FLUOR®

OPTIMIZATION OF COOLING FOR POST-COMBUSTION CARBON CAPTURE

JON ISLEY, EXECUTIVE TECHNICAL DIRECTOR (PRESENTER),
BENJAMIN HENEZI, PROCESS ENGINEER (CO-AUTHOR),
MATTHEW GUTSCHER, PROCESS ENGINEER (CO-AUTHOR)
FLUOR CANADA LTD.

PCCC-8

INTRODUCTION

Presentation is based on Fluor's Econamine FG Plus℠ (EFG+) technology

- EFG+ is Fluor's commercially proven, proprietary post-combustion capture technology
- 30 plants built (to date)
- Designed for capturing CO_2 from low-pressure gas streams containing oxygen
- Experience with a wide range of flue gases
- Compilation of five pre-FEED studies on cooling optimization in 2024 to 2025

EFG+ application flue gas characteristics

3%	CO_2 range	20%
1%	O_2 range	15%

Gas Turbine and Engine	Coal-Fired Boilers	Oil-fired Boilers
SMR in H_2, NH_3, and MeOH Plants	Tail Gas Units in Sulphur Plants	Catalytic Crackers

PCCC-8

THE LOW-GRADE HEAT EXCHANGE PROBLEM

FLUOR®

1) Temperatures for carbon capture technology deployment

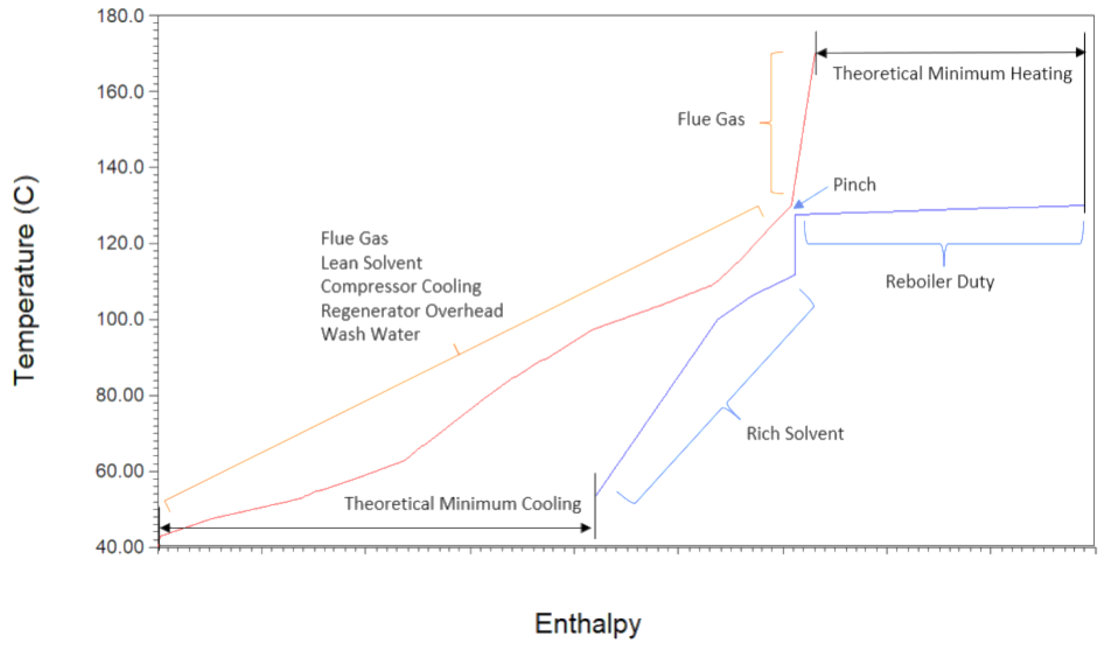
- Flue gas source is hot
  - Typically 160 to 180°C downstream of economizer
  - Further cooling challenged by available heat sinks and condensation
- Majority of capture technologies require modest temperatures
  - Typically 40 to 60°C
  - Aqueous solvents (traditional amines)
  - Solid adsorbents
  - Membranes
  - Cryogenics (even lower)
- Cooling gap of 100 to 140°C

PCCC-8

THE LOW-GRADE HEAT EXCHANGE PROBLEM

2) Thermodynamics of post-combustion carbon capture process

- Carbon capture itself requires energy
  - Energy from reduction in entropy
  - Heat of absorption/solution
  - Heat from compression
- Process temperature cycles between
  - Absorption (40 to 60°C)
  - Desorption (120 to 150°C)
- Heat integration
  - Exhaust economic heat integration options first
  - Net losses through low-grade heat exchange to environment (air and/or water)



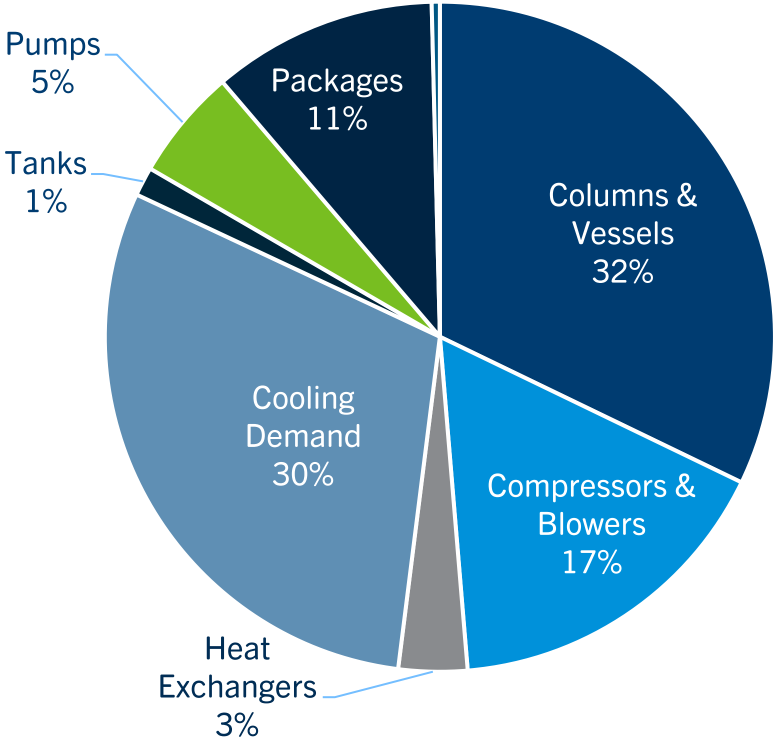
Sample Pinch Analysis Curve

PCCC-8

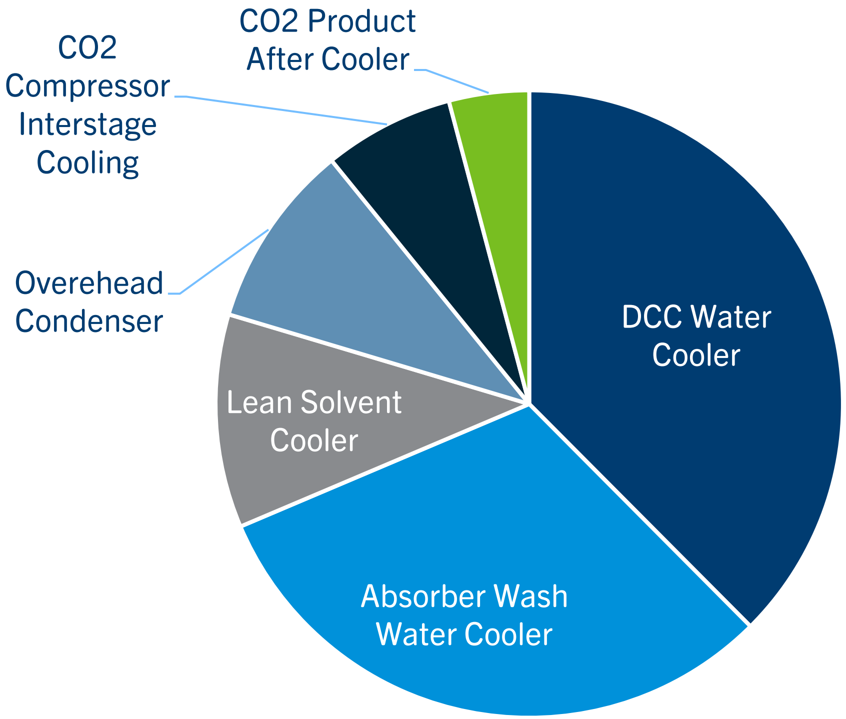
KEY ISSUE

Capital Cost of Carbon Capture*

Plant Equipment Cost



Cooling Duty Breakdown (out of 30%)

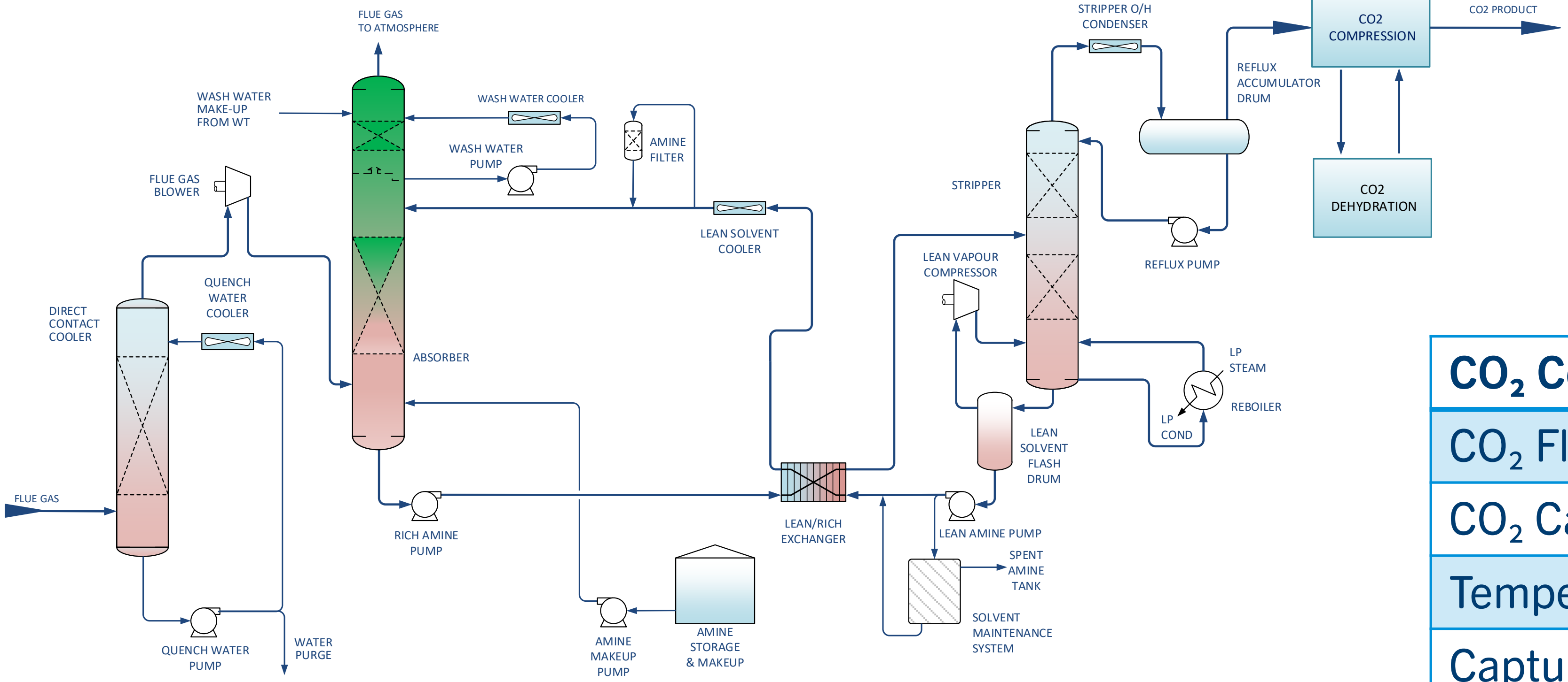


Sample FEED project, optimized with a hybrid air and cooling water design

PCCC-8

CASE STUDY

Gas Turbine Exhaust



CO_2 Concentration	4.5 wet vol%
CO_2 Flow Rate	4,631 MTPD
CO_2 Capture	4,400 MTPD
Temperature	200°C
Capture Efficiency	95%
Cooling Demand	6 GJ/tonne CO_2

PCCC-8

FLUOR®

STUDY METHODOLOGY

- Equipment cost and total installed cost (TIC) from recent Fluor CCS projects *(United States Dollar [USD] basis)*
- Wood-Mackenzie Method[1] utilized for levelized cost of carbon capture, 10 percent discount rate, 25-year project life
- Reference HMB is held constant for the study
- Three process cooling methods considered *(on the following slide)*
- Two project locations considered:
  - Southern California, United States
  - Alberta, Canada
- CCS is self supporting – i.e., no base plant utility availability for cooling

[1] P. Findlay and J. Mageau, "Towards a standard definition of levelised CCUS costs and revenues," in 17th International Conference on Greenhouse Gas Control Technologies, GHGT-17, Calgary, Canada, 2024.

PCCC-8

COOLING METHODS

Cooling Water

- Cooling tower + P&F exchangers
- High efficiency
- Cooling water utility block dedicated plot space
- Make-up water required
- Higher water disposal rates

Air Cooling

- Air-cooled heat exchangers
- Large ISBL plot space requirement
- Low operating costs
- No water requirements
- No fluid disposal

Secondary Medium

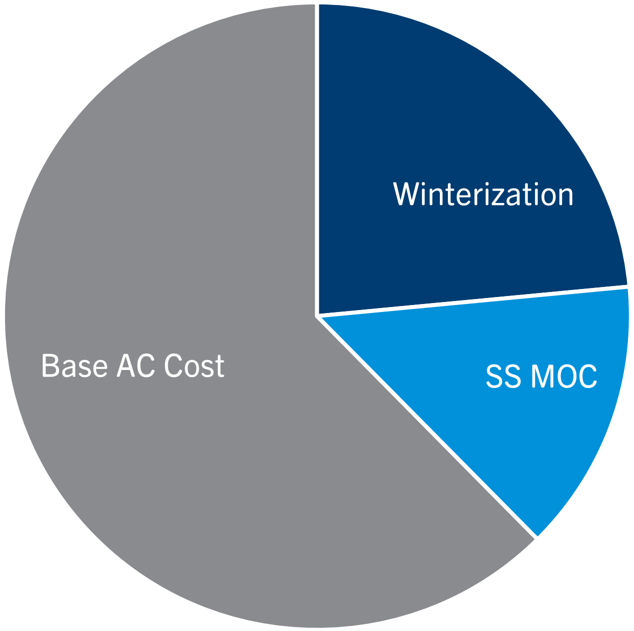
- Glycol or other non-freezing medium
- P&F exchangers + air coolers
- Initial chemical fill required
- Metallurgy and winterization advantages

PCCC-8

AIR COOLING COST DRIVERS

Alberta, Canada Example

Air Cooler Cost Breakdown



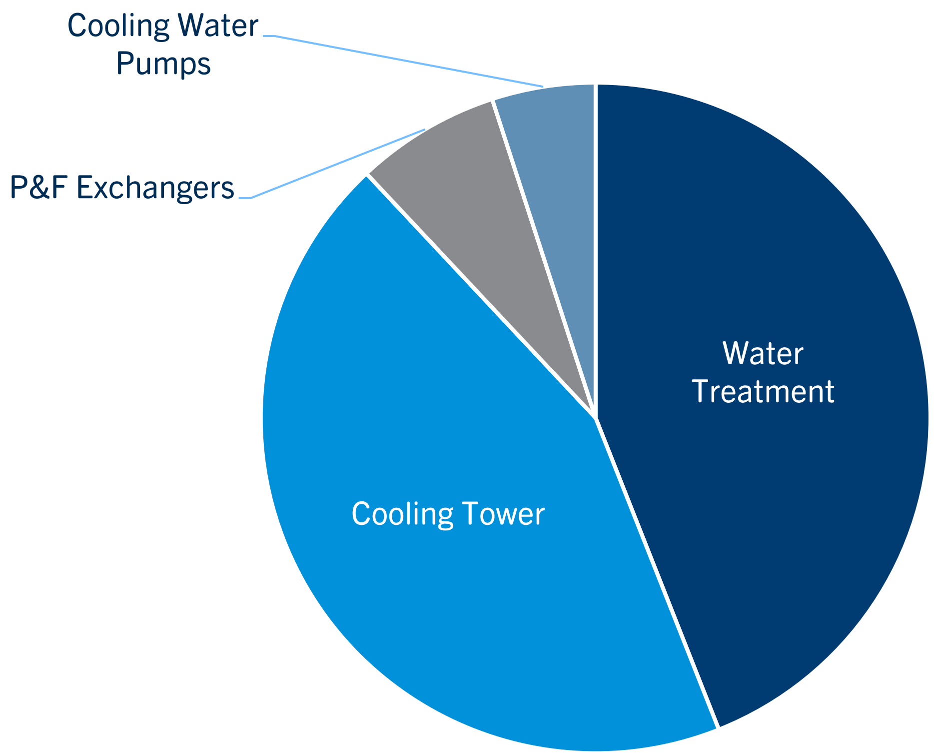
- Secondary cooling (using glycol)
  - Eliminates winterization
  - Reduces materials cost to about half
  - Cost adder for the glycol loop (capex & opex)
  - Net capex is lower, opex is higher
- Operating costs are primarily electricity price
  - No dependence on water

PCCC-8

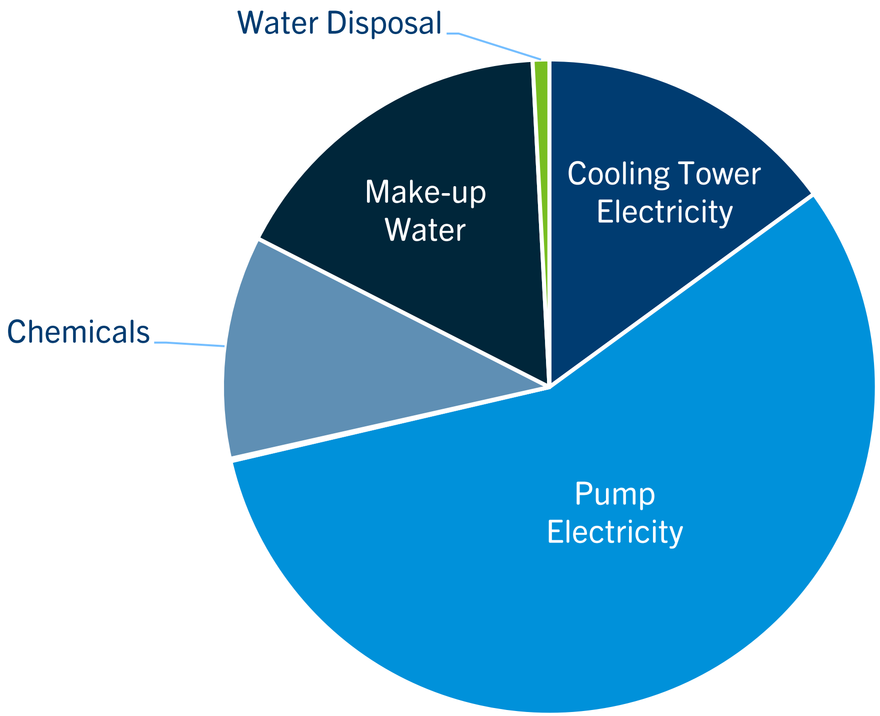
COOLING WATER COST DRIVERS

FLUOR

Capital Cost Breakdown



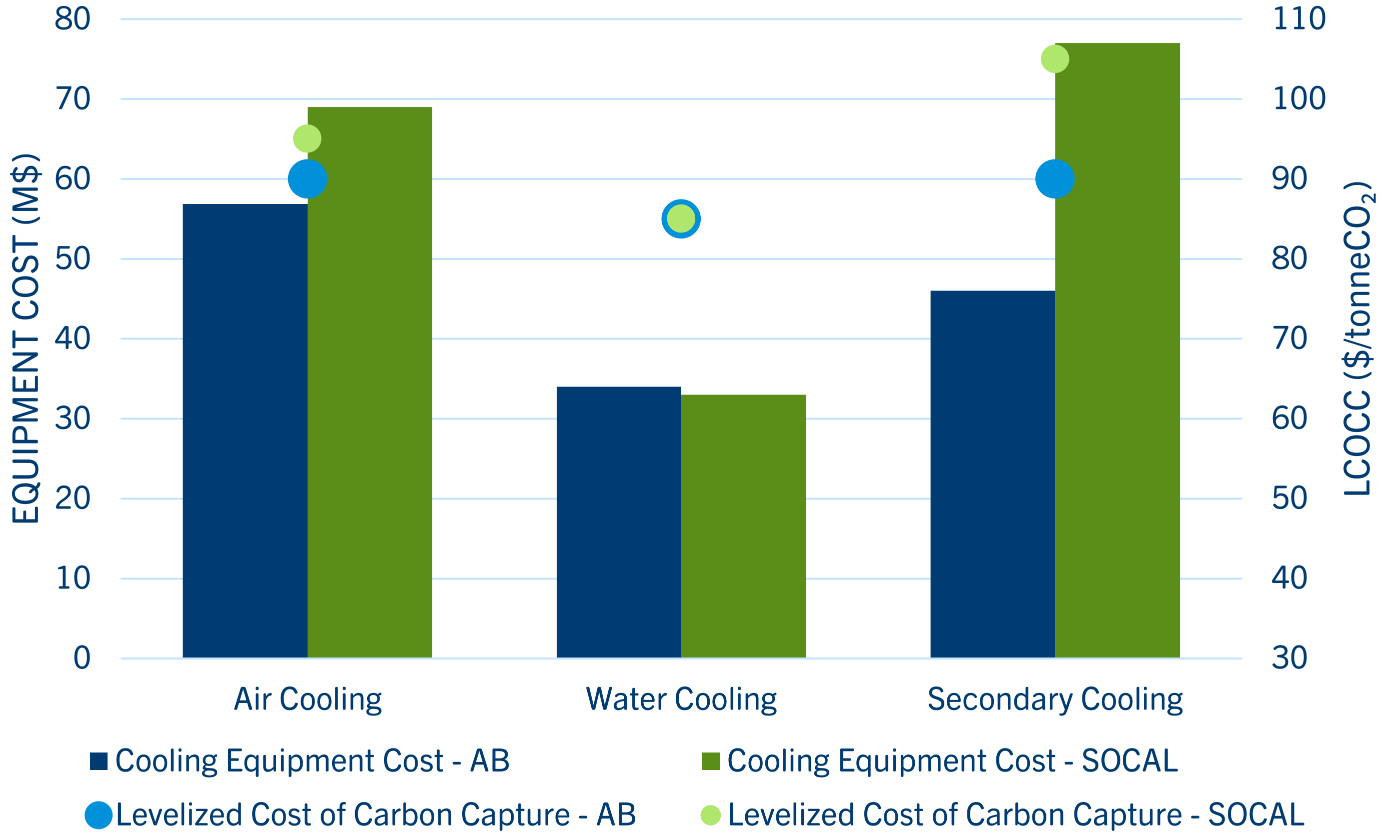
Operating Costs Breakdown

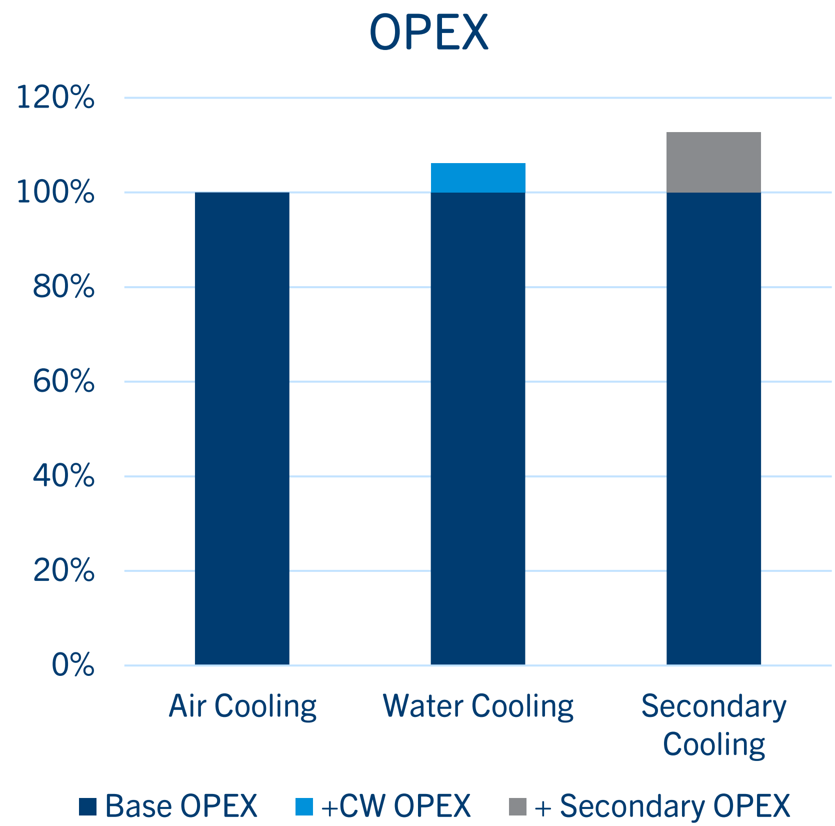


PCCC-8

RESULTS

Case Economics





Only cooling equipment costs are shown.

PCCC-8

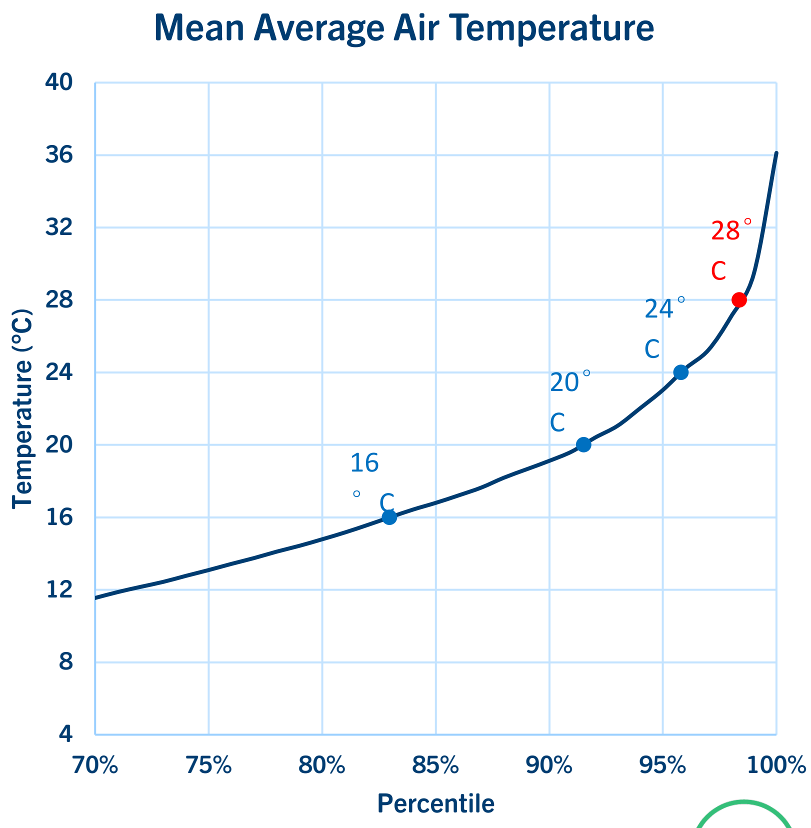
OPTIMIZATION OF DESIGN AIR TEMPERATURE

FLUOR

Alberta, Canada Example

- Ambient air temperature drives cooling in air cooling applications
- Design air temperature, and the difference between design air and process temperature, drives cost
- If the design air temperature is lower, costs are reduced but cooling is undersized on hot days
- Opportunity to take advantage of lower design air temperature in colder climates

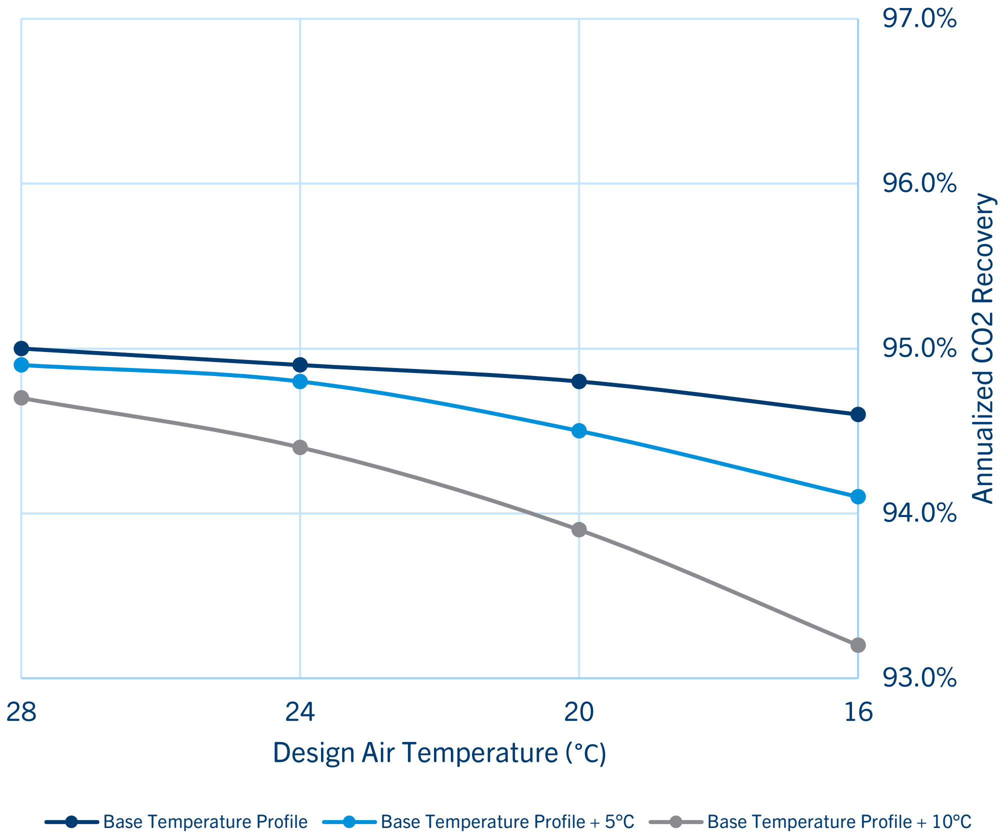
Dry Bulb – Base 28°C	24°C	20°C	16°C
Tube Area Reduction	-24%	-38%	-47%

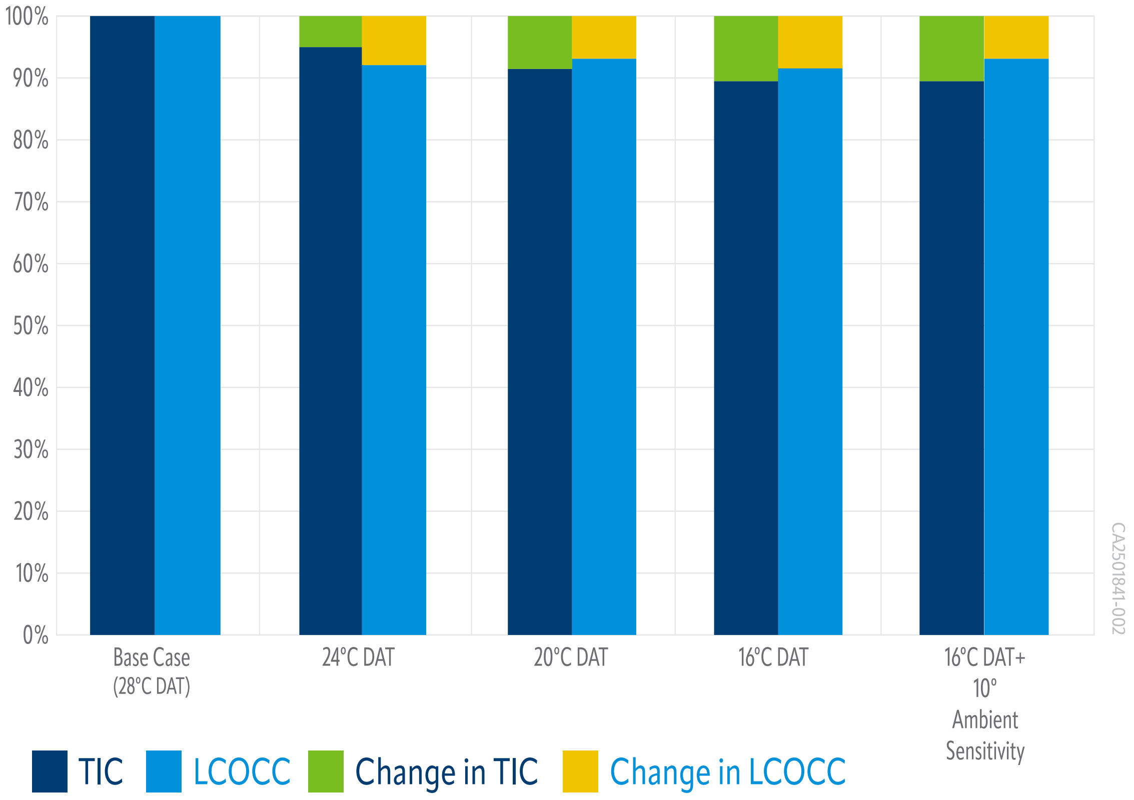


PCCC-8

OPTIMIZATION OF DESIGN AIR TEMPERATURE

How Much CO2 Recovery is Lost if Air Coolers are Undersized?

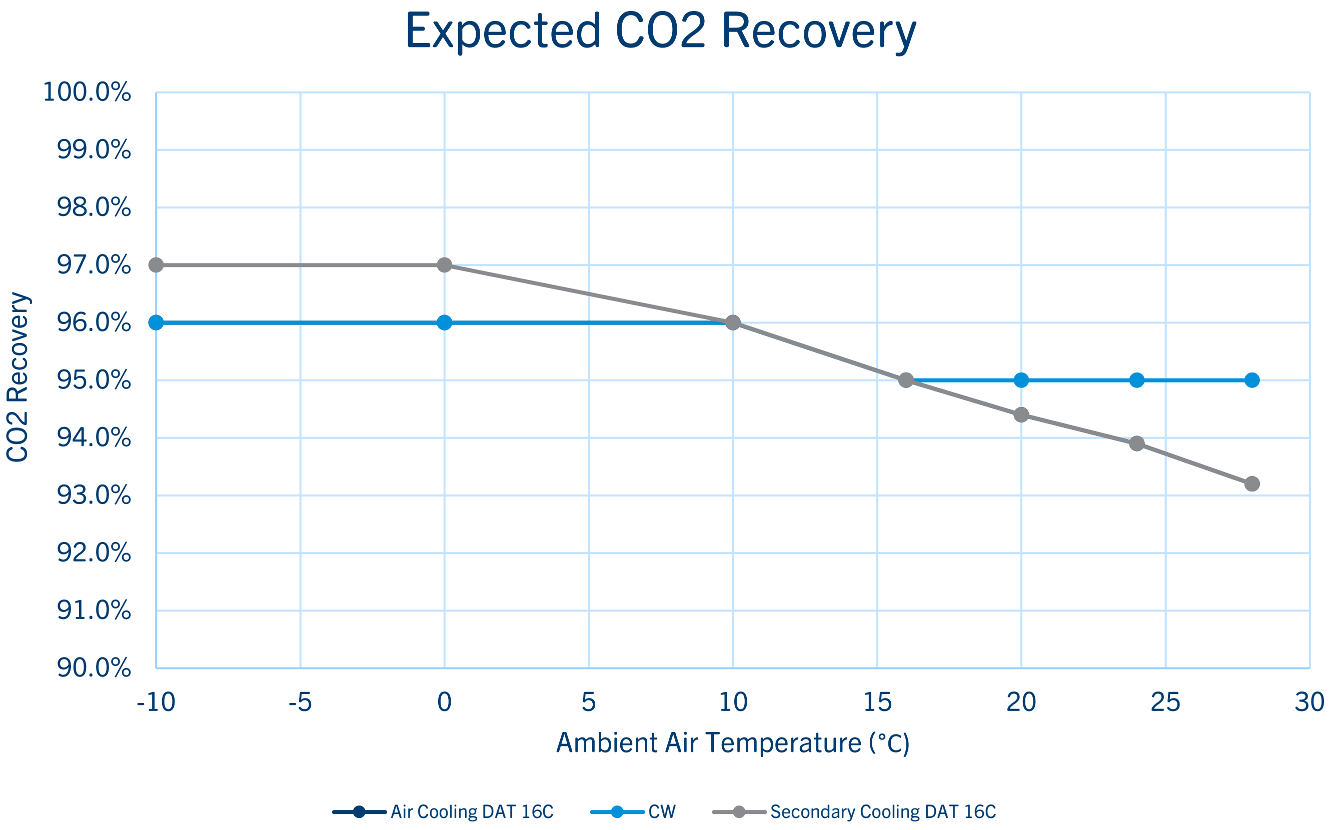


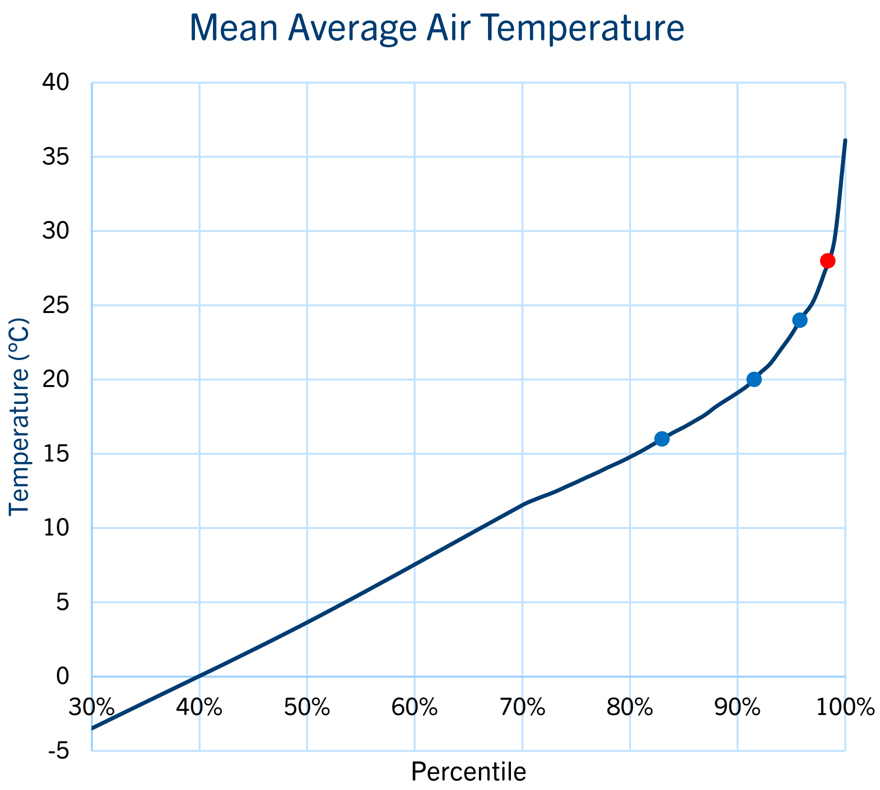


PCCC-8

SEASONAL INTEGRATION OF AIR COOLING

Alberta, Canada Case

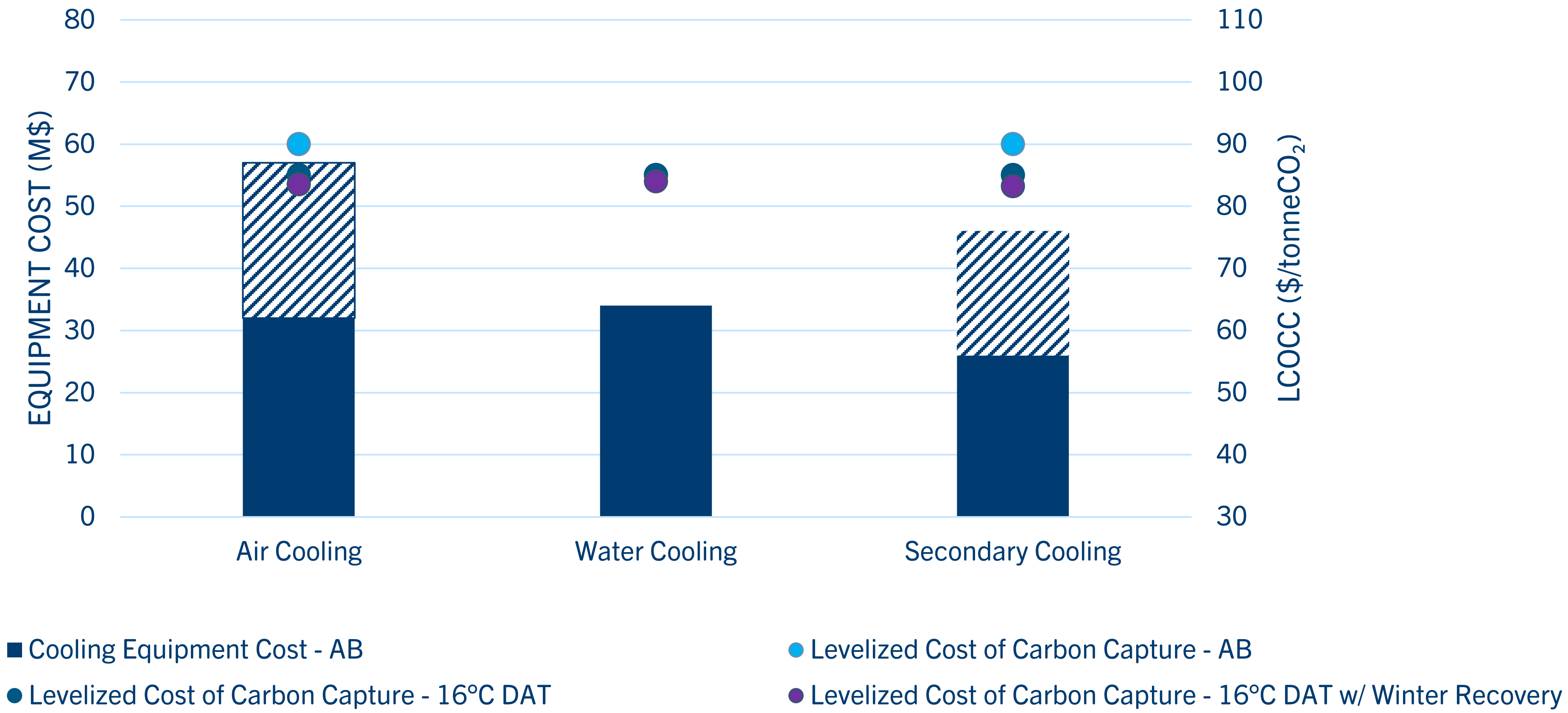




PCCC-8

COOLING IN A COLDER CLIMATE LOCATION

Results from Alberta, Canada Case Considering Seasonal Variability



OTHER CONSIDERATIONS

- Hybrid cooling scheme optimization (air + water)
- Process water balance control is important with seasonal variability
- Solvent health and degradation
  - Capture efficiency cannot be jeopardized
  - Mitigate heat exchanger fouling
- Flow scheme and process optimization
  - Lean vapour compression
  - Heat recovery opportunities

Bellingham Stripper (left), Absorber (middle), and Direct Contact Cooler (right)
Bellingham, Massachusetts, U.S.

PCCC-8

CONCLUSIONS

Optimization of Cooling for PCCC

- PCCC cooling requires significant capital cost
- Climate (location) and utility availability constrain the facility
  - Water cooling, if available, is more economically attractive
  - Air cooling is less competitive using traditional approach
  - Air cooling can be optimized for colder climates
- No ‘single solution’ or wholistic approach available
- Integration of CCS island and BOP presents opportunity to lower costs
- Project economics are best optimized with a wholistic approach with the CCS technology provider

THANK YOU

Jon Isley, P.Eng., Executive Technical Director, Fluor Canada
jon.isley@fluor.com

PCCC-8