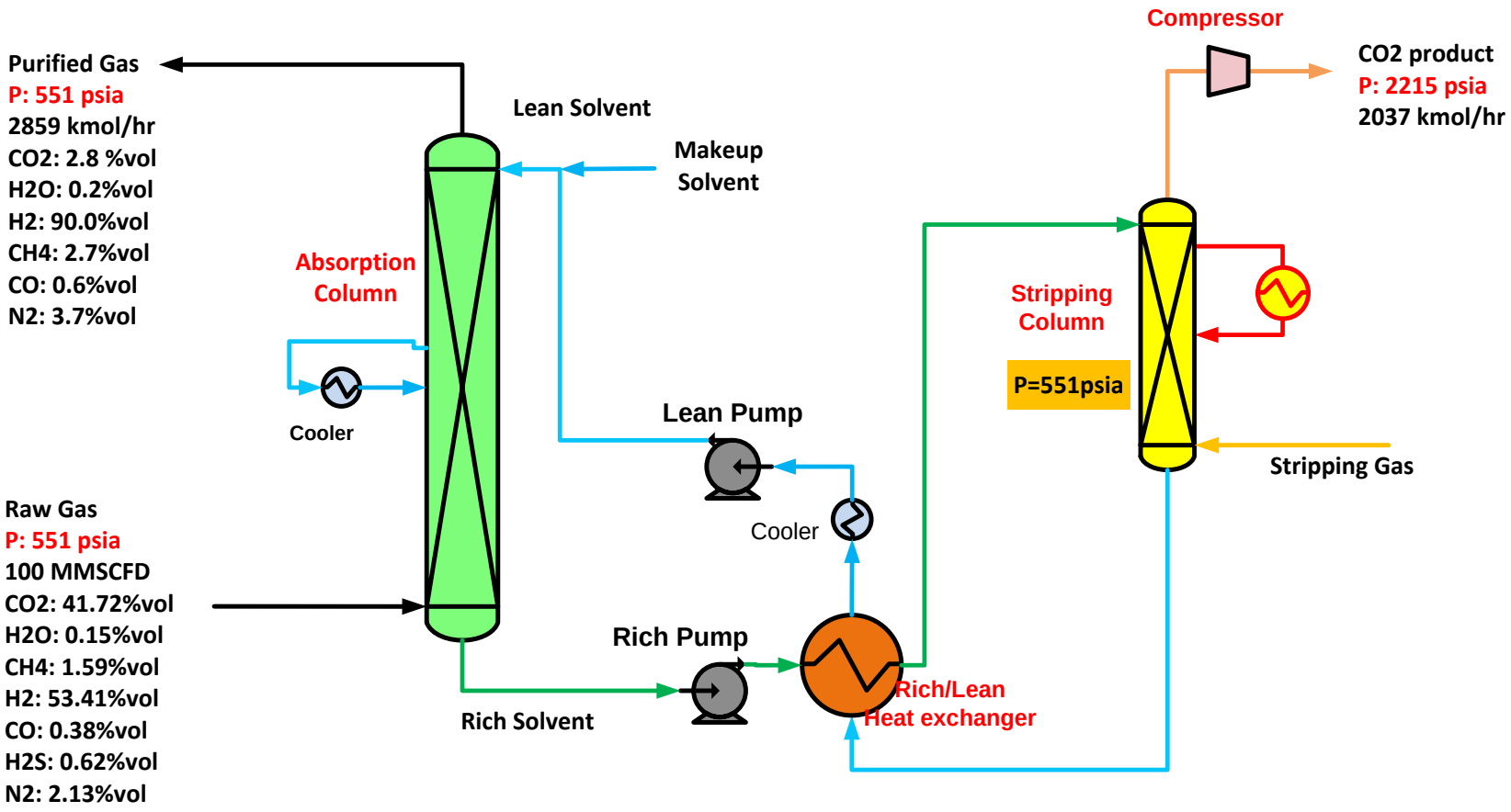
# 40bar IGCC Syngas Purification Example 2



# Contact US

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# Techno-economic Analysis

| | Baseline Case | Nexant Inc. MEA | GPS Process |
|---|---|---|---|
| Total Output at Generator Terminals, kW | 663,445 | 704,032 | 761,909 |
| Auxiliary Load Summary, kW: | | | |
| Coal Handling and Conveying | 490 | 490 | 490 |
| Limestone Handling & Reagent Preparation | 1,270 | 1,270 | 1,270 |
| Pulverizers | 3,990 | 3,990 | 3,990 |
| Ash Handling | 760 | 760 | 760 |
| Primary Air Fans | 1,870 | 1,870 | 1,870 |
| Forced Draft Fans | 2,380 | 2,380 | 2,380 |
| Induced Draft Fans | 10,120 | 10,120 | 10,120 |
| SCR | 70 | 70 | 70 |
| Baghouse | 100 | 100 | 100 |
| FGD Pumps and Agitators | 4,250 | 4,250 | 4,250 |
| Misc Balance of Plant | 2,000 | 2,000 | 2,000 |
| Steam Turbine Auxiliaries | 400 | 400 | 400 |
| Condensate Pumps | 630 | 630 | 630 |
| Cooling Water Circulation Pumps ** | 12,260 | 15,817 | 15,356 |
| Cooling Tower Fans | 6,340 | 4,547 | 4,424 |
| Transformer Losses | 2,300 | 2,441 | 2,641 |
| Amine $CO_2$ Capture Plant Auxiliaries | 21,320 | 18,986 | 22,420 |
| $CO_2$ Compression | 46,900 | 59,187 | 42,223 |
| Total Auxiliaries, kW | 117,450 | 129,308 | 115,394 |
| Net Power Export, kW | 545,995 | 574,724 | 646,514 |
| Net Plant Efficiency, % HHV | 27.2 | 28.7 | 32.2 |
| Net Plant Heat Rate, Btu/kW | 12,536 | 11,910 | 10,587 |

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