Predicted Performance of NCCC Pilot Plant using Piperazine with Advanced Flash Stripping

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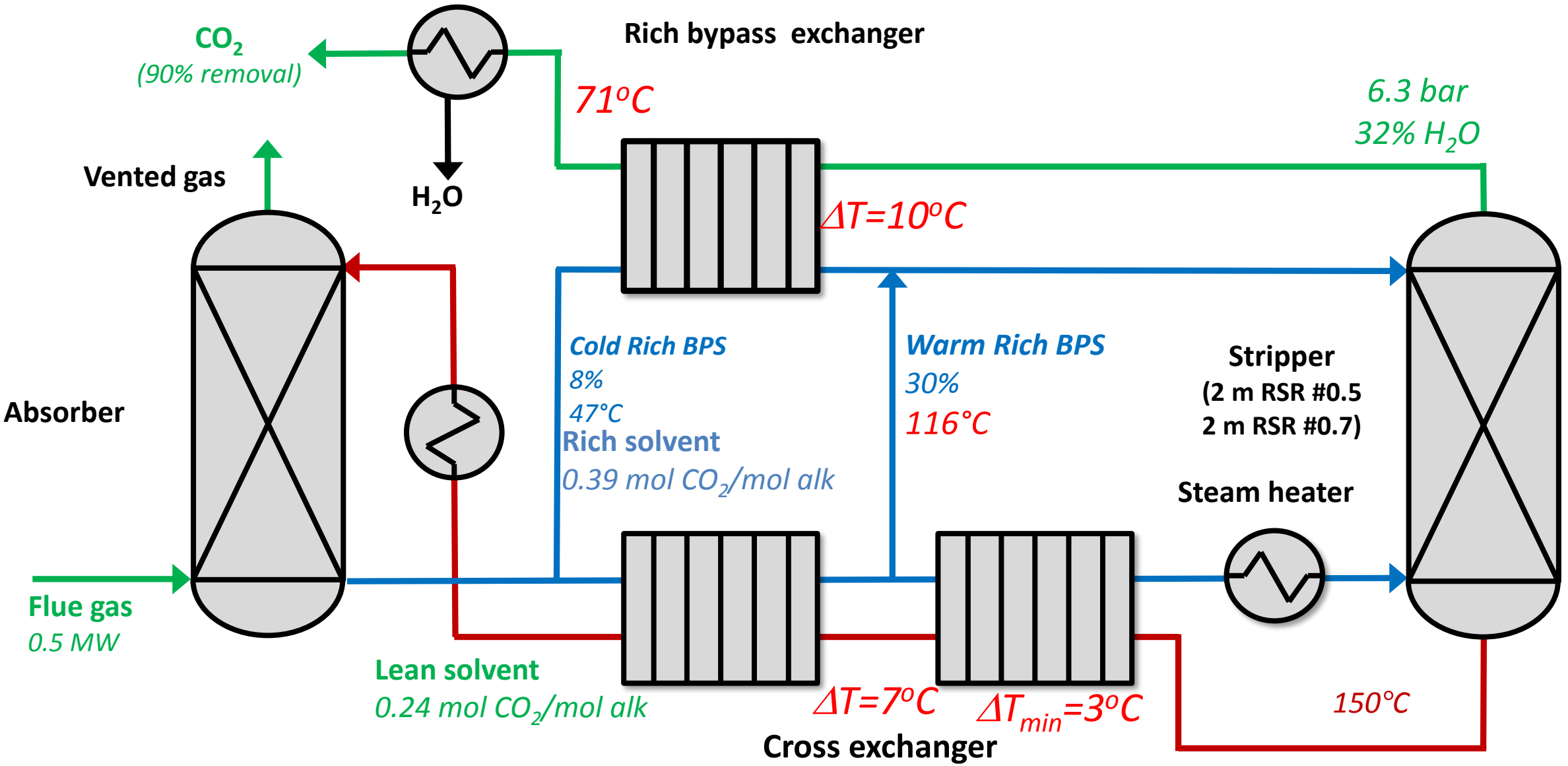
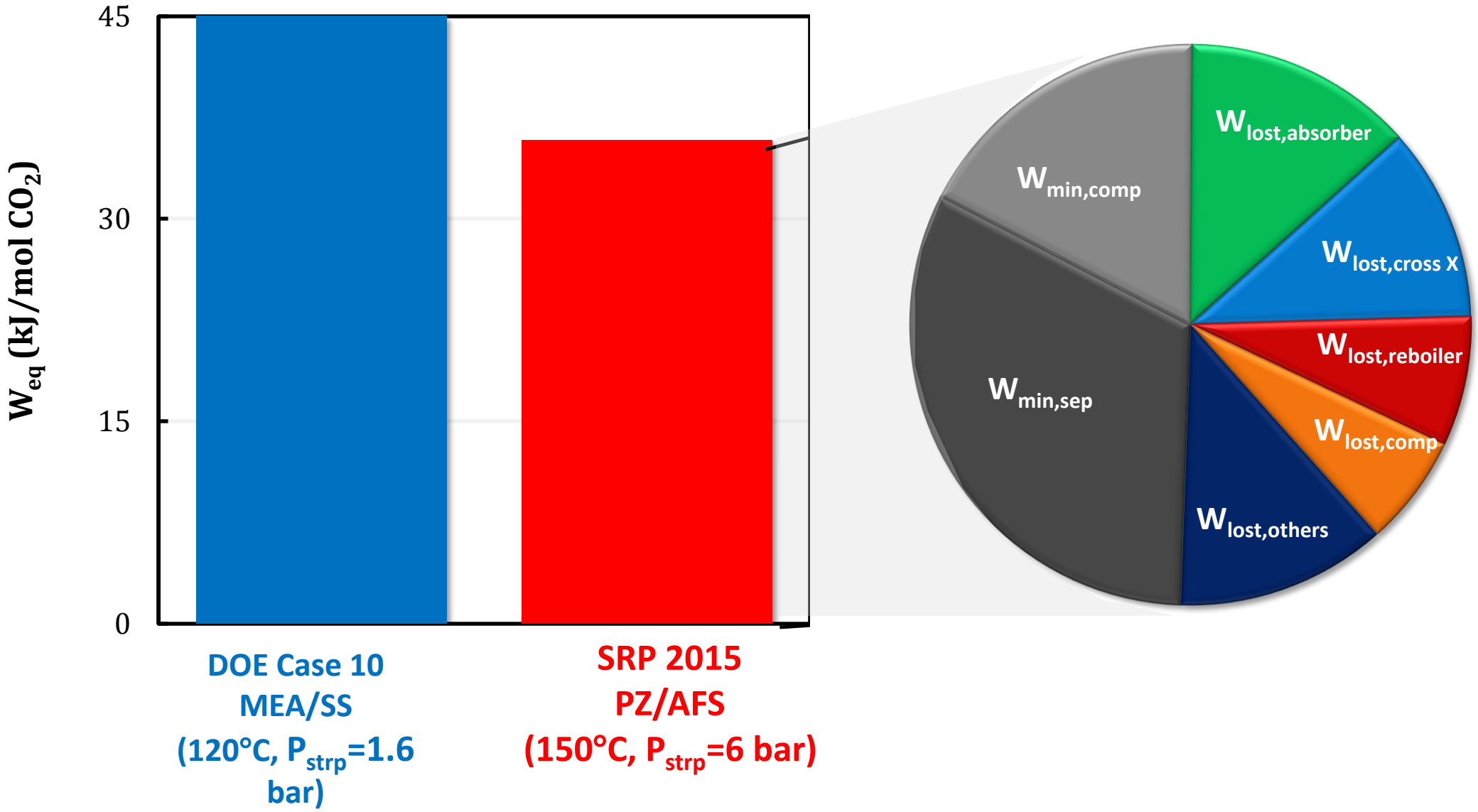
Advanced Flash Stripper (AFS)



Advanced amine scrubbing gives 50% efficiency Limited by capital-energy tradeoff



AFS also works with other solvents

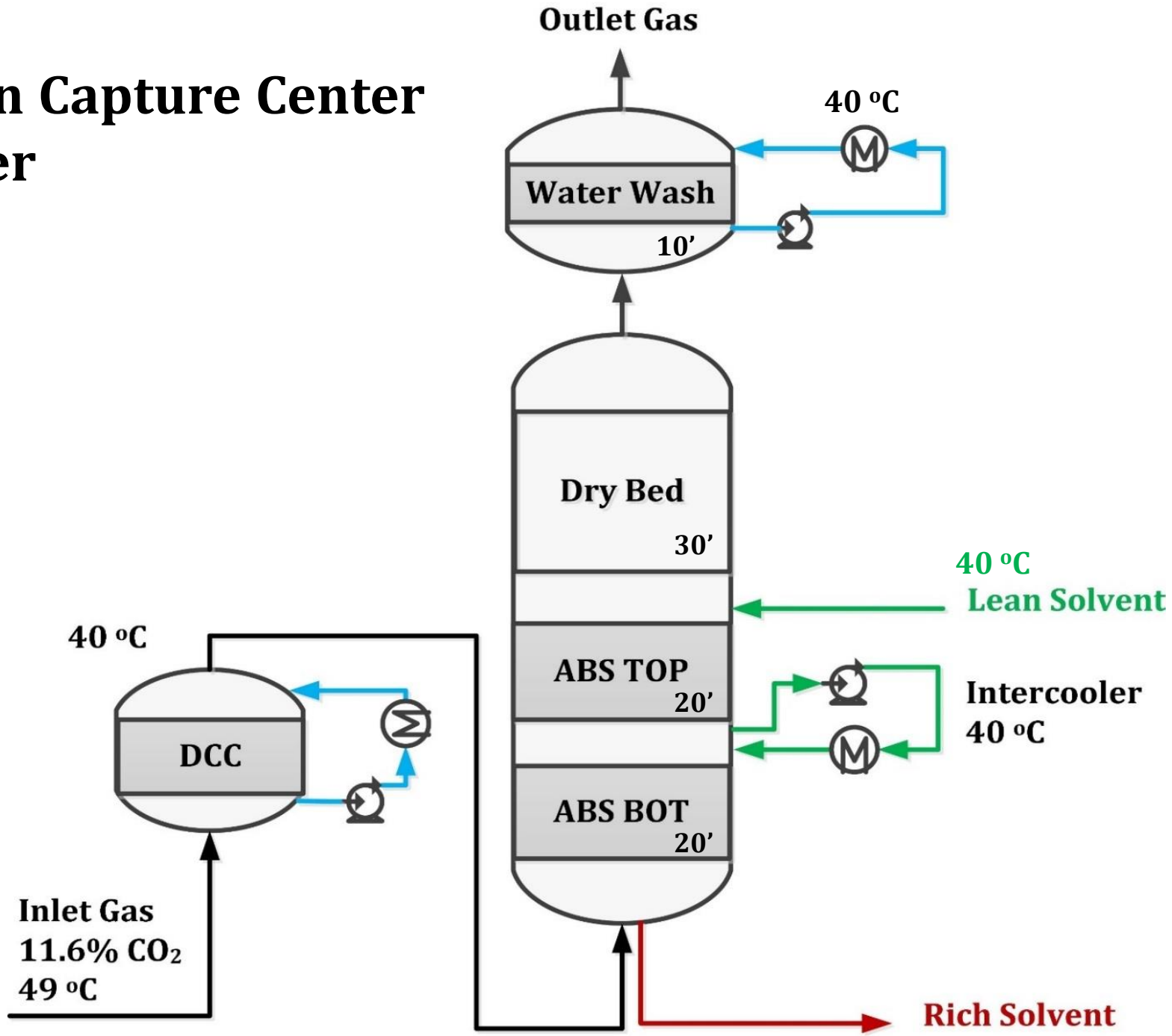
Solvent	kg' (10^{-7}mol/Pa-s-m^2)	W_{eq}(kJ/mol CO_2)	
		Simple stripper	AFS
7m MEA	4.3	36.3	32.7
10m DGA	3.6	37.0	34.2
8m PZ	8.5	34.9	31.4
5m PZ	11.3	36.5	32.3
2m PZ /3m HMPD	10.1	34.9	**31.0**

- $Rich\ P^*_{CO_2} = 5\ kPa, Lean\ P^*_{CO_2} = 0.2\ kPa$
- Optimum cross exchanger $\Delta T_{LM} = 5K\left(\frac{\mu}{\mu_{MEA}}\right)^{0.175}$

Outline

- Absorber performance
- Advanced flash stripper performance
- Performance with maximum cooling

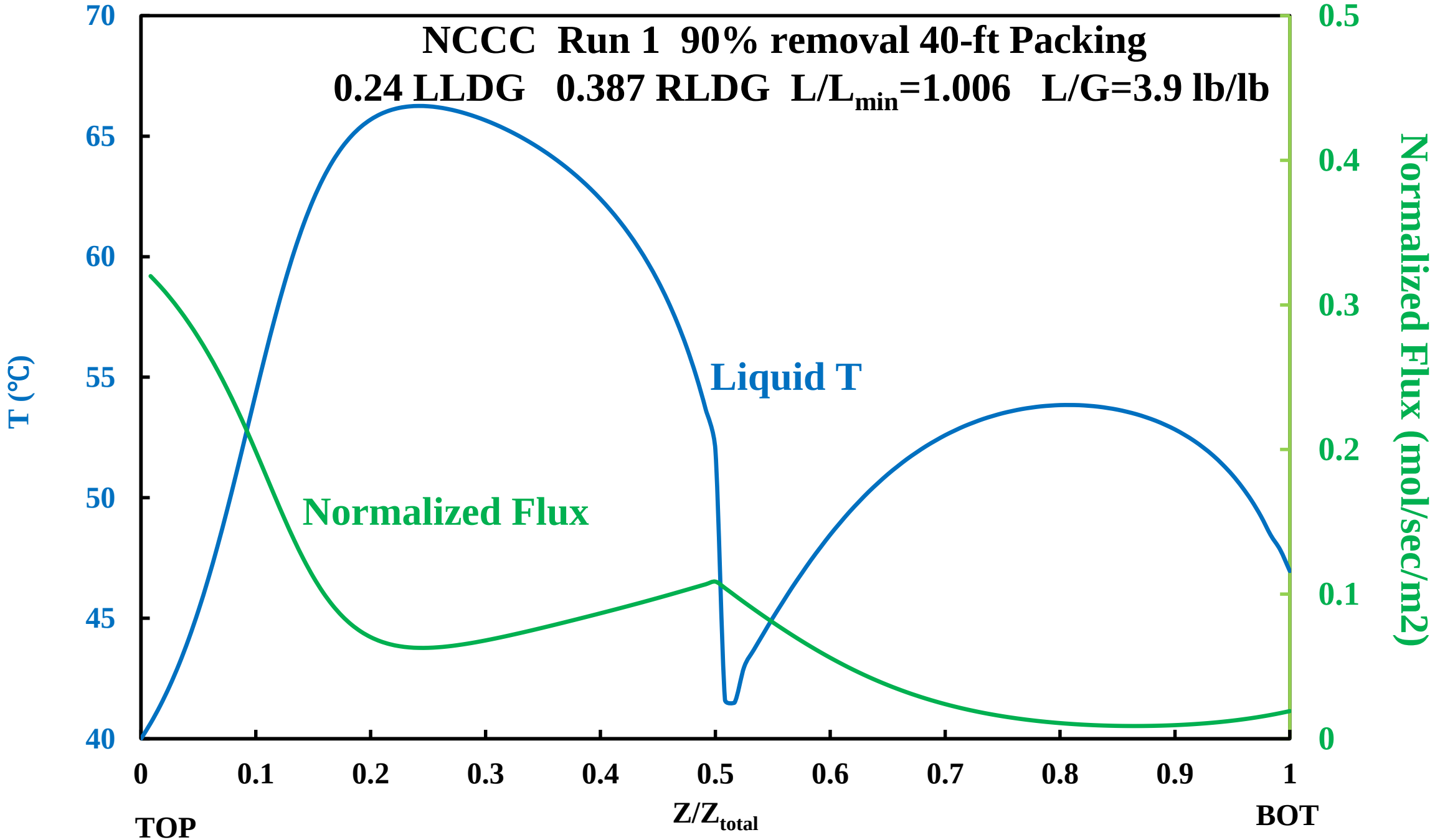
National Carbon Capture Center (NCCC) Absorber

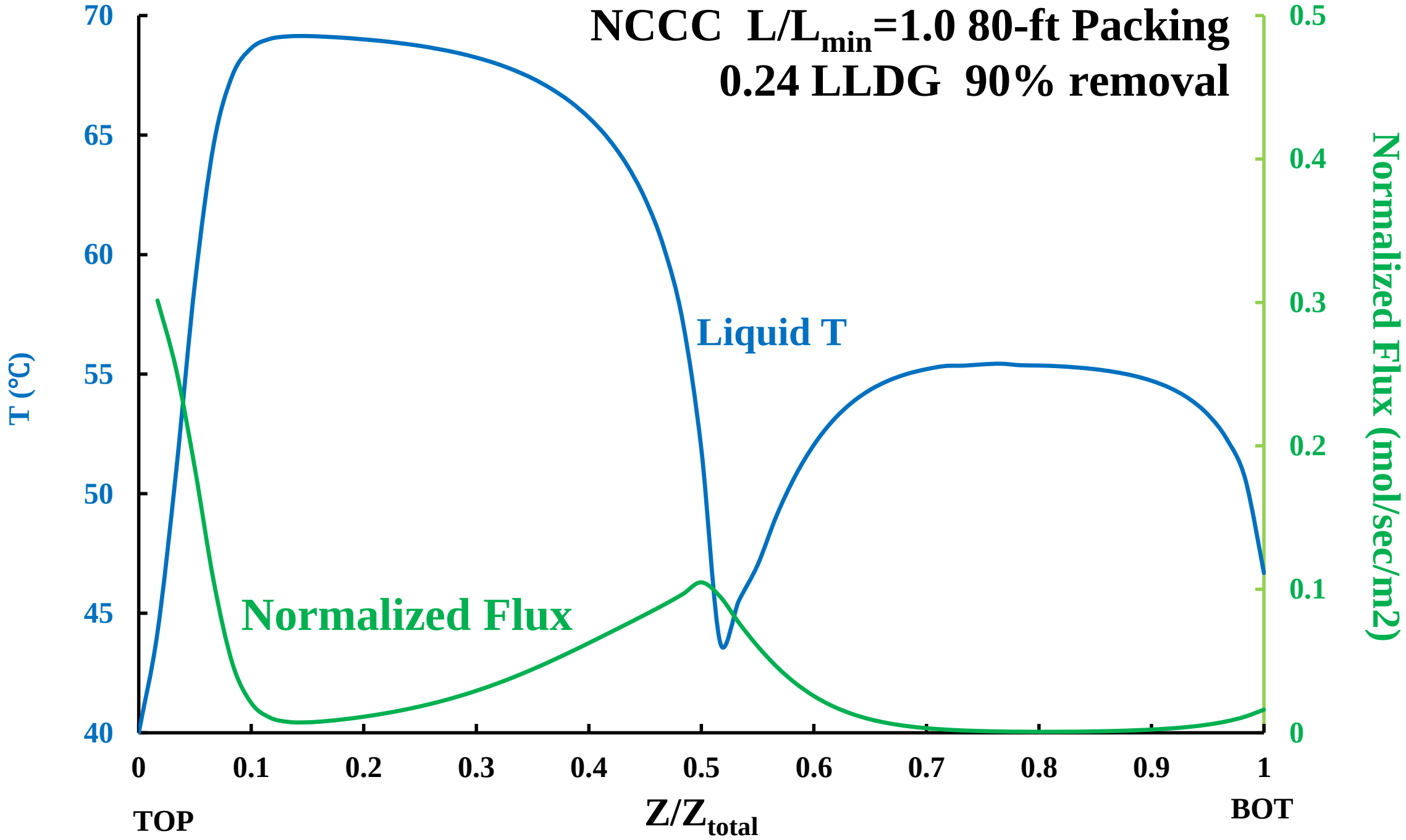


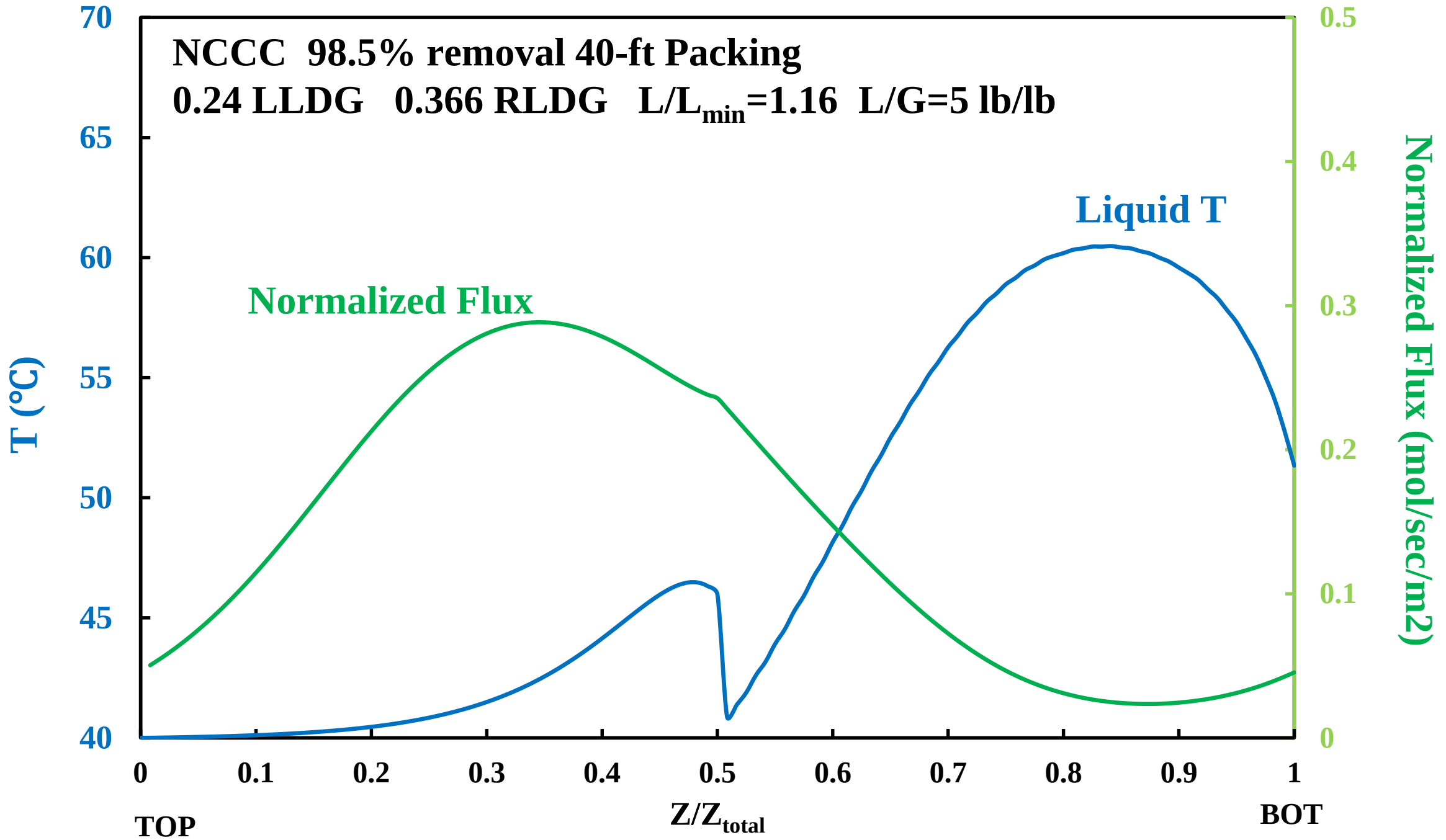
Possible long term conditions at NCCC

0.24 lean ldg, 150°C/82 psia stripper, 2x20 ft absorber packing

CO_2 removal (%)	Gas Rate (MW)	Rich Ldg (mol CO2/eq PZ)	L/L_{min}	W_{eq} (kwh/tonne)	Q (GJ/tonne)
90	0.5	0.387	1.006	256	2.56
98.5	0.5	0.366	1.16	260	2.61
95.4	0.8	0.380	1.10	274	2.77


NCCC Run 1 90% removal 40-ft Packing
0.24 LLDG 0.387 RLDG L/L$_{min}$=1.006 L/G=3.9 lb/lb
Liquid T
Normalized Flux
T (°C)
Normalized Flux (mol/sec/m2)
70
65
60
55
50
45
40
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
TOP
Z/Z$_{total}$
BOT

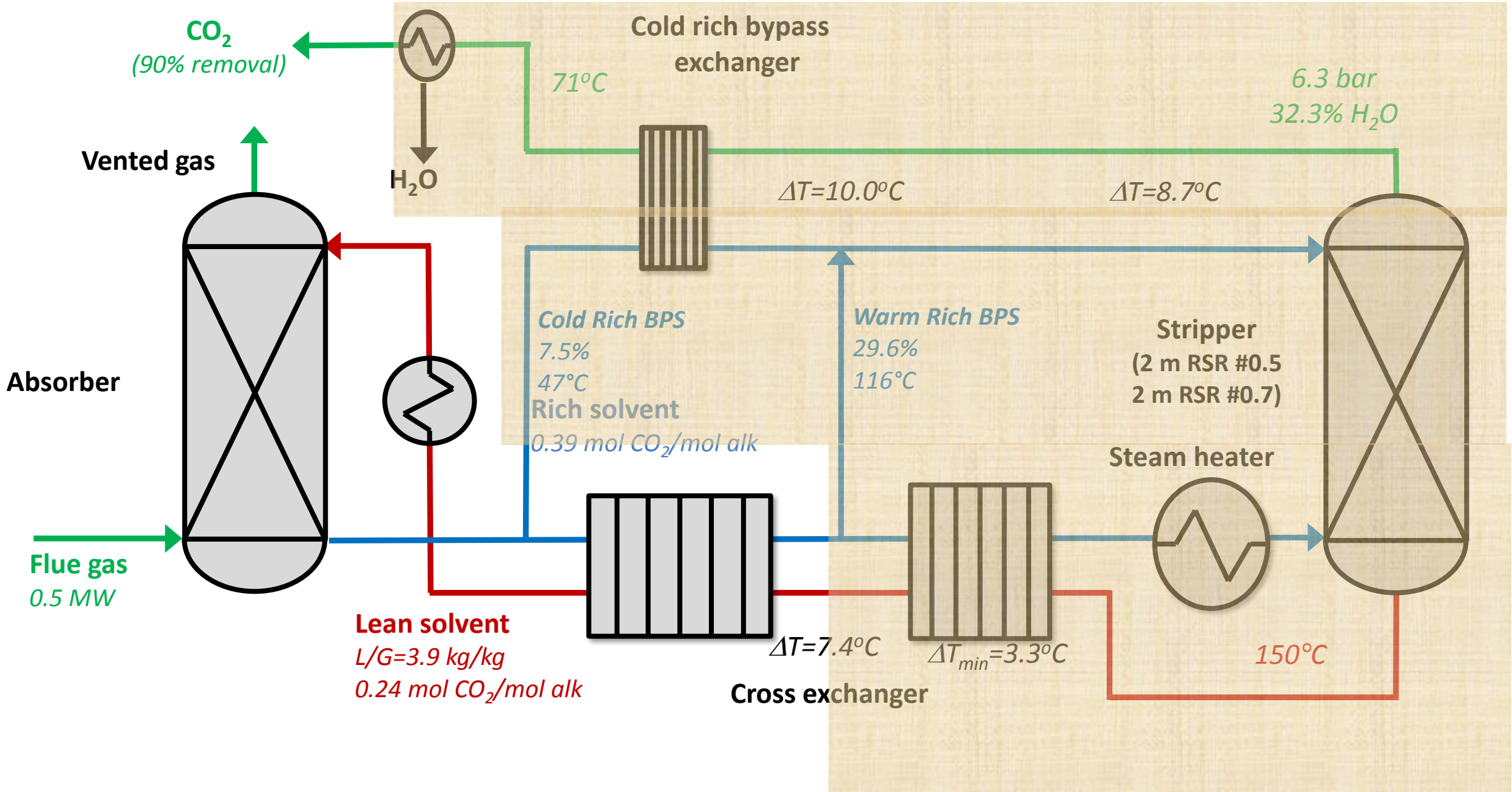

NCCC L/Lmin=1.0 80-ft Packing
0.24 LLDG 90% removal
Liquid T
Normalized Flux
T (°C)
Normalized Flux (mol/sec/m2)
70
65
60
55
50
45
40
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
TOP
Z/Ztotal
BOT


NCCC 98.5% removal 40-ft Packing
0.24 LLDG 0.366 RLDG L/L$_{min}$=1.16 L/G=5 lb/lb
Liquid T
Normalized Flux
T (°C)
Normalized Flux (mol/sec/m2)
70
65
60
55
50
45
40
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
TOP
Z/Z$_{total}$
BOT

Outline

- Absorber performance
- Advanced flash stripper Optimization
- Performance with maximum cooling

AFS Heat Exchangers

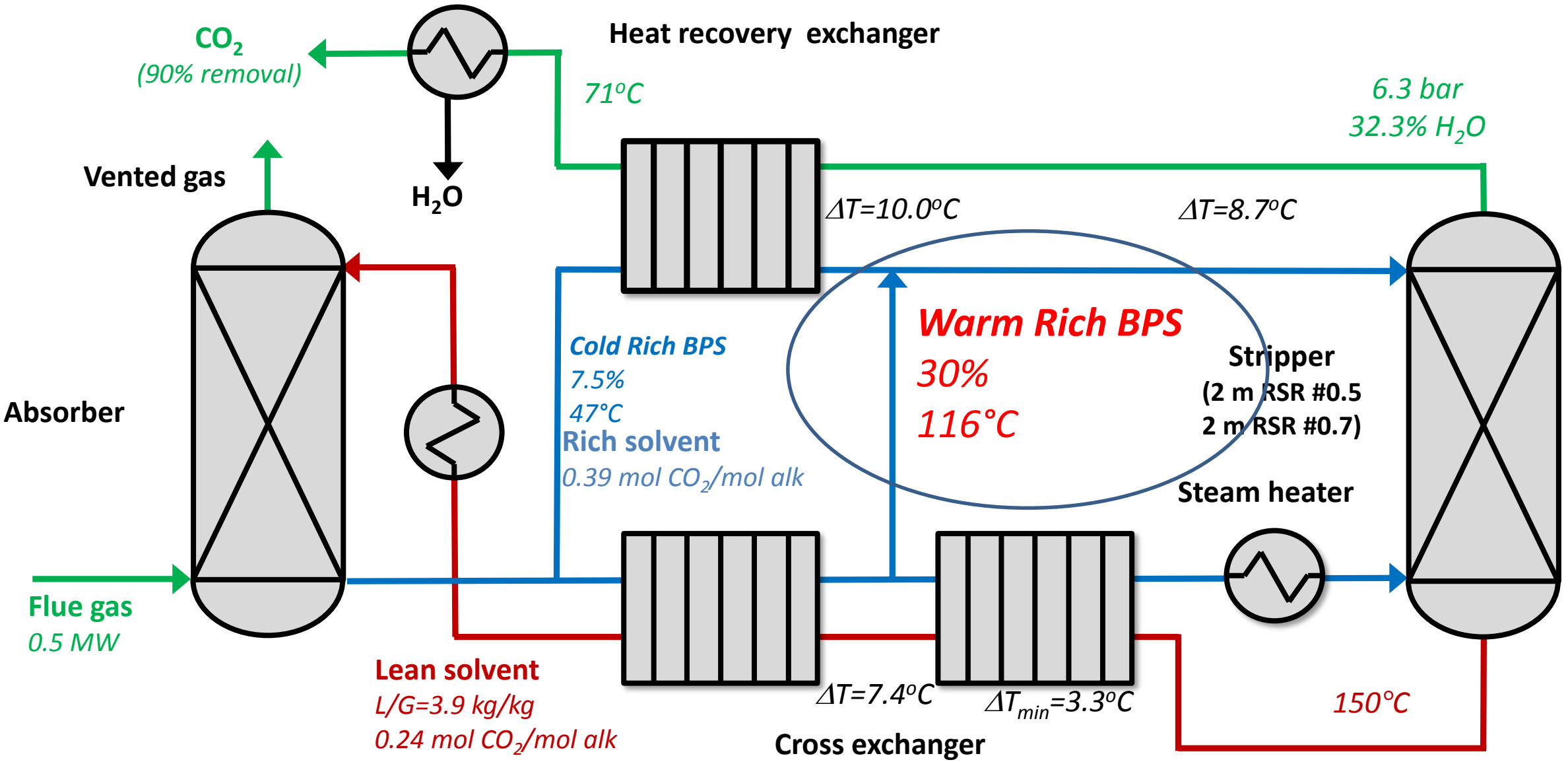


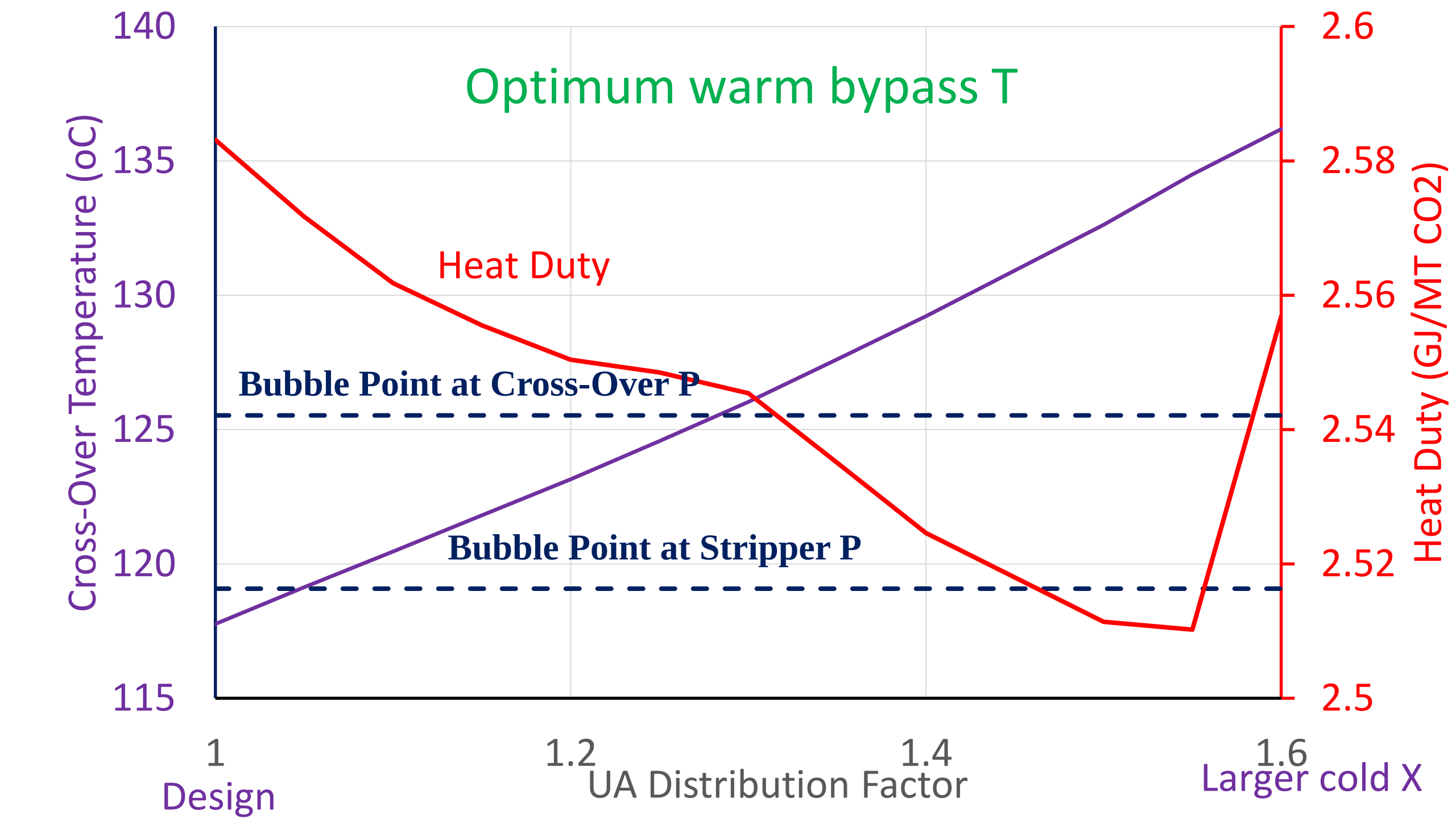
Exchangers at UT-SRP and NCCC

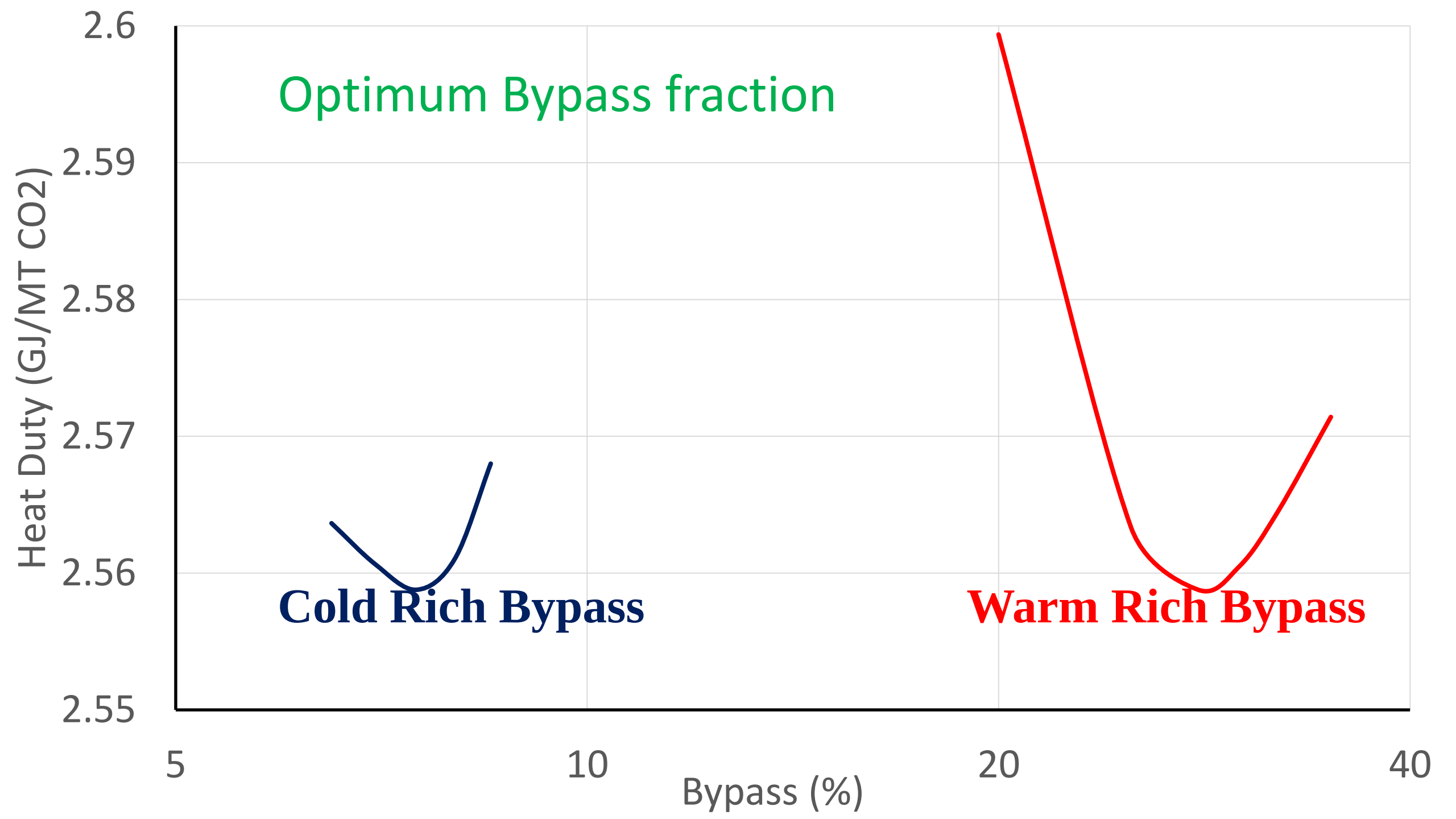
Lean ldg = 0.24, rich ldg = 0.38, $Q = UA\Delta T$

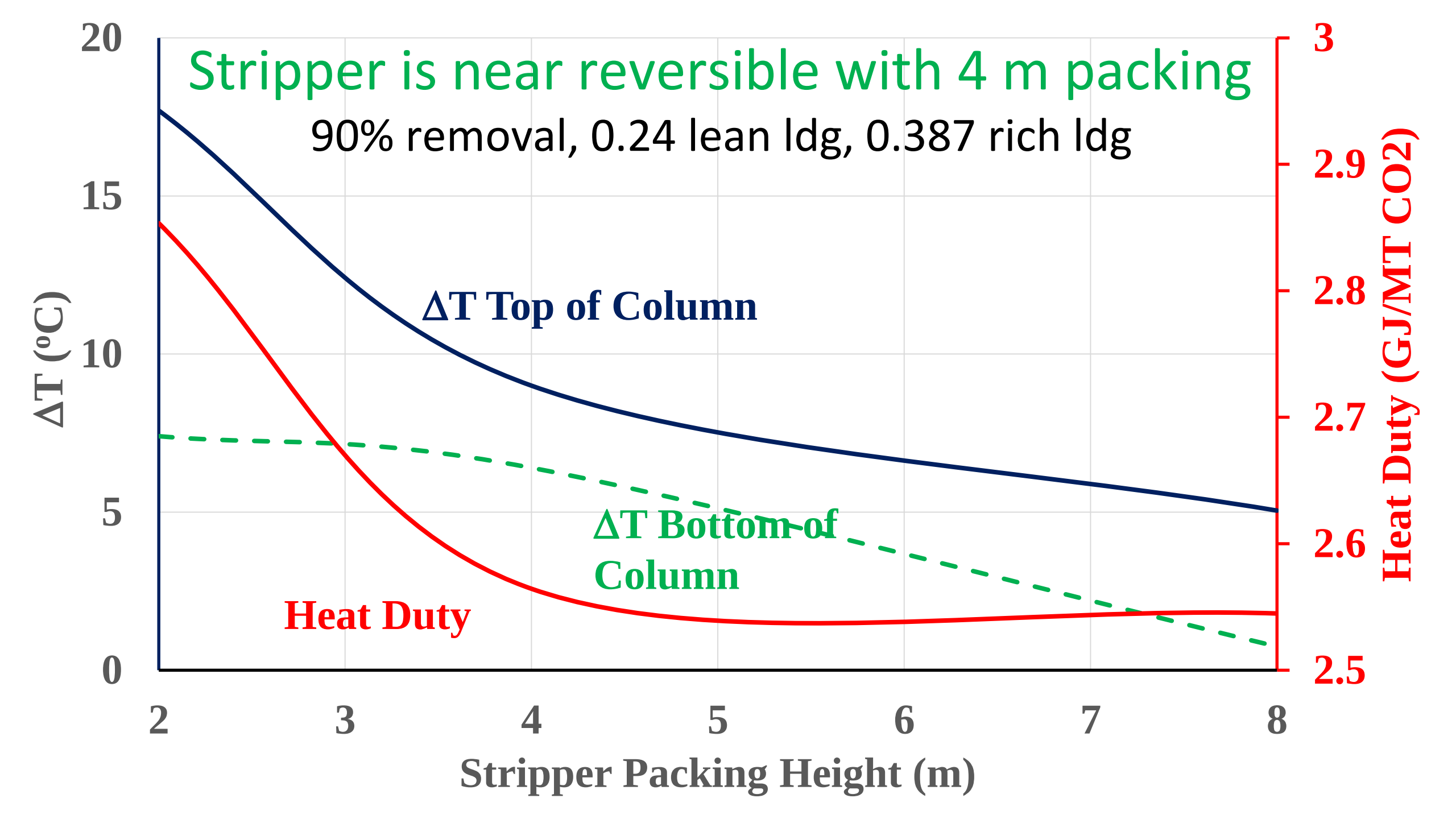
	Area (m^2)	Δp_{avg} (psi)	UA (kW/K)	Heat duty (MJ/t CO_2)
Cold Cross	40 114	12 1.8	108 55	
Steam	2.3 4.1	14 10	16 16	2.3 2.6
Hot Cross	20.4 32	5.5 15	28 31	
Cold Rich Bypass	3.2 8.5	5.7 8	0.46 2.3	

Warm Rich T optimization

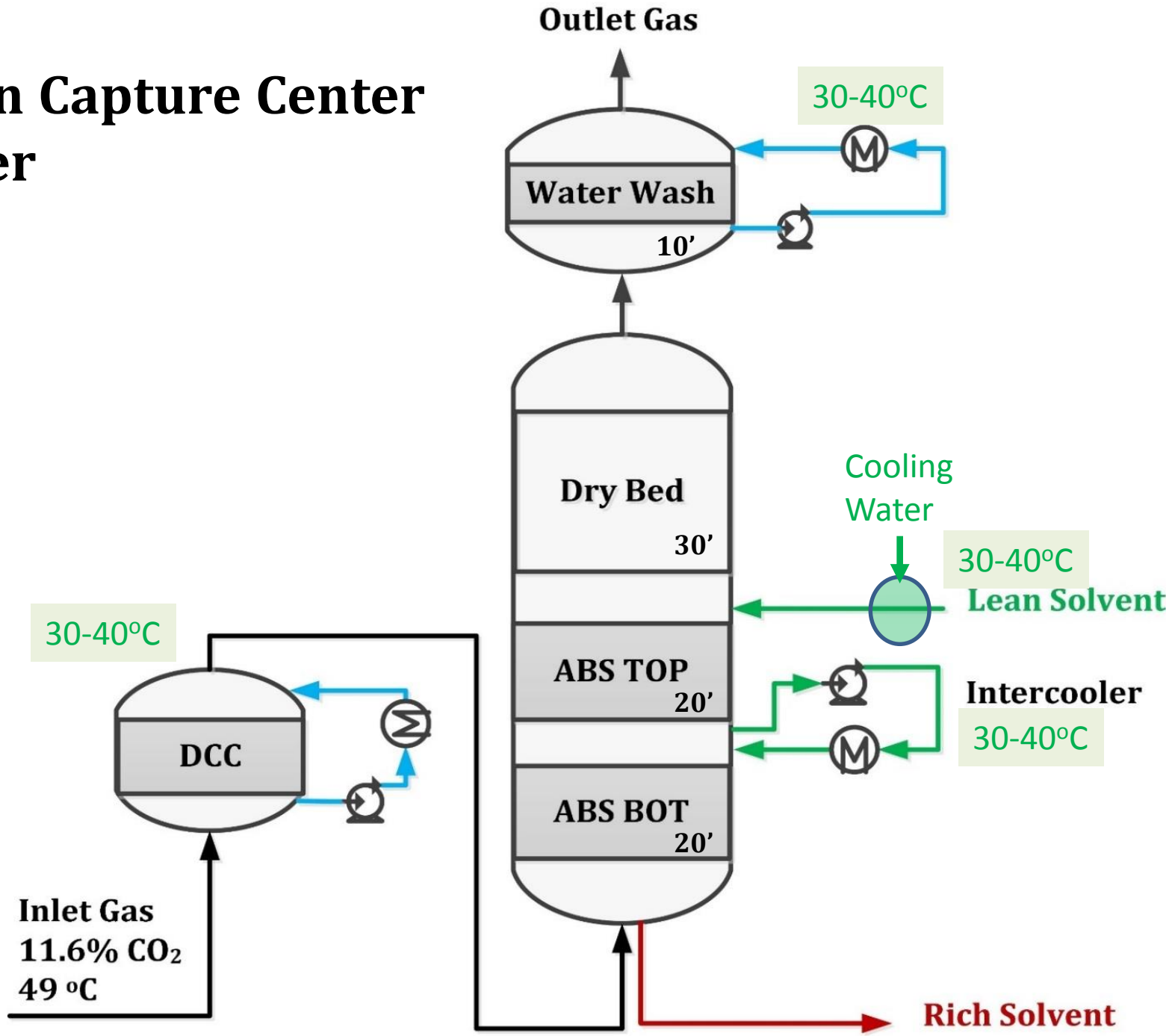



Optimum warm bypass T
Heat Duty
Bubble Point at Cross-Over P
Bubble Point at Stripper P
Cross-Over Temperature (oC)
Heat Duty (GJ/MT CO2)
140
135
130
125
120
115
2.6
2.58
2.56
2.54
2.52
2.5
1
1.2
1.4
1.6
Design
UA Distribution Factor
Larger cold X


Optimum Bypass fraction
Cold Rich Bypass
Warm Rich Bypass
Heat Duty (GJ/MT CO2)
2.6
2.59
2.58
2.57
2.56
2.55
5
10
20
40
Bypass (%)


Stripper is near reversible with 4 m packing
90% removal, 0.24 lean ldg, 0.387 rich ldg
ΔT Top of Column
ΔT Bottom of Column
Heat Duty
ΔT (°C)
Heat Duty (GJ/MT CO2)
Stripper Packing Height (m)
20
15
10
5
0
3
2.9
2.8
2.7
2.6
2.5
2
3
4
5
6
7
8

National Carbon Capture Center (NCCC) Absorber



Full use of cooling enhances energy performance, 90% removal, 150°C Stripper

Lean Loading (mol CO_2/mol alk)	0.24	0.24	0.27
Cooling T (°C)	40	30	30
Rich Loading (mol CO_2/mol alk)	0.387	0.408	0.410
Stripper P (bar)	6.37	6.34	7.34
Heat Duty (GJ/MT CO_2)	2.56	2.44	2.40
W_{EQ} (kJ/mol CO_2)	40.6	39.1	38.8

Conclusions

- The Advanced Flash stripper will reduce W_{eq} by 10-20% for PZ and other solvents
- With the equipment at NCCC, 5 m PZ should provide
  - 90-99% CO_2 removal
  - with 0.5 -0.8 MW gas
  - at 2.5-2.6 MJ/tonne CO_2
- The energy requirement can be reduced with greater exchanger cost and lower cooling T

- **Acknowledgement:** “This material is based on work supported in part by the Department of Energy under Award Number DE-FE0005654.”