An Assessment of CO_2 Compression Options for Near Zero Emission Power Plants

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Ashok Rao, Ph.D., P.E.

Advanced Power and Energy Program

University of California, Irvine

Outline

- **Thermodynamic Assessment of Options for Pressurizing Captured CO_2 in**
  - **IGCC Plants**
  - **Boiler Plants**

- **Options Available**
  - **Compression Only**
  - **Compression + Pumping**
  - **Compression Options**
    - **Intercooled Compression**
    - **“Adiabatic” Compression with Recovery of Heat of Compression**

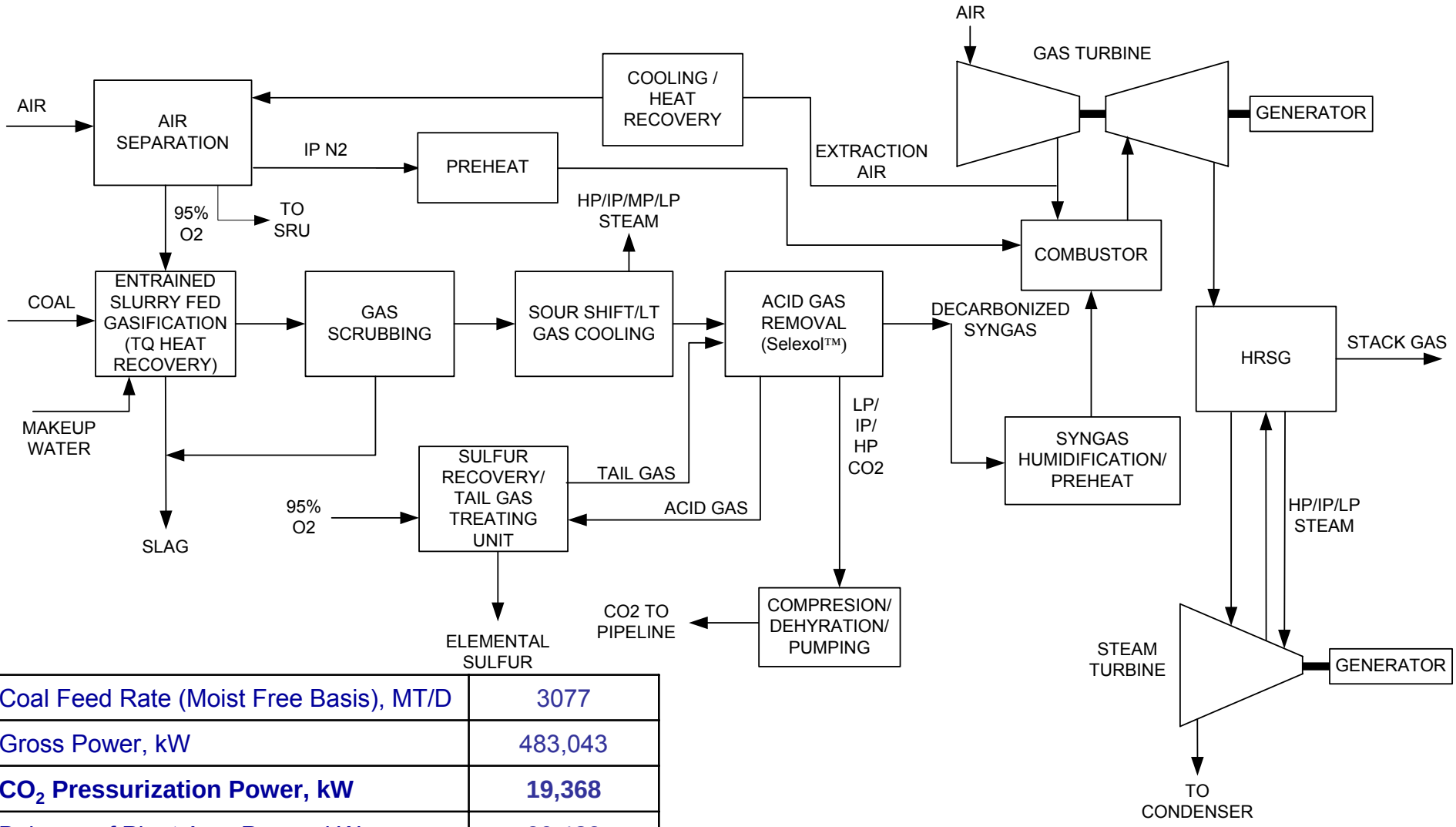
Some Specifications for Sequestration Ready CO_2

- **Pressure at Plant Battery Limits**
  - Remote Sequestration Site: 152 bar
  - Adjacent Sequestration Site: 110 bar

- **CO_2 Purity**
  - Enhanced Oil Recovery: > 95 Vol %
  - Geologic: Based on Economics

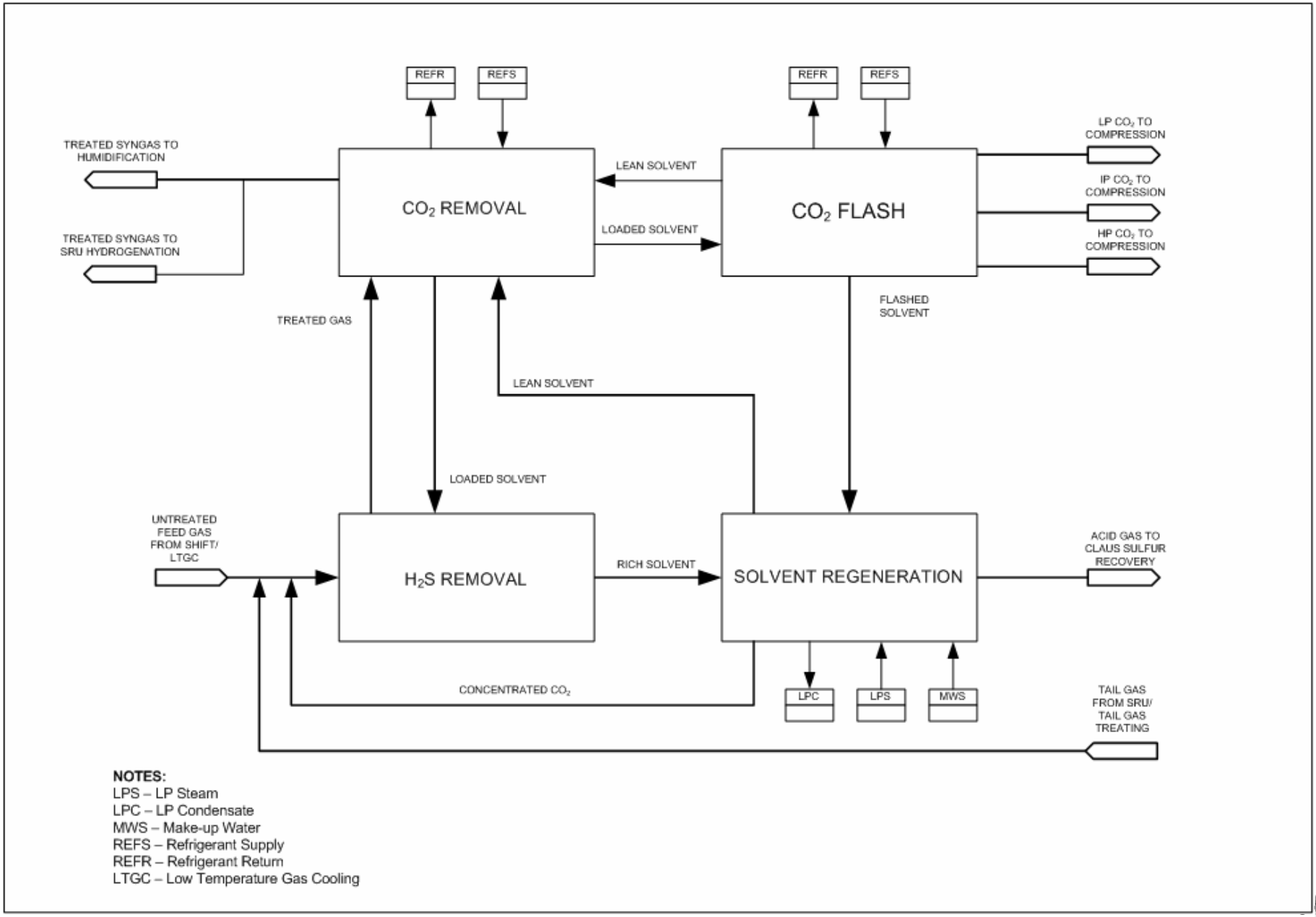
Thermodynamic Assessment of CO_2 Pressurization in IGCC Plants

IGCC with CO_2 Capture (H Class GT)



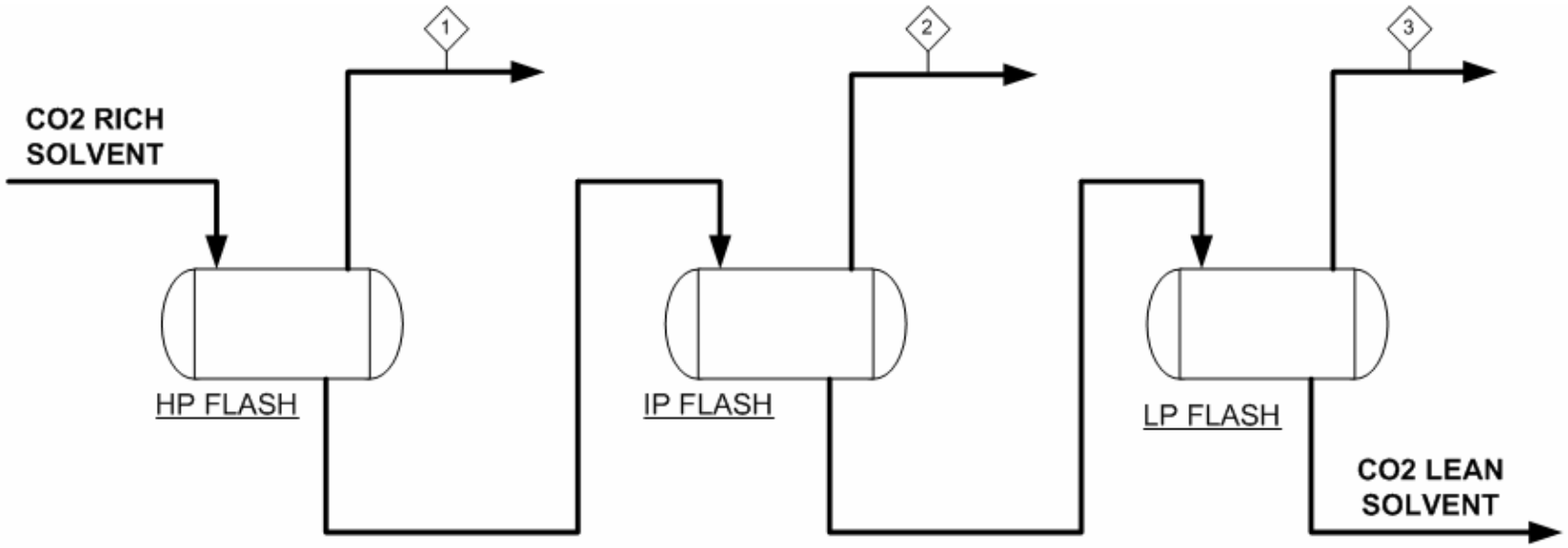
Coal Feed Rate (Moist Free Basis), MT/D	3077
Gross Power, kW	483,043
CO_2 Pressurization Power, kW	**19,368**
Balance of Plant Aux. Power, kW	80,428
Net Electric Power, kW	383,247
Overall Thermal Efficiency, % HHV	**34.94%**
Carbon Capture, %	90

CO_2 Capture – Selexol AGR



NOTES:
LPS – LP Steam
LPC – LP Condensate
MWS – Make-up Water
REFS – Refrigerant Supply
REFR – Refrigerant Return
LTGC – Low Temperature Gas Cooling

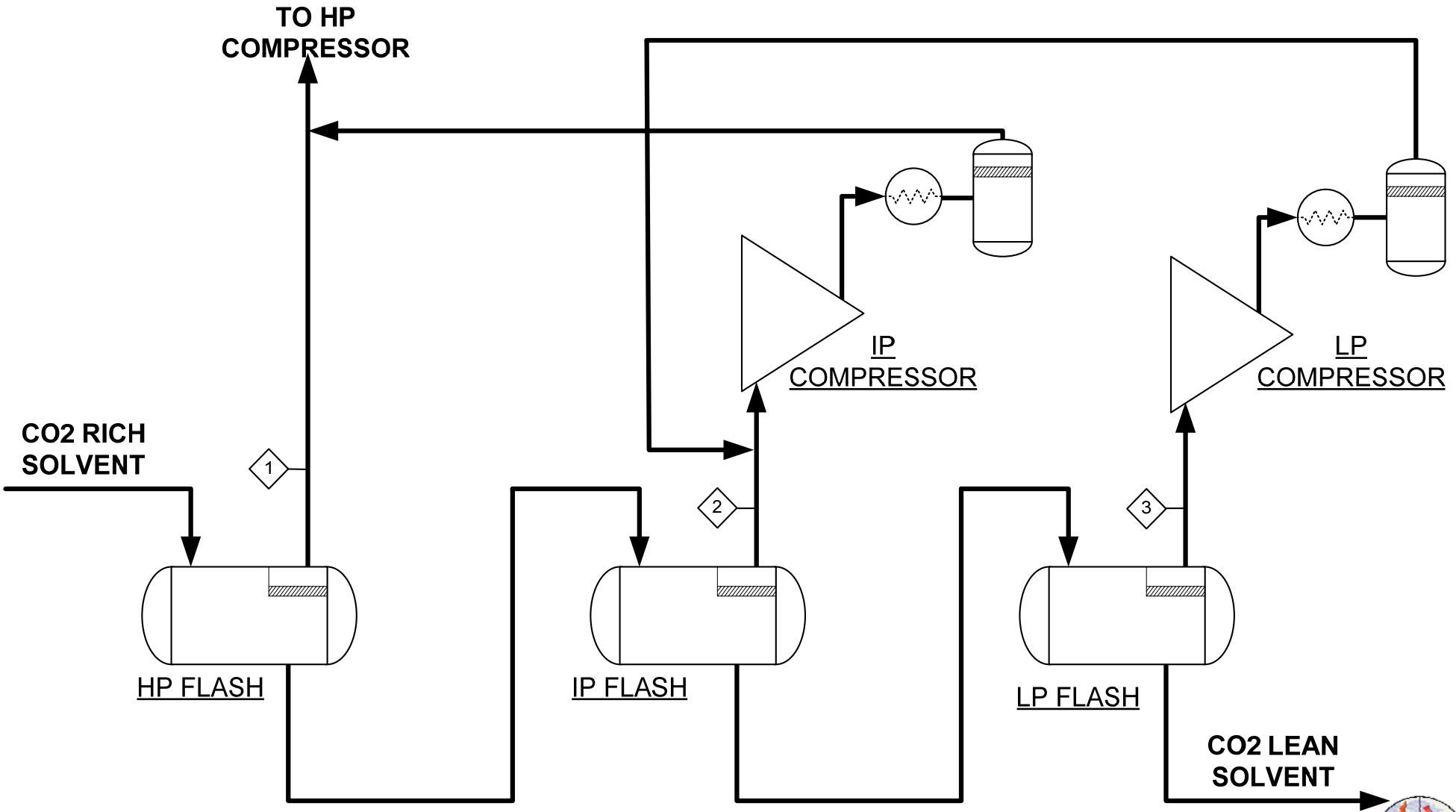
CO_2 Flashes – Selexol AGR
(383 MW IGCC)



Stream No.	1	2	3	
N2	0.02			Mole %
Ar	0.05			Mole %
H2	2.00	0.06		Mole %
CO	0.16	0.01		Mole %
CO2	97.63	99.80	99.73	Mole %
H2O	0.08	0.12	0.27	Mole %
CH4	0.06			Mole %
H2S	9.30	19.17	44.52	ppmV
COS	5.77	10.17	17.95	ppmV
kgmol/hr	3,118.51	2,797.78	1,096.65	
kg/hr	134,415.97	122,962.59	48,186.33	
Temp., C	11.73	3.59	0.08	
Press., bar	10.00	3.24	1.08	

LP & IP CO_2 Compression

Flash Pressures Chosen to have Similar Compression Pressure Ratios



LP & IP CO_2 Compressors

Net Output of IGCC = 383 MW

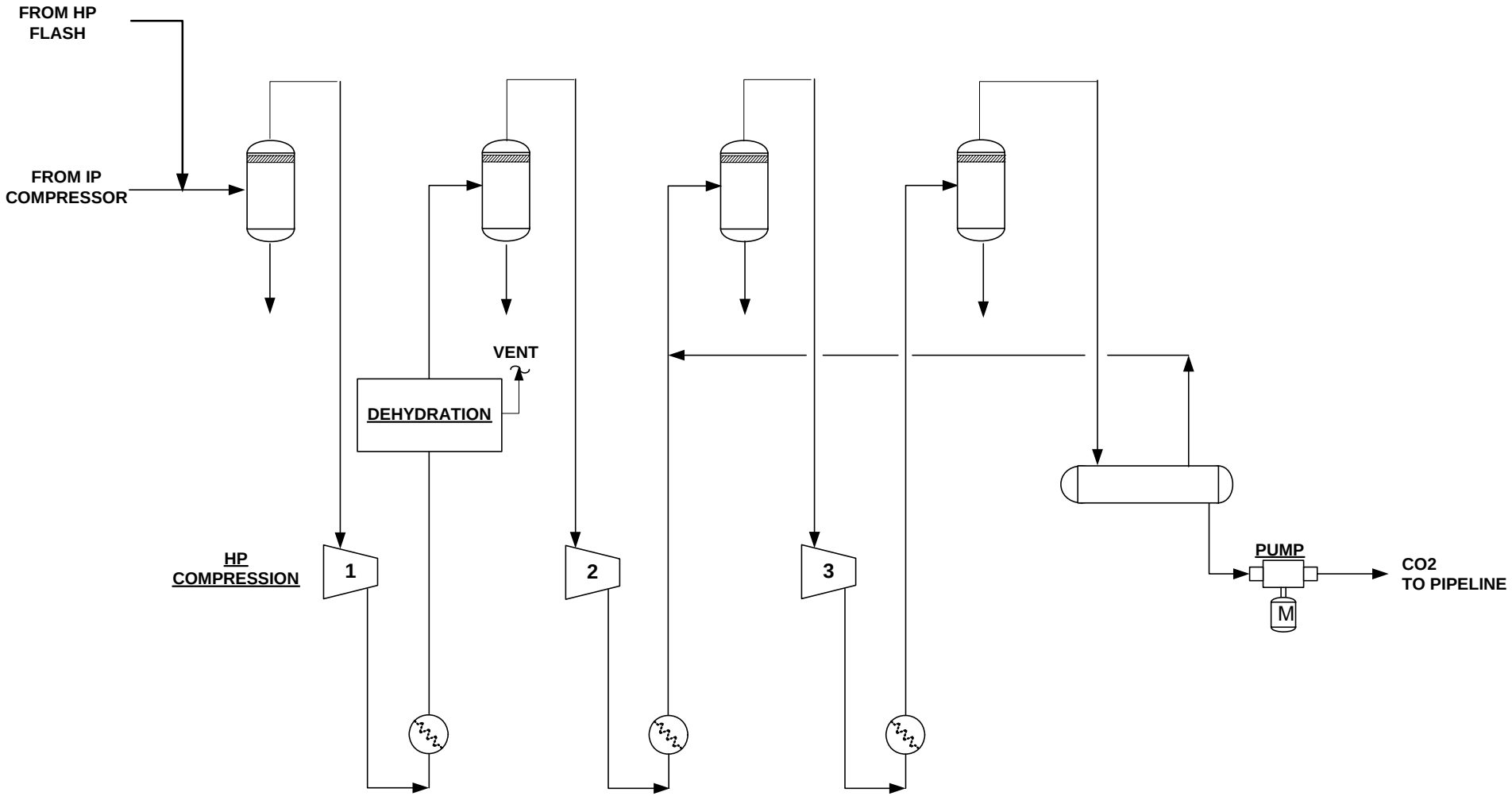
	LP Compressor	IP Compressor
Pressure Ratio	3.1	3.2
Intercoolers	None	None
Isentropic Efficiency, %	~ 83	~ 83
Discharge Temperature, °C	92	107
Adiabatic Compression Power, MW	1.2	4.3
Hypothetical Isothermal Compression Power, MW	1.0	3.7

HP Pressurization to 139 bar

Pressurization Options

- Compression Only
- Compression to Supercritical Pressure + Pumping
- Compression Options
  - Intercooled Compression
  - “Adiabatic” Compression with Recovery of Heat of Compression

Intercooled Compression + Pumping



Compression Only vs Compression + Pumping

Advantage for Compressor + Pumping Design

Net Output of IGCC = 383 MW

	Compressor Only	Compressor + Pump
Compressor Power, MW	20.9	18.2
Pump Power, MW	-	1.0
Total Power, MW	20.9	19.2

- **CO_2 Purity Sets Supercritical Pressure (82 bar)**
- **Purity an Important Issue**
- **~ 99% CO_2 Produced with Present Configuration**
- **Concerns / Issues**
  - **Reliable Thermodynamic Data to Predict Supercritical Pressure**
  - **Plant Upsets**

Intercooled vs Adiabatic Compression

Net Output of IGCC = 383 MW

	Intercooled	Adiabatic
Number of Intercoolers	2	None
Isentropic Efficiencies, %	82 - 84	90
Compressor Discharge Temp, °C	80 - 110	211
Compressor Power, MW	12.5	14.4

Increase in Compression Power for Adiabatic Option = 1.9 MW

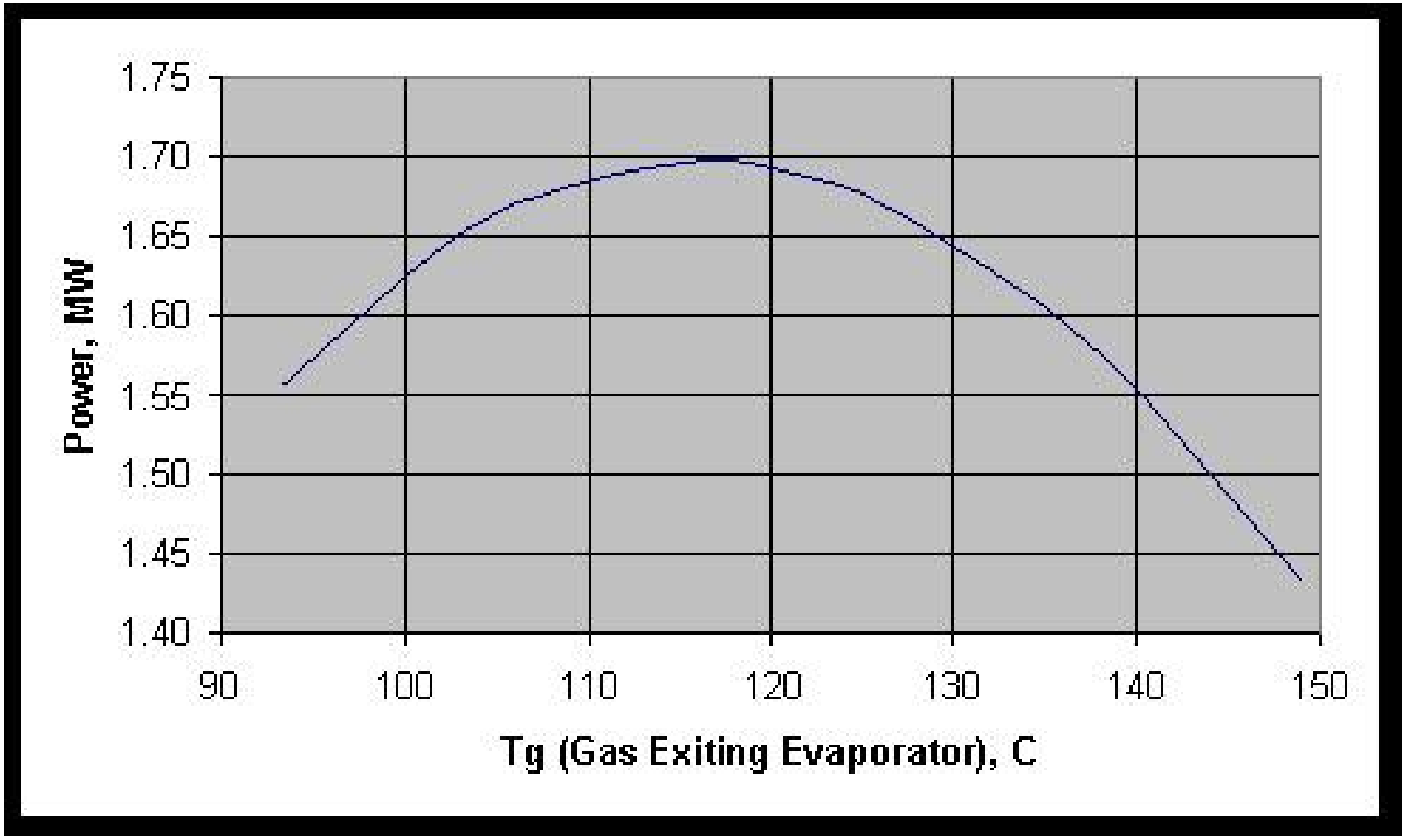
HP CO_2 Adiabatic Compressor

Options Evaluated for Utilization of Heat of Compression (Compressor Discharge Temperature = 211°C)

- LP Steam Generation
- Low Temperature Rankine Cycle
- NH_3 Absorption Refrigeration (for Selexol Solvent)
- LiBr Absorption Refrigeration (for Selexol Solvent)
- Syngas Humidification while Freeing up Heat in LTGC for MP Steam Generation
- Combination of Above Two
- Hypothetical Working Fluid with Variable Evaporation and Condensation Temperatures
  - Establish Upper Limit

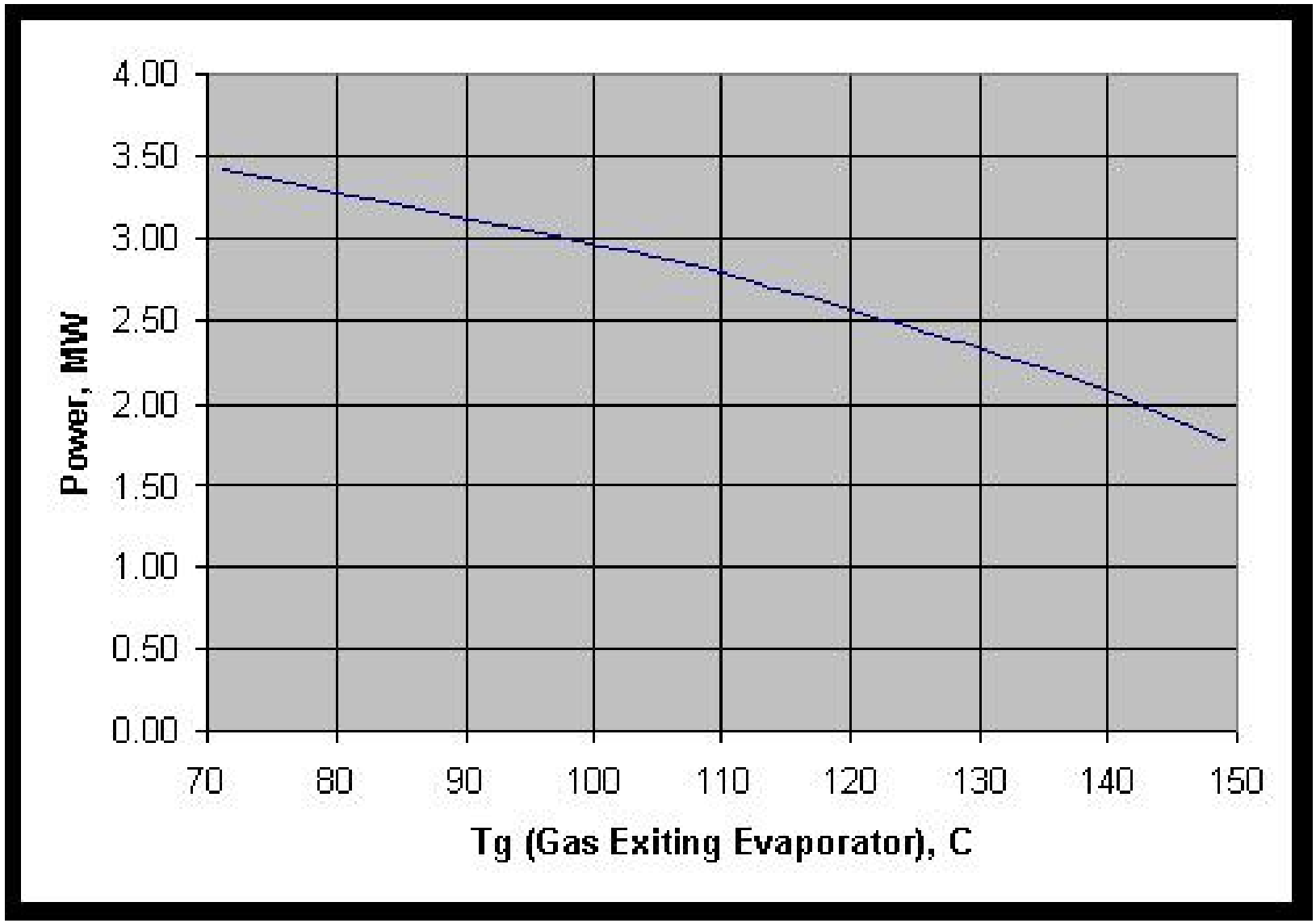
Low Temperature Rankine Cycle Power

Net Output of IGCC = 383 MW



Hypothetical Working Fluid Power – Upper Limit

Net Output of IGCC = 383 MW

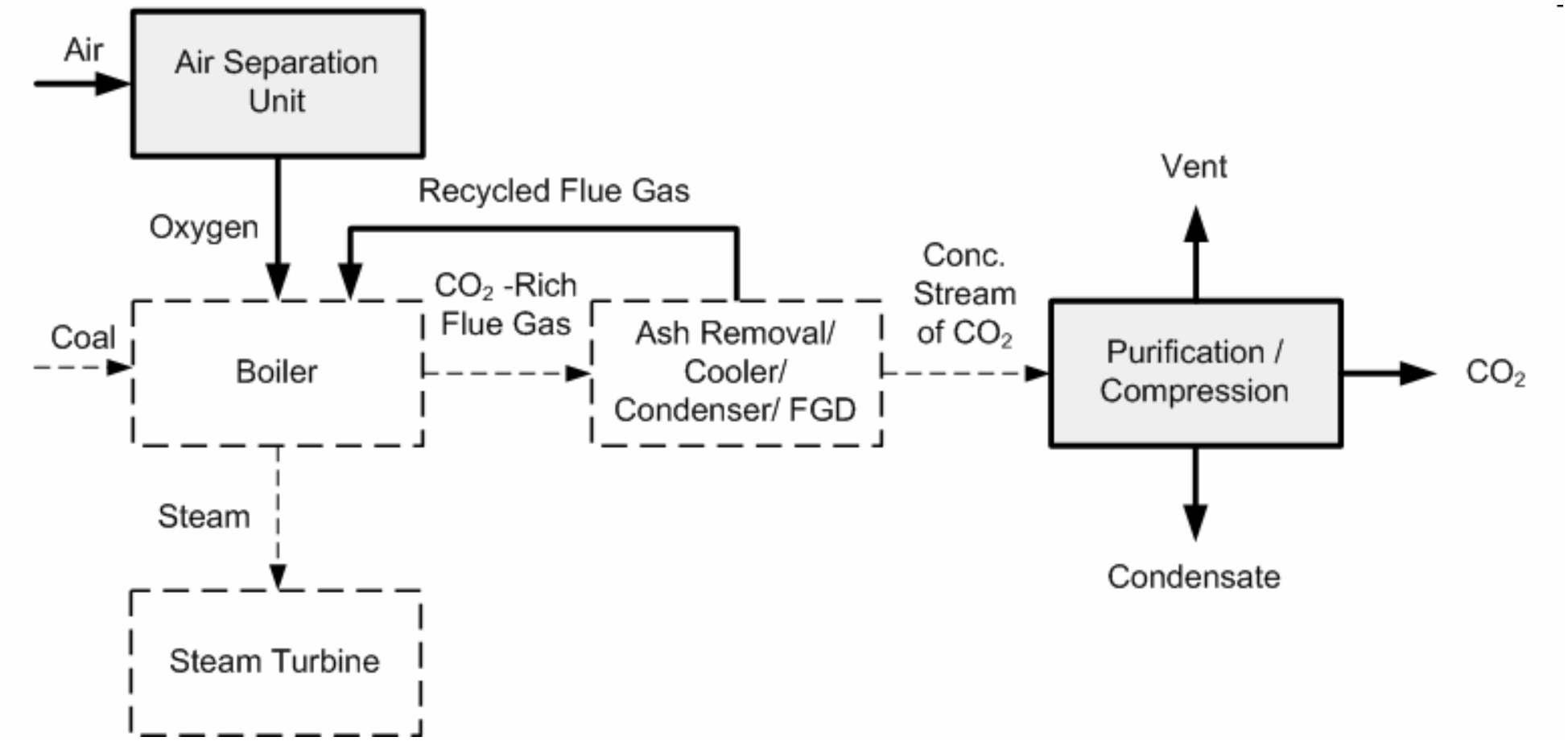


Intercooled vs. Adiabatic HP Compression

- **Among Practical Options Considered**
  - **Compressor with Intercooling Saves Power**
- **Only 0.3% Lower Net Plant Output than Adiabatic Compression + Heat Recovery with Hypothetical Working Fluid**

CO_2 Pressurization in Boiler Plants

Oxy-Fuel Combustion Retrofit Example



Pressurization of Raw CO_2

- Pressurize Boiler Exhaust from 1 bar to 31 bar Prior to Cryogenic Purification Step
- Options
  - Intercooled Compression
  - Adiabatic Compression (Reduced Number of Intercoolers)
    - Heat of Compression for BFW Preheat
    - Reduce Steam Extraction
- Adiabatic Compression
  - Potential for Efficiency Advantage
  - Reduction in Irreversibility associated with Cooling of Superheated Extraction Steam to Sat Temp

Summary

Choice of CO_2 Pressurization Option Specific to Type of Plant

- Depends on
  - Need for Low Temperature Heat
  - CO_2 Purity Requirements
- IGCC Applications
  - Plenty of Low Temperature Heat Available
  - Choice: Intercooled Compression
  - For High Purity (~99%) CO_2, Compression to Supercritical Pressure followed by Pumping
- Boiler Plant Applications
  - Shortage of Low Temperature Heat
  - Possible Choice: Adiabatic Compression with Recovery of Heat of Compression for BFW Preheat